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Abbreviations and acronyms

Abbreviation	Description
BEMS	Building Energy Management System
BUC	Business Use Case
CO2	Carbon dioxide
DER	Distributed Energy Resource
DH	District Heating
DRMS	Demand-response Management System
EMS	Energy Management System
EV	Electric Vehicle
FMI	Finnish Meteorological Institute
FTP	File Transfer Protocol
HEMS	Home Energy Management System
HLUC	High Level Use Case
iFA	iFLEX Assistant
MLOps	Machine Learning operations
MQTT	Message Queuing Telemetry Transport
PUC	Primary Use Case
PV	Photovoltaics
PL API	Programming Language Application Programming Interface
RAI	Resource Abstraction Interface
SGAM	Smart Grid Architecture Model
SGIS	Smart Grid Information Security
VPP	Virtual Power Plant

1 Executive summary

This document describes the common architecture for the iFLEX Framework. The architecture design is an iterative process, and the work begins by identifying how the iFLEX Assistant interacts with end-users, other stakeholders and its environment (i.e., context view). Then the iFLEX Assistant is divided into logical subcomponents (i.e., functional view) after which it is defined how these components process and manage information (i.e., information view). Once the functional requirements are addressed, the architecture design focuses on the deployment view that describes how the iFLEX Assistant can be configured, packaged and deployed into energy services provided to the end-user. Interoperability, scalability, security and privacy perspectives are documented to ensure that these non-functional requirements are properly addressed by the iFLEX Framework architecture.

The architecture design is implemented in three phases. This document describes the first phase of the design process, consisting of context, functional and information views for the common iFlex Framework, and interoperability, security and privacy perspectives. These views and perspectives were recognized as the most apparent in the first phase. In addition, this document describes an application of the common context and functional views to a Finnish pilot that is used here as an instantiation example of an iFlex Assistant. The other architectural views and perspectives will be described in the next iterations if identified as necessary.

2 Introduction

2.1 Requirements for the common iFlex framework

This work takes the identified requirements (defined in [1] and in [2]) as input for the design of the common architecture for the iFLEX Framework. These include:

- business requirements
- end-user requirements
- system requirements
- security requirements
- socio-economic requirements, and
- functional requirements – use cases and pilots.

These requirements will be elaborated in the next project iteration, and the more detailed requirements will be documented in the project deliverables of WP3 and WP4.

2.2 Overview of the followed standards and best practises

The iFLEX architecture design follows the ISO/IEC/IEEE 42010:2011 standard [3] in the architecture documentation, which is an international standard addressing creation, analysis and sustainment of architectures of systems. The standard specifies required contents of an architecture description, such as the de-facto stakeholders and views. In addition, the iFLEX architecture design uses the architectural perspectives [4] to ensure the particular set of related quality properties across the architectural views.

The iFLEX architecture will also be aligned and mapped to the CEN-CENELEC-ETSI Smart Grid Reference Architecture [5] and the associated flexibility management concepts. In March 2011, the European Commission and EFTA issued the Smart Grid Mandate M/490 which was accepted by the three European Standards Organizations; CEN, CENELEC and ETSI. In the context of Mandate M/490, a holistic viewpoint of an overall architecture; Smart Grid Architecture Model (SGAM), was developed. The main components of the Reference Architecture are: 1) European Conceptual Model: An evolution and extension of the NIST Smart Grid model, which takes Europe specific requirements into account. The main extension is the of distributed energy resources (DER). 2) Architecture Viewpoints: SGAM utilizes following viewpoints in the architecture documentation: Business, Function, Information, Communication and Component. 3) SGAM Framework: Provides support for the design and development of Smart Grids systems. The framework takes into account already identified relevant aspects such as interoperability (e.g. the GridWise Architecture Council Stack [6], multi-viewpoints (SGAM Layers) and provides a functional classification on required and available data models, interfaces and communication layers. The iFLEX architecture design utilises the Interoperability dimensions of SGAM, especially information and communication layers for syntactic and semantic interoperability.

2.3 Description of the design process

The architecture design is an iterative process implemented in three phases. These phases follow the planned pilot phases (see the Grant Agreement):

- Phase 1: A pre-pilot with the Minimum Viable Product of the iFLEX Framework and Assistants will be carried out with selected users.
- Phase 2: A small-scale pilot including the iFLEX Framework with full functionality will be validated with small-scale pilot groups.
- Phase 3: The improved iFLEX Framework will be deployed and validated in large-scale pilots.

A common architecture is first designed for the common iFLEX Framework. Then, more detailed descriptions are defined for each of the different types of iFLEX Assistant (iFA) (households, building communities). Finally, the commonalities of those descriptions are generalized back to the common iFLEX architecture. Architecture design begins by identifying how the iFA interacts with end-users, other stakeholders and its environment (i.e., context view). After that, the iFA is divided into logical subcomponents (i.e., functional view), and the interactions between the sub-components are described. The component specific requirements are identified after the functional decomposition of the architecture. The list of requirements will be added as an appendix to this deliverable in later phases. After component definition, it is defined how these components process and manage information (i.e., information view). Finally, the deployment view describes how the iFA can be configured, packaged and deployed into energy services provided to the end-user. Interoperability perspective is described to understand how the different components interact for a particular purpose to reach a common goal. Security and scalability perspectives will be documented to ensure that these non-functional requirements are properly addressed by the iFLEX Framework architecture.

This document describes the architectural work done for the phase 1. The following views and perspectives were recognized as the most apparent in this phase: Context view that describes how the iFLEX framework interacts with its environment, functional view that describes the common functionalities of the iFLEX framework (with the help of use cases) and the information view that identifies the data items that the iFLEX framework manages. In addition, the interoperability perspective identifies the technologies and standards for different interoperability layers of the iFLEX framework, and the security and privacy perspectives describe the approach and means to fulfil the security and privacy requirements. Furthermore, this document describes the application of iFA to building communities as an instantiation example with applied context view and more specific and detailed functional view.

In the second phase, the architectural work will concentrate on improving the information view by refining the data flow between the functional elements and describing the data items in more detailed. In addition, the preliminary deployment view is defined. The iFA is also applied to the building communities, and the context and functional views between different iFA (households and building communities) are compared and the common parts of the iFLEX framework is refined. In the third phase, iFLEX framework will be deployed with the help of the pilots (one building community and two households) and validated.

3 Architecture for the common iFlex Framework

3.1 Context view

Context view typically describes a system in its environment with the related external actors that interact with it. Figure 1 presents the actors, the elements and the relationships of the iFLEX Framework in the context view. The detailed description of the elements is represented in Table 1.

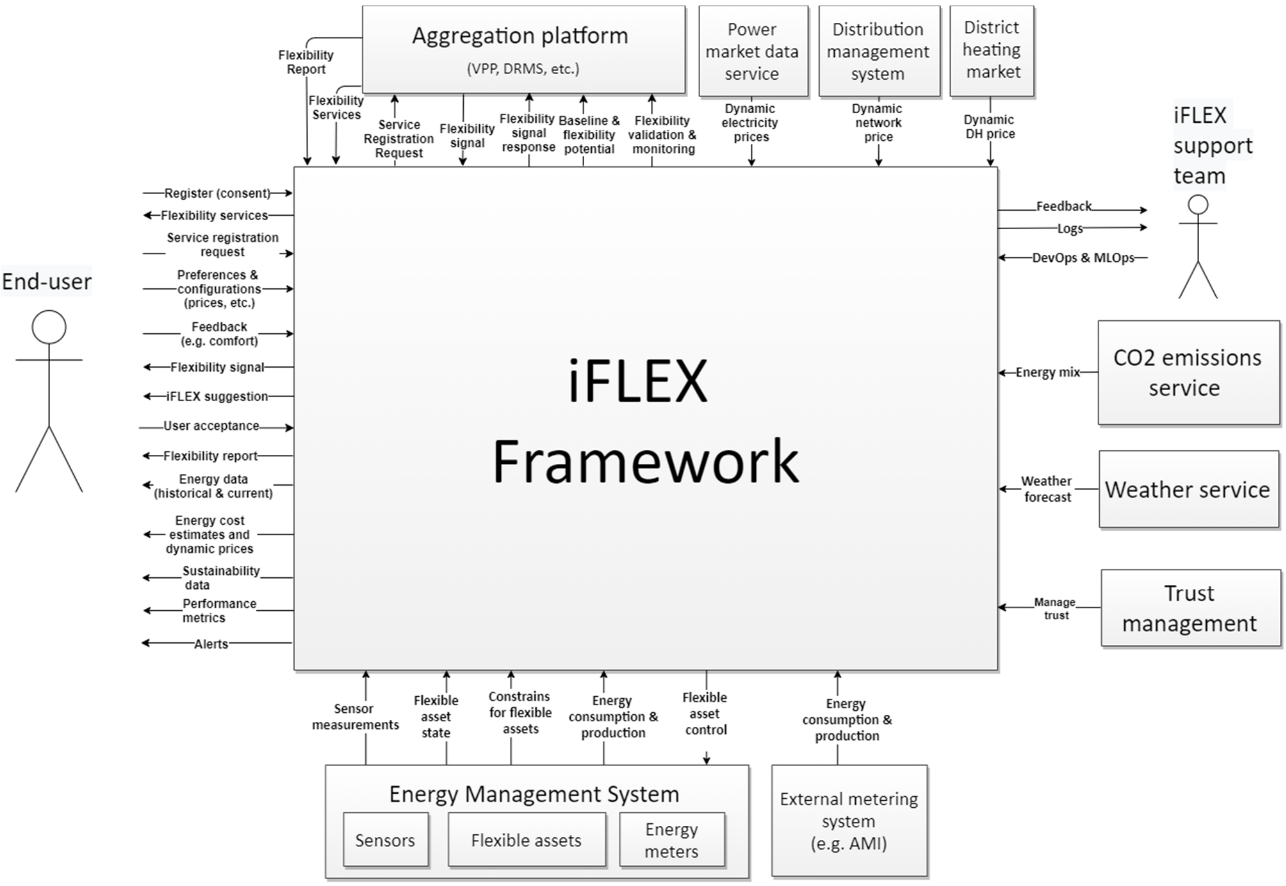

Figure 1: The common context view of the iFLEX Framework.

Table 1: Description of elements of the context view.

Element	Description	Managed data
Sensor	A device that measures certain variables (e.g. temperature) within the end-user's premises	Sensor measurement data
Energy meter	A device that provides near real-time metering data about energy flows of flexible/non-flexible assets or of the whole facility.	Energy consumption and production data
Flexible asset	Dispatchable unit (e.g. residential PV system, controllable home appliance, energy storage, EV) that can be controlled via the EMS.	• Energy consumption and production data • Flexible asset state • Constraints for flexible asset

Element	Description	Managed data
Energy management system (EMS) • Home energy management system (HEMS) • Building energy management system (BEMS)	• Monitors the energy flows of the building • Provides information about energy consumption and production, and the state of the flexible asset • Controls the building's energy resources (devices, flexible asset) according to control commands	• Sensor measurement data • Energy consumption and production data • Flexible asset state • Constraints for flexible asset • Flexible asset control
Weather service	Provides weather data	Weather data (current, history)
Power market data service	Provides current electricity market data	Dynamic electricity price
iFLEX Assistant (iFA)	The system under design. • Learns from the consumption behaviour of the end-users. • Predicts and analyses the consumption of DERs. • Calculates and suggests relevant flexibility services based on the information from sensing devices, external services and the preferences and behaviour of the end-user.	• Flexible asset control • Feedback data • Logs data • Service registration request • Flexibility signal response • Baseline and flexibility potential • Flexibility validation and monitoring • Flexibility services • Flexibility signals • iFlex suggestions • Flexibility report • Energy data (historical and current) • Energy cost estimates and dynamic prices • Sustainability data • Performance metrics • Alerts
End user	The end-user of the iFA. Could be an individual resident or a facility manager. Provides: • Preferences and configuration • Feedback on operation of the assistant • Authorization/Consent to assistant's activities Receives: • Demand-response notifications • Advices on energy efficient behaviour • Visualizations of energy, cost and sustainability metrics.	• Service registration request • Register (consent) • Preferences and configurations • Feedback data • User acceptance
Aggregation platform (electricity retailer, district heating	A solution for aggregating and managing flexible resource (e.g. DRMS, VPP). • Receives flexibility offerings by the iFA • Activates flexibility according to the preferences of the end-user	• Flexibility report • Flexibility services • Flexibility signals

Element	Description	Managed data
provider, energy service provider)		
Distribution management system	Provides the current distribution network prices	Dynamic network prices
District heating market	Provides the current district heating prices	Dynamic district heating prices
CO2 emission service	Provides data about the equivalent CO2 emissions	Energy mix
iFLEX support team	Collects feedback from end-users and manages software of iFLEX system	DevOps & MLOps
External metering system	External metering system that provides data about energy consumption and production	Energy consumption and production data
Trust management	Manages trust among entities in the system. Enables recognition of end user identities and their relation to roles in the system. Allows for giving end user a consent to a data controller.	Manage trust

3.2 Functional view

Figure 2 describes iFLEX Framework as elements, relationships and their responsibilities. In Table 2, the use cases are mapped to the elements that implement them. One use case can be mapped to several elements.

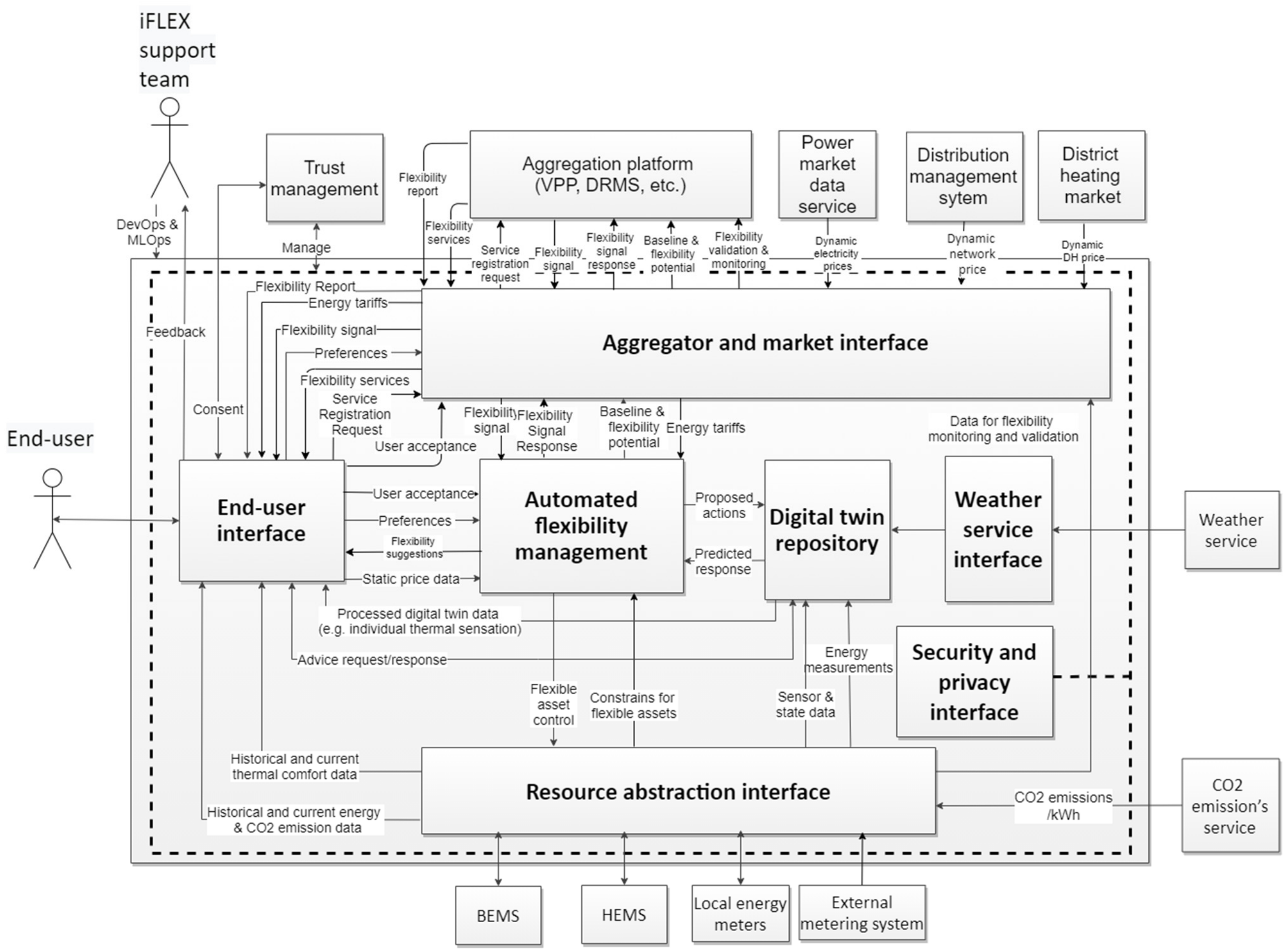

Figure 2: Functional view of the common iFLEX Framework.

Table 2: Functional elements of the common iFLEX Framework.

Element	Description	Managed data
End-user interface • Resident • Facility manager	**Define comfort levels:** The end-users will be able to select among predefined modes and customise them according to their preferences. (PUC1) **Flexibility management policy**: The assistant will offer a prioritization of end-user motives for proposing the optimal schedule(s) of devices operations. Based on the flexibility management policy selected by the user, the assistant will automatically process with the selection/execution of the 'best' control action schedule. (PUC1) **Communication personalization**: End-users will be granted the capability to customise their interaction with the iFA according to their preferences. (PUC1) **Providing feedback:** End-users are able to provide feedback about their residential conditions any time. (PUC1) **Performance management:** The end-user can set goals on the performance of their installed devices in relation to chosen metrics such as sustainability, energy consumption and cost savings. (PUC7) **Flexibility service registration:** End-user expresses interest for flexibility service, and retrieves a list of current and relevant services. (PUC6) **Approve actions:** The end user provides consent for sharing information with third parties: • on sharing baseline load and flexibility information with the aggregator. (PUC8) One also is able to approve: • Flexibility suggestions (e.g. load rescheduling) provided by iFA • DR events (including opt-in/out response) • Notifications, alerts, advice (PUC1) (PUC5) **Visualising:** • Sustainability metrics and goals (PUC3) • Advice, notifications, alerts (PUC1) (PUC5) (PUC7) • Short and long term consequences of the advices (PUC5) • User participation and engagement reports (PUC4) (PUC5) • Energy consumption/production (real-time data, historic (trends) data) (PUC7) **Control iFLEX Assistant properties:** The preferences of end-users are fine-tuned (PUC5)	• User acceptance • Preferences • Static price data • Feedback data • Service registration request • Consent
Resource abstraction interface • BEMS • HEMS • Metering interface	**Fetching data from sensors:** Smart meter, submeter, temperature sensor (PUC2) (PUC8) (PUC9) **Provide setpoints of operation to local dispatchable assets:** Residential PV systems, home appliances, energy storage systems, EVs (PUC2) **Controlling the operation of dispatchable devices and assets:** The devices and assets are controlled according to the selected policies/schedules (PUC1) (PUC9)	History of energy consumption and CO2 emission data History and current thermal comfort data Constraints for flexible assets Sensor and state data Energy measurements

Element	Description	Managed data
		Data for flexibility monitoring and validation
Weather service interface	**Fetching weather data** (PUC2) (PUC8) (PUC9)	Weather data
Aggregator and market interface	The interface will support seamless interaction between the iFA and the market (PUC2), providing access to publicly available market data, communication of flexibility signals (incentives) and preferences for flexibility provision. It will also enable historical tracking of the measured flexibility offered supporting transparent documentation of fair remuneration and rewards by the flexibility providers.	Energy tariffs Flexibility signal Flexibility services Flexibility signal response Service registration request Baseline and flexibility potential Flexibility validation and monitoring
Automated flexibility management	**User engagement evaluation and reporting:** Manage participation reports, calculate participation and rewards, evaluate engagement, prepare reports, visualize reports (PUC4) **Electricity consumption and performance analysis:** Providing detailed analysis of the electricity consumption and performance (real-time and historic) (PUC7) **Calculate relevant services:** Calculating and updating the list of relevant services (to be offered for end-users) (PUC6) **Analyse and calculate savings, forecast, simulate:** Advises are formed to end-users to reduce energy consumption and reach the goals (PUC5) **Engage end-user in energy advice:** Keeps track of the decision success and evaluates the engagement after the end-user has chosen an advice to follow (PUC5) **Offer flexibility:** The baseline load profile is forecasted with the help of information from sensing devices, external services and the preferences and behaviour of the consumer/prosumer. The baseline load profile and associated flexibility offers are provided to the aggregator. (PUC8) **Flexibility management policy**: Based on the flexibility management policy selected by the user, the assistant will automatically process with the selection/execution of the 'best' control action schedule. (PUC1) **Providing the end-user with an optimal energy scheduling:** Exploiting past experience to come up with an optimized energy schedule for the premises. The calculation/acceptance the schedule(s) are communicated to the EMS, which controls the operation of dispatchable devices and assets (PUC9)	Flexibility suggestions Flexibility signal response Baseline and flexibility potential Flexible asset control Proposed actions
Digital twin repository	Develops and tests predictions by modelling user behaviour and energy systems. Stores the models and predictions.	Predicted response
Security and privacy interface	The security and privacy interface module provides the following functionality: • Needed services to boost up trust management on a side of iFA, if necessary also for the end user interface • Communication security among the external subsystems and the iFA; data origin authentication	Trust management data Identities Access control policies

Element	Description	Managed data
	and integrity services are provided together with confidentiality services • Authentication, Authorisation and Accounting for access from external entities to the iFA interfaces, administrative border is denoted with a dashed line in Figure 2. • Provides confidentiality, integrity of the data stored in the iFA and availability of the services providing the access, • Provides security of the iFA at rest	

3.3 Information view

Table 3 summarizes the identified data elements of the iFA.

Table 3: The data elements of iFLEX Assistant.

Units	Data types	Resources	Systems	Information/ knowledge
•Power, energy, capacity, … •Temperature, humidity, CO2,… •Location	•Measurement •Flexibility data •State data •Weather data •Market data •Feedback data •Maintenance data •Report •Analysis and forecast data •Alerts and ackonwledgement •Control data •Constraint • End-user data	•Sensors •Flexibility assets •Energy metering	•Distribution management system •District heating management system •Power market data service •Energy management systems (BEMS, HEMS) •Third party services (e.g. weather service, CO2 emission service) •Aggregator's systems	•Common measurements and baseline •Building/home specific data •End-user specific data •Models (digital twins) •Offerings description •Flexibility service description •Contracts •Consents •Laws, standards •Market rules

The data items identified in the context view and the functional view are described in more detailed in Table 4.

Table 4: The description of data items.

Data item	Description	Data type
Sensor measurement data	Data that is produced by sensors in end-user's premises. E.g., temperature and humidity.	Measurement data
Energy consumption and production data	Data about energy consumption and production of flexible asset (historical and current) to be visualised to end-user	Measurement data
Flexibility validation and monitoring	Relevant energy metering and/or flexible asset state information that can be used to monitor the situation during flexibility management and to validate the flexibility management event (e.g. to compare measured consumption to the baseline and activated flexibility)	Measurement data
Performance metrics	The performance metrics that are visualized to the end-user. The visualization is related to the end-user's goals visualization and is guided according to the user preferences.	Measurement data
History and current thermal comfort data	Data about the historical and current thermal comfort (collected by the EMS) provided to the end-user.	Measurement data (report)
Energy measurements	The required energy measurement (consumption, production) for the future prediction with the help of digital twin.	Measurement data

Energy mix	Data about the emissions (e.g., CO2) provided by a third party service provider.	Measurement data
Sustainability data		
Flexibility signals	A signal to inform iFA about a flexibility. Flexibility signal can be either an explicit DR event (i.e., activation of flexibility potential) or an implicit DR event (i.e., dynamic price information).	Flexibility data
iFLEX (flexibility) suggestions	A proposal for the end-user to modify a schedule or setpoint of a flexible assets. iFLEX suggestions need to be approved (User acceptance signal) before they are taken into account by the iFLEX Assistant.	Flexibility data
Flexibility report	Report on flexibility event results (e.g. rewards, cost-reductions, etc.).	Flexibility data
Flexibility services	A list of available services for end-users.	Flexibility data
Flexibility report	Report on flexibility event results (e.g. rewards, cost-reductions, etc.).	Flexibility data
Flexible asset state	Data about the current state of the flexible asset.	State data
Weather data	Data about the weather (current, historical).	Weather data
Energy cost estimates	Estimates (not official) of end-user energy costs based on consumption and energy price data (possibly for different energy vectors).	Market data
Dynamic district heating (DH) prices	The current district heating price defined by district heating operator.	Market data
Dynamic network prices	The current network price defined by network operator.	Market data
Dynamic electricity price	The current electricity price defined by electricity provider.	Market data
Static price data	Information on end-user energy and network fees. This information is used to estimate the energy costs.	Market data
Energy tariffs	Includes all the energy related tariffs, such as dynamic electricity price, network price and district heating price.	Market data
Feedback data	End-users' feedback about the residential comfort.	Feedback data
Logs data	Logging data from different functional components for debugging and maintenance purposes.	Maintenance data
DevOps&MLOps	Software updates and maintenance information.	Maintenance
History of energy consumption and CO2 emission data	Data about the historical consumption and CO2 emissions (collected by the EMS) provided to the end-user.	Report
Baseline and flexibility potential	The available flexibilities and baseline load profile at different time periods (learnt from the consumption behaviour of the user and the dynamics of relevant energy systems) that is exposed to the market actors.	Analysis data
Proposed actions	A request for the Digital Twins to predict the system response with respect to specific flexible asset control commands.	Forecast request
Predicted response	Response to the proposed actions (modelled with the help of the digital twins)	Forecast
Alert	An alert that is sent to end-user according to certain (predefined) events e.g., the power consumption exceeds a certain predefined threshold.	Alert
Flexibility signal response	An acknowledgement of the flexibility signal.	Acknowledgement
Flexible asset control	The control commands for the flexible asset that are used to control the assets according to schedules.	Control data

Constraints for flexible asset	Description of current constraints of the flexible asset.	Constraint
Preferences and configurations	A set of operational constraints and configuration of communication with iFA defined by the end-users.	End-user data Configuration data
Service registration request	End-user's expression about his/her interest to register to a service.	End-user data
Register (consent)	A message from end-user to register to the iFLEX Assistant. Registration process includes the informed consent of the end-user that is required for collecting, storing and processing data under GRPR.	End-user data (registration/ informed consent)
User acceptance	End-user's acceptance on iFLEX suggestions.	End-user data
Manage trust	End-user identity and related security interface data, access control policies, consent.	End-user data

3.4 Interoperability perspective

SGAM (Smart Grid Architecture Model) represents following interoperability dimensions: Business, Function, Information, Communication and Component (see Figure 3).

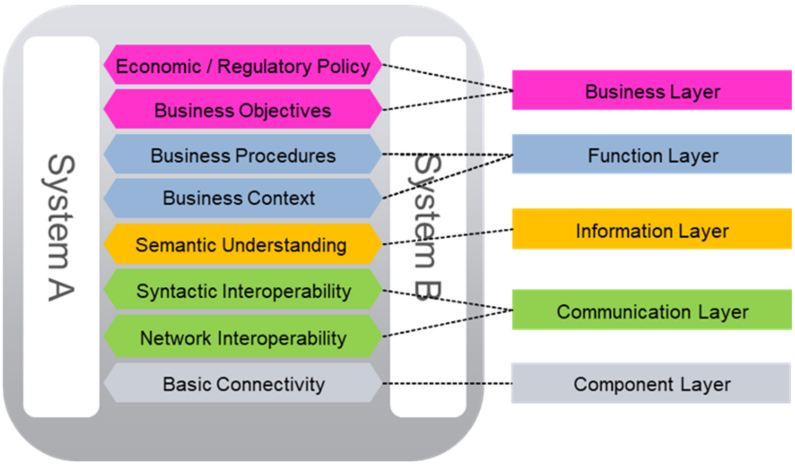

Figure 3: Interoperability dimensions of SGAM [7].

The business layer: Regulatory and economic (market) structures and policies, business models, business portfolios (products & services), business capabilities and business processes.

The function layer: Functions and services and their relationships from an architectural viewpoint.

The information layer: The information (i.e., information objects and the underlying canonical data models) that is being used and exchanged between functions, services and components.

The communication layer: The 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.

The component layer: The physical distribution of all participating components (system actors, applications, power system equipment, protection and tele-control devices, network infrastructure, and any kind of computers) in the smart grid context.

In the first phase of the iFLEX architecture design, the interoperability focus is on Information and Communication layers. The different technologies and standards utilized in the iFLEX Framework with mappings to the corresponding interoperability levels of GridWise Architecture Council [6] are summarized in Table 5.

Table 5: Technologies and standards for different interoperability layers.

Technology	Interoperability layer
IEC 62746-10-1 (OpenADR2.0)	Semantic interoperability

SAREF/SAREF4ENER	Semantic interoperability
LonWorks	Semantic interoperability (covers also lower layers)
BACnet	Semantic interoperability (covers also lower layers)
KNX	Semantic interoperability (covers also lower layers)
Z-Wave	Semantic interoperability (covers also lower layers)
ZigBee	Semantic interoperability (covers also lower layers)
M-Bus	Syntactic interoperability (covers also lower layers)
HTTP (REST)	Syntactic interoperability (covers also lower layers). Does not specify the payload syntax.
MQTT	Syntactic interoperability (covers also lower layers). Does not specify the payload syntax.
JSON	Syntactic interoperability
oBIX	Semantic interoperability (covers also lower layers)
FTP	Syntactic interoperabililty

How the above listed technologies are planned to be used between the iFLEX Framework and external systems, as well as, between functional components of the iFLEX Framework is presented in Figure 4. In some cases, there are several arrows between components represented in the Figure 4. This means that there are several options for realizing the interoperability and the technology choice is always case specific. The term Programming Language Application Programming Interface (PL API) is also listed as an option in several places. This refers to a case where parts of a functional component are imported as a software library and the interoperability is realized within the programming language of choice. This case is typical if the components are deployed into the same software process for practical reasons. It is again case specific when this option is the preferred one. In addition to the machine-to-machine interfaces and standards, some information is fed into the system via User Interfaces (UI). Examples of practical deployment will be presented in D6.5 Initial Application-specific iFA prototypes and its successive versions.

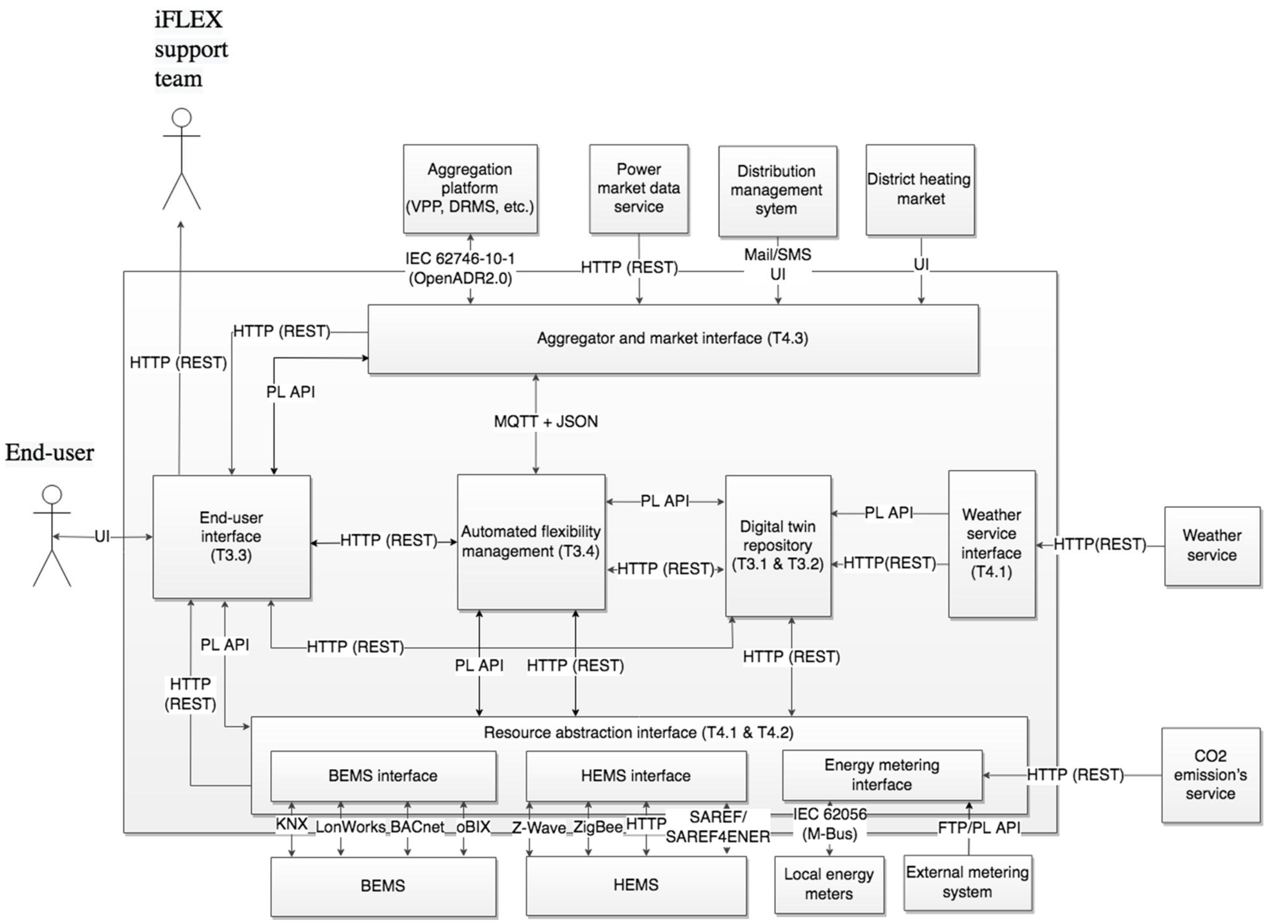

Figure 4: Mapping of the interoperability technologies to the functional architecture of the iFLEX Framework.

3.5 Security and privacy perspective

Smart Grid Coordination Group document on Smart Grid Information Security (SG-CG/M490/H_ Smart Grid Information Security, 2014) rightfully exposes a need to address the security perspective at each layer of the SGAM architecture as are introduced in Section 3.4. The iFLEX architecture addresses only a small subset of the smart grid architectural model (SGAM) domains and zone plane but all the interoperability layers. The security perspective should therefore address all the layers of the SGAM.

The component layer is represented with BEMS and HEMS components and local or external metering systems, as are depicted in Figure 4. The communication layer is represented with a bunch of potential protocols for interconnecting the devices at customer premises with the iFA. To the SGAM communication layers the other iFA protocols could be added, denoted in the figure with HTTP (REST), PL API and MQTT. The iFLEX architecture can only reuse any security features provided by the denoted protocols and make sure that the protocols security features are implemented and used properly on iFA's side. In the project deliverable D2.1 the requirements related to the component layer and communication layer were denoted with the requirement SEC-06-ECOSYS and SEC-03-COMSEC. The iFA protocols will be used a means to implement necessary information exchange to fulfil D2.1 requirement SEC-02-AAA. The information layer covers the data models and related data. The D2.1 requirements related to the data are SEC-04-CIA covering confidentiality, integrity and availability of the data and SEC-05-REST, addressing security of the data at rest. The requirement SEC-02-AAA partly covers confidentiality requirements related to the information layer. The functional layer covers functions and services to the end user, aggregator and iFLEX support team. The security of these functions and interfaces is covered again with the requirement SEC-02-AAA. The system needs to fulfil the requirement SEC-01-TRUST so the entities in the system could recognize and relate each other to foreseen roles in the system. The iFLEX architecture does not expose particular business layer functions per se, the business use cases as were presented in D2.1, build upon the functional layer.

Privacy has been a real concern noted in Smart Grid Information Security (SGIS) document (SG-CG/M490/H_ Smart Grid Information Security, 2014). The privacy requirements exposed in the deliverable D2.1, from PRI-01-CONSENT to PRI-07-RTBF, cover all the major concerns denoted in the SGIS document. Both the security and privacy requirements will be further developed and expanded in forthcoming deliverable D4.3 on Secure consumer data management module.

4 Architecture of an iFLEX Assistant for a building community

This section introduces a system architecture for an example iFA in the phase 1. The example focuses to the iFA targeted for the building community, but very similar architecture is used for the iFA targeted for single family houses. The iFA for a building community documented in this report is related to the following Business Use Cases:

- BUC-3: Offer the flexibility of a multi-vector energy system (building community) to the energy markets.
- BUC-4 - Optimal energy consumption for multi-vector energy system (building community) based on the behaviour of consumers and market price signals.

Furthermore, to the following High Level Use Case:

- HLUC-3: Manage flexibility requests or price signals at building level.

The main goal of this iFA is to automate the flexibility management in an apartment building where the costs of HVAC, domestic hot water, and electricity for common areas are paid collectively by the building community (also known as building association). So instead of serving a single family the iFAs serves the whole building community. This particular iFA will be deployed and evaluated in the Finnish pilot.

4.1 Context view

Figure 5 illustrates the context view of the iFA to be developed for the building community in the first phase of the project. This iFA in serving the whole building community and it has two types of end-users: Residents and Facility manager.

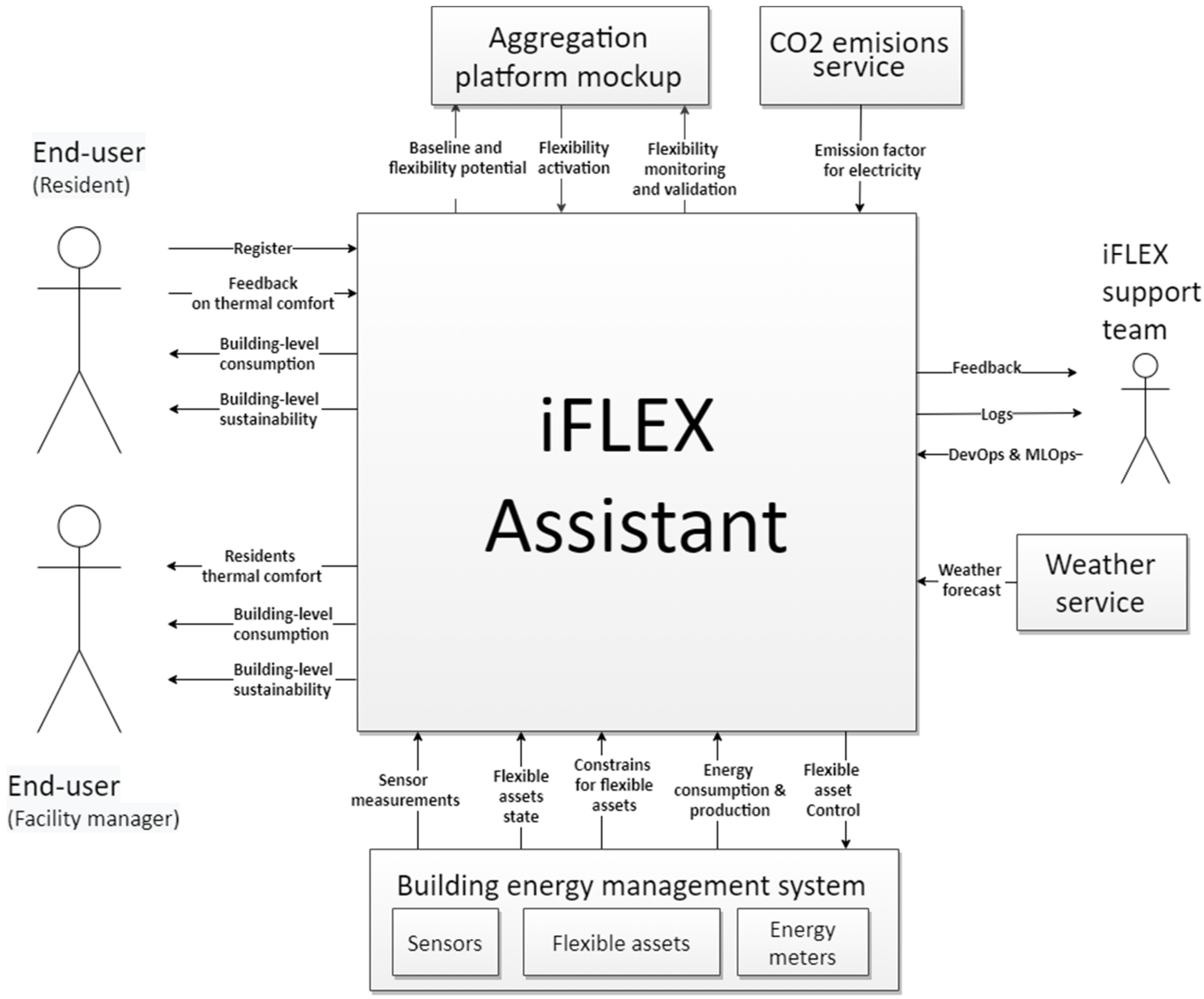

Figure 5: Context view of the iFLEX Assistant to be customized for the apartment building (FIN pilot).

The Facility manager is an entity responsible for ensuring functionality and comfort in the apartment building. In the phase 1, the iFA provides the facility manager with three types of visualizations:

- First, it visualizes the historical energy consumption both for electricity and district heating at the apartment building level.
- Second, the assistant provides estimates on CO2 footprint of the apartment building. Both electricity and district heating vectors are included.
- Third, it provides the facility manager with visualizations on the resident's thermal comfort. The thermal comfort of residents includes three types of information: 1) temperature and humidity measurements, individual thermal sensation index that maps the temperature and humidity into individual body type of a person, and feedback on thermal provided by the residents.

It should be noted that there is no interface for providing constraints and preferences for temperatures and other measurements as this type of information is fetched directly from the Building Energy Management System of the apartment building.

Residents are iFA's end-users that live in the apartment building. The iFA provides residents with visualization on the building-level energy consumption and sustainability metrics (i.e., CO2 footprint). Residents can also provide feedback on their thermal comfort via the iFA. This feedback is provided to the facility manager as well as utilized by the iFLEX support team to further improve the iFA. Residents can also access visualizations on the DR events executed at the apartment building level.

In the first phase, there is no aggregation of different buildings in the Finnish pilot cluster. For this reason, the aggregation platform is replaced with a simple mockup in the context view. Instead the key focus is on experimenting and demonstrating the building level flexibility management functionalities. In practice, this is done by directly activating the flexibilities offered by the iFA and monitoring how well it is able to follow the forecasted load profiles without compromising end-user comfort. The mockup of the aggregation platform will also visualize the baseline and flexibility forecast, as well as, display the actual measured consumption both for electricity and district heating. This will allow to monitor and evaluate the flexibility management activities.

Important external systems for the iFA include the Building Energy Management System, Weather Service provided by Finnish Meteorological Institute (FMI), and Fingrid Open Data platform, which is used for accessing estimated CO2 emissions for the electricity consumed in Finland.

4.2 Functional view

The first phase functional view of the iFA serving a building community is depicted in Figure 6.

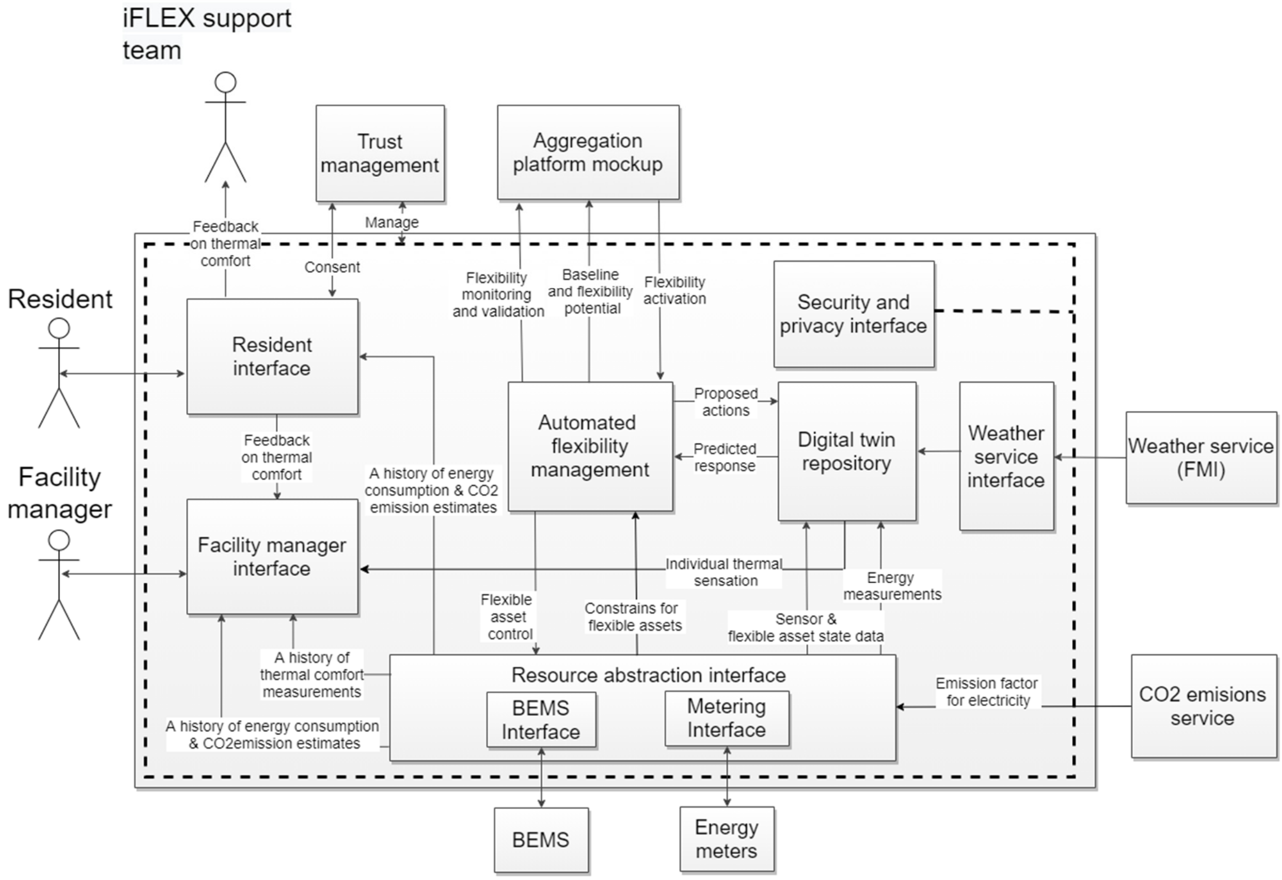

Figure 6: Functional view of the iFLEX Assistant to be customized for the apartment building (FIN pilot).

As can be seen, most of the functional components of the iFLEX Framework are present in the first phase architecture of the apartment building iFA. The main omission is the Aggregator and market interface module that is replaced with a simple mockup of the aggregation platform. This module is not present in the architecture of this iFLEX Assistant because no aggregation is executed in the first phase and the main focus is on demonstrating and evaluation the explicit DR capabilities of the apartment building.

It is noteworthy that there are two types of End-user interfaces in the functional view: one for Residents and one for the Facility manager.

The interaction between the functional components is further illustrated in sections 4.2.1 - 4.2.5 that represent the main use cases provided by the iFA in the phase 1.

4.2.1 PUC-1 - Manage my preferences

In the 1st phase, this use case focuses on thermal comfort of the residents. The default settings and constraints related to thermal comfort in an apartment building is provided by the BEMS of the building. This information is utilized by the Automated flexibility management component to estimate the amount of flexibility and to optimize flexibility management (please refer to PUC-8 and PUC-9 for further details). The information is accessed via the Resource Abstraction Interface (RAI). The associated thermal comfort measurements are also accessed via the RAI. In addition to the raw temperature and humidity measurements, the iFA will model individual thermal sensation of end-users. It is important to provide individual perspective as people with different body types feel thermal comfort in different ways. In practice the individual thermal sensation for different body types will be calculated by the consumer digital twin that is part of the Digital twin repository module. The iFA visualizes the key measurements and the individual thermal sensation for the facility manager to enable continuous monitoring. Figure 7 represents a sequence diagram of the abovementioned interaction between the functional components. Please note that the sequence diagram contains several independent exchanges of information that are visualized in a single diagram as they are thematically interlinked with each other.

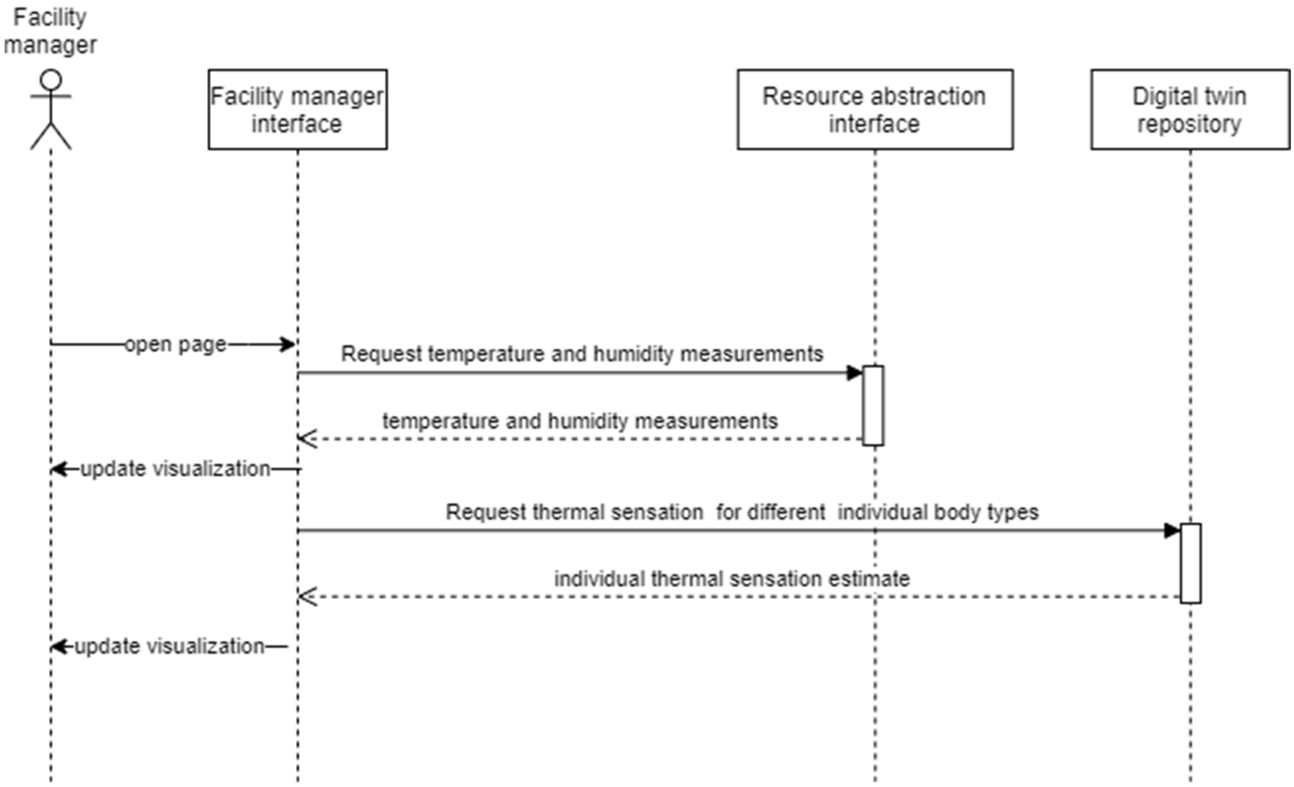

Figure 7: Sequence diagram for collecting and visualizing thermal comfort related data.

In addition to the raw measurement data and the individual thermal sensation estimate illustrated above, end-user feedback is a key part of the thermal comfort monitoring. This feature enables the residents to provide their preference in form of a direct feedback that is measured using thermal sensation index. In the 1st phase the feedback is utilized manually by the facility manager and the iFLEX support team. In later phases, the feedback could be also used for fine-tuning the automated flexibility management automatically. Figure 8 illustrates a sequence diagram of the feedback mechanism.

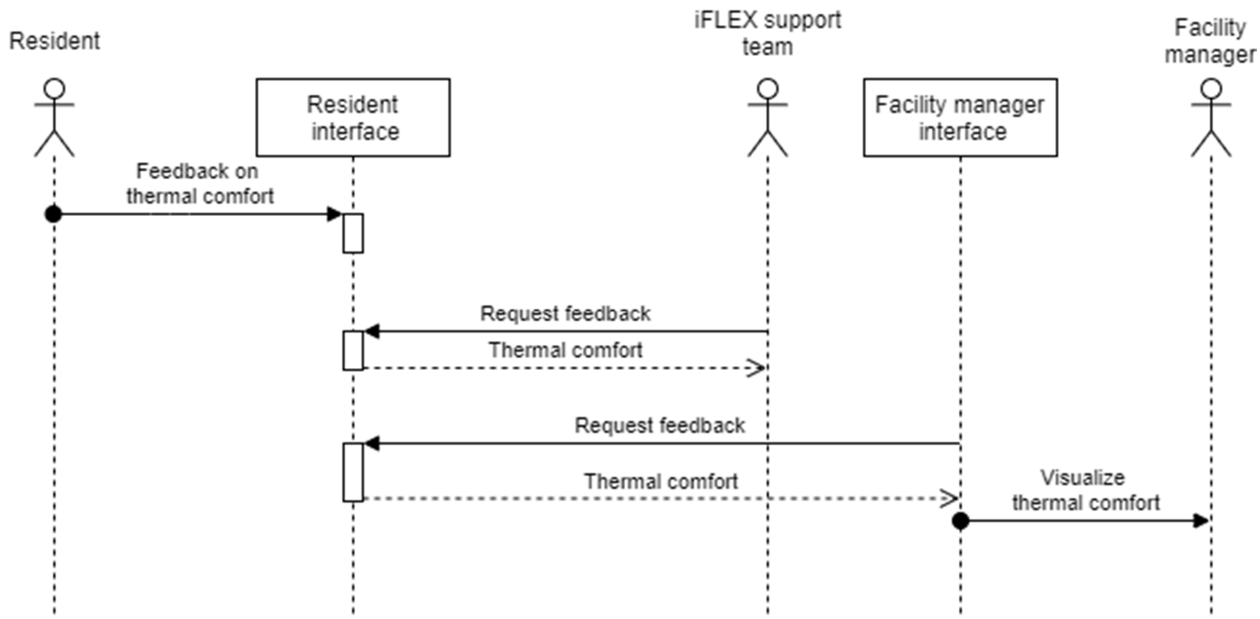

Figure 8: Sequence diagram for feedback on thermal comfort.

Residents are provided with a user interface that enables them to send feedback on their thermal comfort. The feedback is stored into a database of the resident interface, where it can be accessed by the Facility manager interface and the iFLEX Support team. The Facility manager interface visualizes the thermal comfort feedback for the facility manager that is responsible for ensuring the thermal comfort of the residents. This feedback is used for fine-tuning the building automation system. This functionality is outside of the scope of the iFA.

The feedback is also utilized by the iFLEX support team to analyse that the iFA works as expected. To elaborate, this information is used as an additional feedback to the measurement data available via the RAI, to make sure that the thermal comfort is not compromised during the flexibility management. I.e., if correlation between thermal discomfort and flexibility management is identified, the situation will be analysed and corrective actions executed (e.g. improve sensoring).

4.2.2 PUC-3 - Monitor my sustainability metrics

In the phase 1 of the building community iFA, this use case focuses on visualizations of the apartment building-level CO2 footprint. The footprint is calculated based on CO2 emission estimates and energy consumption measurements for electricity and district heating. For electricity the CO2 emission estimates (gCO2/kWh) are fetched from Fingrid's Open data service that provides high resolution estimates for electricity consumed in Finland. For district heating, similar real-time estimates for CO2 emissions are not available. For this reason, a static estimate is provided by the iFLEX support team based on the estimate provided by the DH provider. Figure 9 illustrates an example interaction between the functional components responsible for implementing the use case.

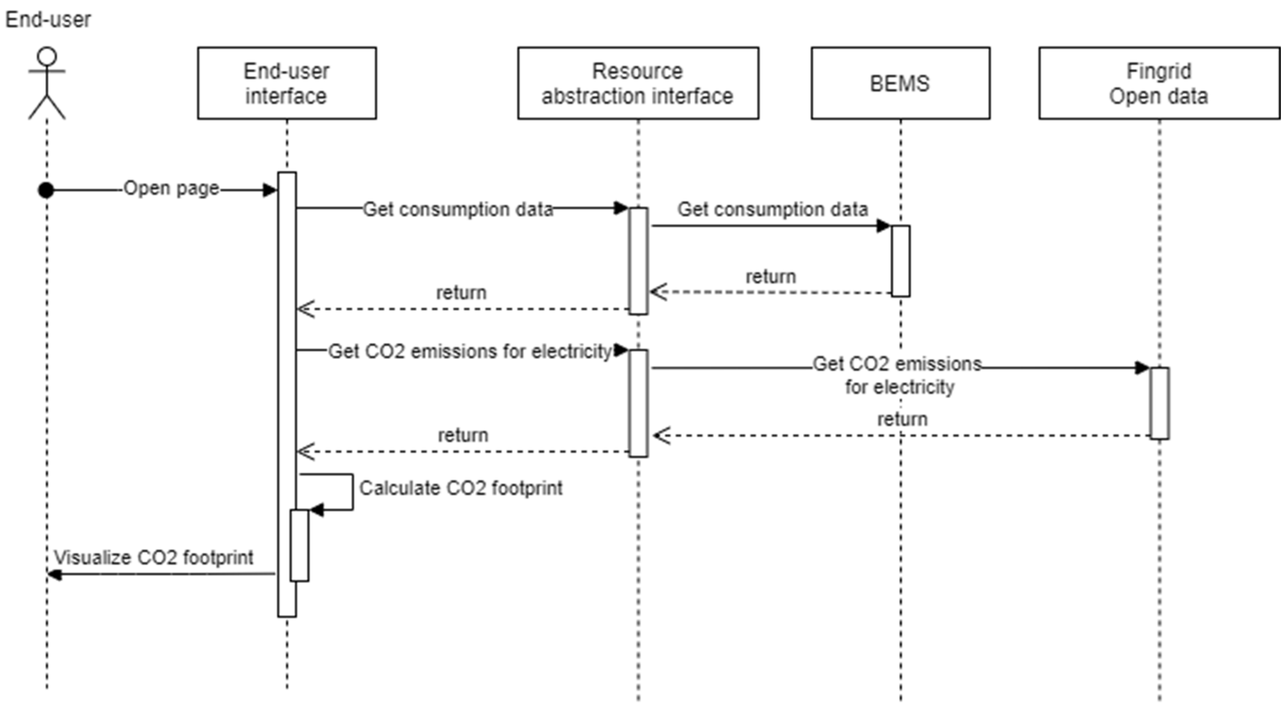

Figure 9: Sequence diagram for monitoring sustainability metrics.

4.2.3 PUC-7 - Monitor my energy in real-time

The energy monitoring use case for phase 1 of the building community iFA is straightforward as illustrated in Figure 10. The End-user interface fetches energy consumption data for district heating and electricity consumption from the Resource abstraction interface and visualized it to the end-users. Similar functionality is provided both for Residents and the Facility manager.

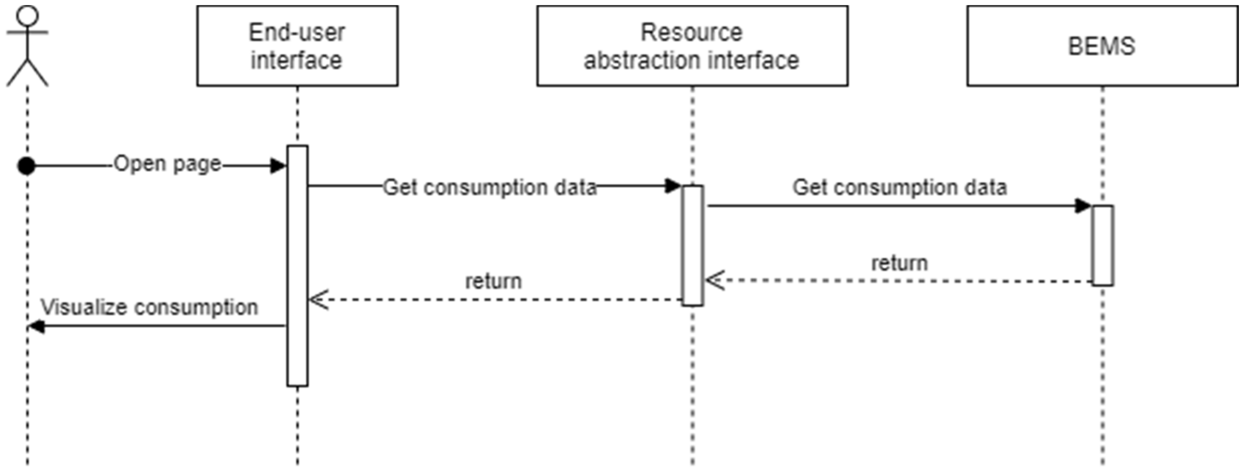

Figure 10: Sequence diagram of energy consumption monitoring use case.

4.2.4 PUC-8 - Offer flexibility

The offer flexibility use case to be demonstrated in the phase 1 of the building community iFA is depicted in Figure 11. The focus on phase 1 is demonstrating and evaluating the associated technical functionality and no aggregation is actually performed.

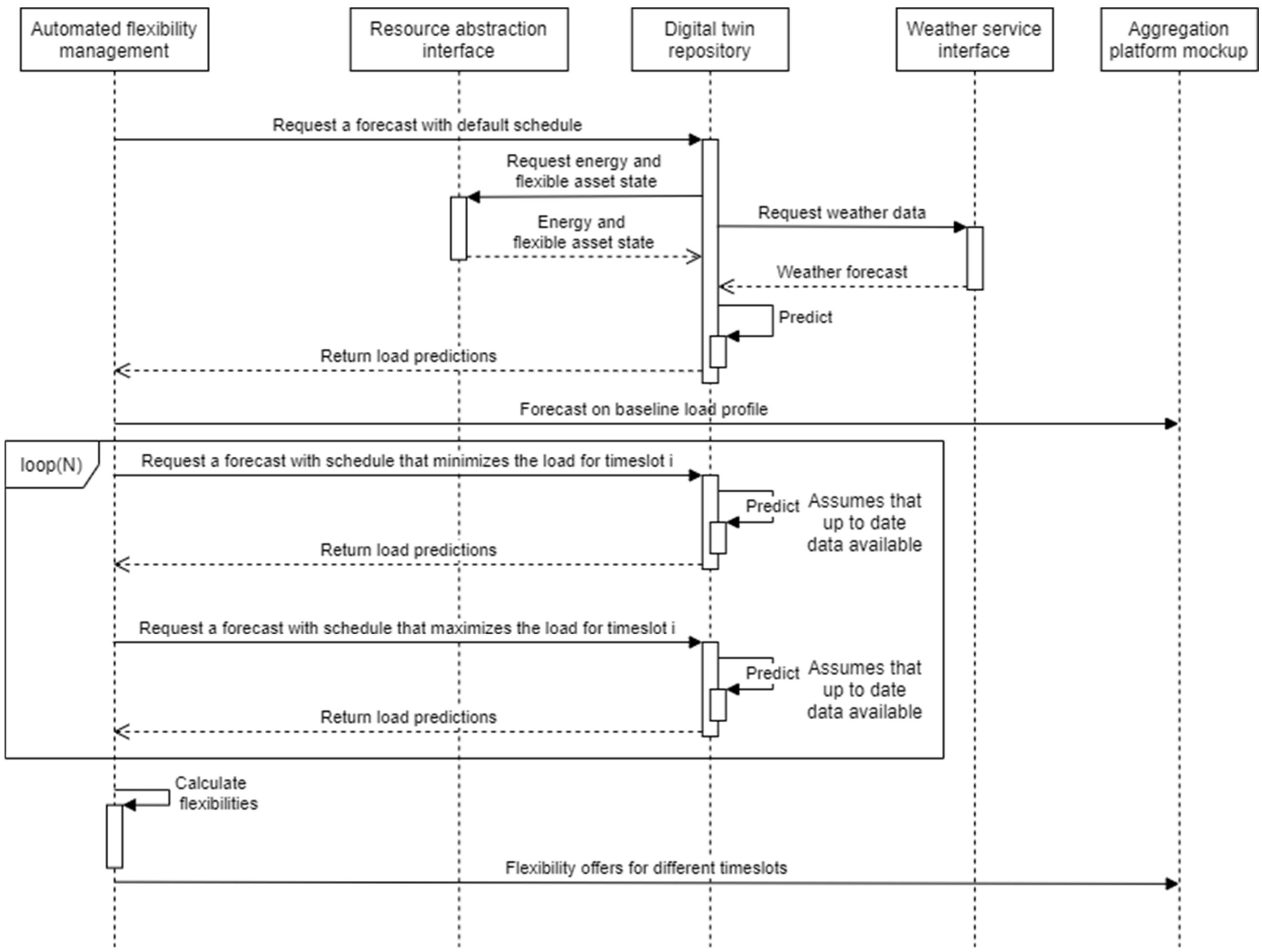

Figure 11: Sequence diagram for the offer flexibility use case.

The Automated flexibility management module is responsible for offering the buildings flexibility to the Aggregator and market interface component. To this end, it request the Digital twin repository to first perform a forecast on electricity and district heating consumption for a specified time horizon. The first forecast is performed with default set points for the flexible assets.

To perform a forecast the Digital twin repository request latest data (i.e., flexible assets state and energy consumption data) from the Resource abstraction interface component. In parallel. weather forecast data is requested from the weather service interface. This data is then feed as input for the digital twin models providing a forecast for the baseline consumptions (electricity and district heating) and the forecasts are returned to the Automated flexibility management module. The Automated flexibility management module sends the baseline information to the Aggregator and market interface module. As stated above, the Aggregator and market interface module is replaced with a simple mockup of the aggregation platform whose role is to demonstrate the functionality of the iFA. To this end, it visualizes the baseline forecast for electricity and district heating.

After the Automated flexibility management module has obtained the baseline it will continue to estimate the maximum and minimum loads for each time period. This is again done by requesting energy consumption forecasts from the Digital twin repository. First, the minimum load for each time period is requested. The Digital twin repository does not request new state of weather forecast data since it already has the latest information from the last call. To estimate the minimum load for each time period and for both energy vectors multiple forecast are required. The details will be presented in D3.1 - Initial Hybrid-modelling module and D3.7 - Initial Automated flexibility management module. Once the minimum load for each time period and for both energy commodities are forecast the Digital twin repository will return the minimum load forecast to the Automated flexibility management module. The maximum load for each time period is requested and forecast in the same way as the minimum load. Again it is assumed that the Digital twin repository has the latest information on flexible asset state, energy consumption and weather forecast available.

Once the Automated flexibility management module has obtained the baseline, minimum and maximum loads for both energy vectors, it calculates the flexibility potential by calculating the delta between the different scenarios and the baseline load profile. The information on the flexibility potential is then sent to the Aggregation platform mockup where it is visualized for demonstration purposes.

4.2.5 PUC-9 - Optimize schedule considering prices and/or incentives

In phase 1 the PUC-9 focuses on demonstrating automated flexibility management under explicit demand response. This use case continues from PUC-8 and assumes that the flexibility offers/potentials provided by the iFA are visualized in a simple mockup of the Aggregation platform (implemented for demonstration purposes in the 1st phase of the Finnish pilot). Figure 12 and Figure 13 illustrate an example of flexibility activation and optimization in form of a sequence diagram.

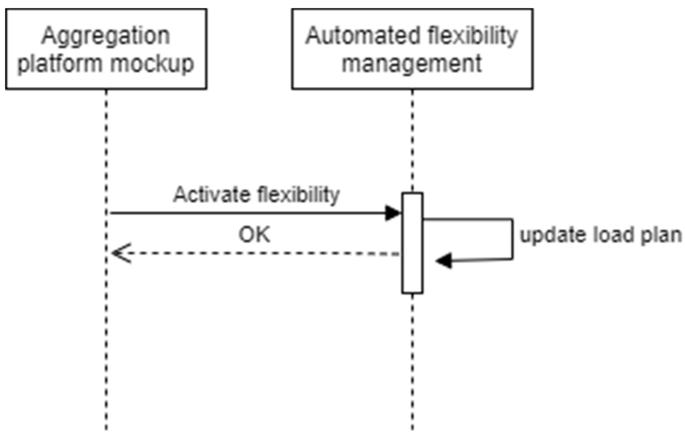

Figure 12: Sequence diagram illustrating a flexibility activation.

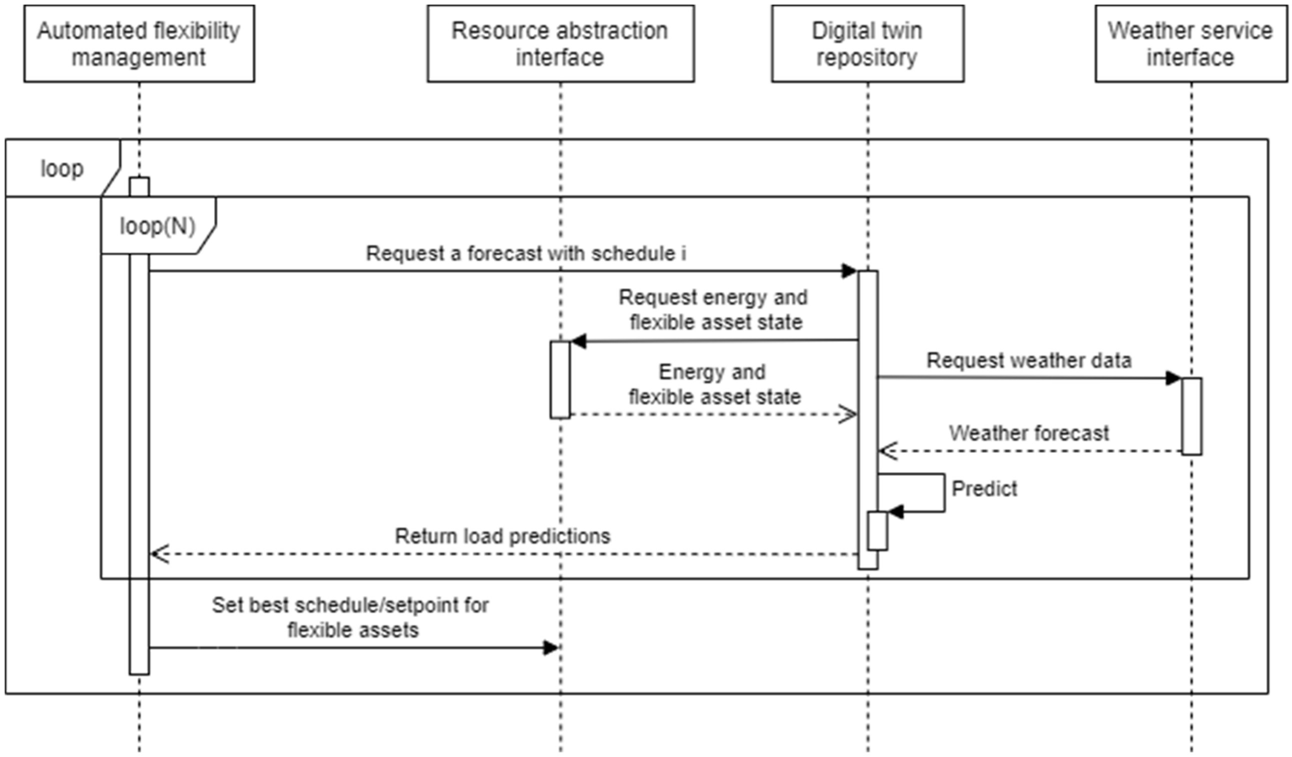

Figure 13: Sequence diagram of schedule optimization for flexible assets.

Explicit demand response is realized by activating offered flexibilities (see PUC-8 for details on how the flexibilities are offered) as illustrated in Figure 12. In the phase 1, this is done manually from the mockup interface that is set-up for demonstration purposes. The Aggregation platform mockup notifies the Automated flexibility management module about the flexibility signal and the Automated flexibility management module modifies the baseline load profile with the flexibilities that were activated.

The flexibility activation is taken into account the next time the Automated flexibility management module optimizes the schedule for the flexible assets.as illustrated in Figure 13. In phase 1, there is no implicit DR optimization and the optimization target is only to follow the load plan (i.e., baseline load profile) as accurately as possible without compromising the end-user preferences. The optimization is performed at fixed intervals. In practice, there are many ways to optimize a schedule. In this example, the Automated flexibility management requests a forecast for every possible scenario (i.e., brute force) from the Digital twin repository. Similarly to PUC-8, the digital twin repository fetches the necessary input data from the Resource abstraction interface and the Weather interface components. Once all possible scenario have been executed the Automated flexibility management component compares the forecasted loads with the baseline load profile and selects the one with minimum deviation. Finally, the new schedule is activated by sending a control command to the RAI.

5 Conclusions

This document describes the common architecture for iFLEX Framework, and its design process. The document represents:

- how iFLEX Framework interacts with end-users, other stakeholders and its environment
- how the logical subcomponents of the framework interact with each other
- how the components process and manage information
- what technologies and standards are used between the iFLEX Framework and external systems, and between functional components, to achieve interoperability
- how to address security and privacy in the iFLEX Framework architecture

In addition, this document describes an application of the iFLEX Framework to an iFLEX Assistant targeted to a building community.

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7 References

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