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D2.9 – Services and Modules for Oulu ICT Platform

WP2; Task 2.7

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25/11/2021	3.0	VTT	Jussi Kiljander	Final version for submission

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Abbreviations and Acronyms

Acronym	Description
AI	Artificial Intelligence
API	Application Programming Interface
BEMS	Building-level Energy Management System
DEM	District-level Energy Manager
DMS	District-level Monitoring System
DSO	Distribution System Operator
FMI	Finnish Meteorological Institute
ICT	Information and Communication Technology
KPI	Key Performance Indicator
PED	Positive Energy District

Executive Summary

This deliverable documents the final version of D2.9 - Services and Modules of Oulu ICT Platform. It is the outcome of T2.7 (subtask 2.7.2). The objective of WP2 is to deliver Lighthouse demonstration actions in Oulu. Task 2.7 is in charge of developing and integrating services and modules to ensure the performance monitoring, as well as, energy management objectives.

Subtask 2.7.1 Existing ICT-Oulu Platform adaptations towards an open-specifications approach. In this subtask, the current existing Oulu ICT platform will be adapted to an open concept. Data from the different demonstrative actions will be integrated and open APIs will be implemented for that. New data sets are integrated via open standards and according to these open specifications.

Subtask 2.7.2 New Services to integrate energy management, monitoring and KPIs calculation services to be integrated to the Urban Platform. This deliverable describes the new services and modules developed on top of the Oulu Urban Data Platform. In particular, the new services and modules focus on monitoring and realizing the project-level KPIs documented in D5.2. The new services and modules are represented as a standalone Energy Management and Monitoring Platform, which is integrated to the existing Oulu Urban Platform via open interfaces.

This deliverable first documents the main use cases of the Oulu PED area that need to be supported by the Oulu ICT platform. These use cases include: 1) providing data for KPI and SCIS calculations, 2) increase energy awareness via visualizations, 3) provide efficient energy management at the building level, 4) enable building flexibility to be accessed for PED area management, and 5) provide capability for PED area level energy management. Then the functionality and scope of the existing Oulu Urban Platform is briefly summarized. The existing Oulu Urban Platform is targeted to provide citizens with means to get information on things happening in Oulu, as well as, to provide feedback on issues concerning the citizens. In contrast, the Oulu PED area use cases require a platform that can provide energy and flexibility management and monitoring both at the building and PED area level. To this end, a new Energy Monitoring and Management platform is designed and implemented in the project. The main part of this deliverable documents the architecture design of this platform and how it links to the existing Oulu Urban Platform. The actual details on the implementation is provided in the other deliverables, namely D2.5, D2.6 and D2.8, of the work package 2.

1 Introduction

1.1 Purpose and target group

This report constitutes Deliverable *"D2.9 Services and Modules of Oulu ICT Platform"* which is the outcome of the *"Task 2.7 ICT City platform services integration"*.

The main objective of the deliverable is to represent the new services and modules of the Oulu ICT Platform. The new services and modules focus mainly on energy monitoring and management within the Positive Energy District (PED) pilot area. Therefore, these new services and modules are implemented as a standalone Energy Monitoring and Management Platform, which is integrated to the existing Oulu Urban Platform via open interfaces.

In general, the Oulu Energy Monitoring and Management Platform provides an overall ICT perspective of the Oulu Positive Energy District (PED) pilot. ICT technologies play an important role in the Oulu PED pilot. Many of the technologies and approaches designed in tasks 2.2 - 2.5 will be realized and integrated with ICT technologies via the Oulu Energy Monitoring and Management Platform.

This deliverable documents the software architecture of the Oulu Energy Monitoring and Management Platform. It is targeted for stakeholders interested in developing and deploying similar PED systems. The rest of the deliverable is structured as follows. Section 2 introduces the use cases that describe the approaches for adopting new technologies or business processes, and thus justify the development of the system architecture and associated services. Section 3 provides a general overview of the existing Oulu Urban Platform. Section 4 represents the software architecture of the Oulu Energy Monitoring and Management Platform. Following standard practices, the architecture is documented with viewpoint-based approach [1]. Section 5 concludes the deliverable.

The main impact of the EMM platform is to provide the ICT solutions for enabling energy and flexibility management in the Oulu PED area. This will reduce the CO2 footprint and costs in the PED area buildings by providing more energy efficient operation of the building infrastructure. Additionally, the EMM platform will enable reduction of peak loads in the PED area and thus reduce the operational and investments costs in the local district heating and distribution networks. Moreover, the flexibility provided by the PED area could be also utilized as a demand-side asset for load balancing in the transmissions system level.

1.2 Contribution partners

The following Table 1 depicts the main contributions from participant partners in the development of this deliverable.

Table 1: Contribution of partners

Partner nº and short name	Contribution
20-VTT	Sections 1, 2, 3 and 4. Editor of the deliverable.
13-OUK	Section 2

1.3 Relation to other activities in the project

The following Table 2 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the MAKING-CITY Project and that should be considered along with this document for

further understanding of its contents. In particular, this deliverable documents Oulu ICT platform from a software architecture perspective at high level. The deliverables D2.5, D2.6 and D2.8 listed in Table 2 provide details on the different functional components, actual implementation, and interfaces provided by the Oulu ICT platform.

Table 2: Relation to other activities in the project

Deliverable nº	Relation
D2.5	D2.5 presents the details on Building-level energy management approach in Oulu PED pilot.
D2.6	D2.6 Presents the details on the district-level energy monitoring and management approach introduced in this deliverable.
D2.8	D2.8 presents the details on the Oulu ICT platform implementation.
D5.7	D5.7 presents the implementation of the monitoring programme in Oulu.
D5.9	D5.9 provides a common background information for ICT-City Platforms.
D3.9	D3.9 presents the new services and modules of the Groningen ICT Platform.

2 Use cases of Oulu ICT Platform

This section describes the main use cases of Oulu ICT Platform. The following template was defined to unify the use case descriptions.

Use case template:

Use case name	Illustrative name
Use case ID	UC_<PED_AREA>_<INTEGER>
Actor(s)	The name of the actors that participate to the use case.
Brief description	A short description of the use case.
Preconditions	The conditions that must be satisfied before this use case can be invoked.
Post-conditions	The conditions that will be established as a result of invoking this use case successfully.

2.1 Parameters of KPI and SCIS data calculation

Use case name	Parameters for KPI and SCIS data calculation
Use case ID	UC_OULU_01
Actor(s)	Any stakeholder interested in the KPI and SCIS data (e.g. Citizens, End-users, Decisions makers, Technical Operators, etc.).
Brief description	The Oulu ICT Platform provides data for the needs of KPI calculation and SCIS reporting upon request. The details of the KPIs and data needed for SCIS database (to be produced via the open interfaces) is specified in D5.2 and D5.5. The relevant data for the KPI calculation and SCIS is stored into the Oulu ICT Platform. Whenever a client requests data or parameters for KPI calculations and/or SCIS via the open interface, the requested data is returned to the client. The platform only provides the data or parameters, not ready KPI calculations.
Preconditions	Necessary data for KPI and SCIS calculation is measured and/or available via external services. In practice this includes: - Energy meters are deployed at the buildings/systems and data is available over the Internet. - Environmental & weather measurements and forecasts - Historical data from buildings and systems - Data from other parties (city, energy company, housing company etc.) - Design data, simulated data, market data - Qualitative data (surveys, feedback etc.) - IEQ measurements

Post-conditions	1. Requested KPI parameters are returned to the client 2. Requested SCIS parameters are returned to the client

2.2 Increase energy awareness via visualizations

Use case name	Increase energy awareness via visualizations
Use case ID	UC_OULU_02
Actor(s)	Citizens, End-users, Decisions makers
Brief description	The user interface(s) of the Oulu ICT Platform visualize energy consumption, productions and energy-efficiency data in order to increase awareness among stakeholders.
Preconditions	Necessary data for visualizations is measured and/or available via external services. In practice this includes: - Energy meters are deployed at the buildings/systems and data is available over the Internet. - Design data, simulated data, market data - Qualitative data
Post-conditions	1. Energy consumption, production, efficiency and flexibility is visualized at a building level. 2. Energy consumption, production, efficiency and flexibility is visualized at a PED area level.

2.3 Building-level energy efficiency

Use case name	Building-level energy efficiency
Use case ID	UC_OULU_03
Actor(s)	End-users, Technical Operators
Brief description	The Oulu ICT Platform provides data and forecast on the energy efficiency of the buildings in different situations. This data is used by Technical Operators to improve the performance, for example, trough more optimized control of heating and cooling. Relevant constrains (i.e., room temperatures, etc.) are provided by the End-user.
Preconditions	Necessary data for energy-efficiency is measured and/or available via external services. In practice this includes: - Energy meters are deployed at the buildings and data is available over the Internet. - Relevant environmental and process data from HVAC and other relevant systems is available over the Internet.

Post-conditions	1. Detailed visualization of the energy consumption and process data are available for the Technical Operators. 2. Forecasts and simulations for energy behaviour in different conditions are provided for the Technical Operators.

2.4 Building-level flexibility management

Use case name	Building-level flexibility management
Use case ID	UC_OULU_04
Actor(s)	End-users, Retailer, DSO, District heating provider
Brief description	This use case covers both top down and bottom up based flexibility management at the building level. In top down based flexibility management, the building energy management system (BEMS) reduces the costs and maximizes End-user benefits by reacting to external signals such as energy and network prices, as well as, energy mix and CO2 data. In practise, BEMS, covered by the Oulu ICT Platform, utilize demand-side flexibility for reducing peak loads, shifting consumption to cheaper hours, and maximizing the utilization of the local renewable energy. In bottom-up based flexibility management, the BEMS provide support for PED level energy management systems and Utilities to harness the flexibility potential in the buildings. To this end, the BEMS provide aggregators with forecasts on energy consumption, generation and flexibilities, as well as, interfaces for activating flexibilities at the building level.
Preconditions	Necessary data for energy-efficiency is measured and/or available via external services. In practice this includes: - Energy meters are deployed at the buildings and data is available over the Internet. - Relevant environmental and process data from HVAC and other relevant systems is available over the Internet. - Lower level building management systems (BMS) are deployed and provide support for controlling energy resources such as HVAC.
Post-conditions	1. Oulu ICT Platform manages demand-side flexibility in order to reach monetary and environmental objectives set by the End-user. 2. Oulu ICT Platform provides forecast on energy load (consumption - generation) and flexibilities (i.e., capacity to reduce or increase consumption at specified time) via open interfaces accessible by the Aggregator (e.g. Retailer, DSO, District heating provider).

	3. Oulu ICT Platform provides aggregator (Retailer, DSO, District heating provider) with control interface for flexibility management at the building level.

2.5 PED level energy management

Use case name	PED level energy management
Use case ID	UC_OULU_05
Actor(s)	End-users, Retailer, DSO, District heating provider
Brief description	The Oulu ICT Platform aggregates and manages building level flexibilities in order to reduce peaks and maximize local renewable energy within the PED area. PED area is offered as an aggregated flexibility resource for power grid and district heating management purposes.
Preconditions	- BEMS expose the building level flexibilities as described in UC_OULU_04
Post-conditions	1. Oulu ICT Platform is able to manage flexibility at the PED area level in order to minimize the cost function defined as the control objective (e.g. reduce peaks and maximize the utilization of local renewables). 2. Oulu ICT Platform provides forecasts on energy consumption, generation and flexibility at the PED area level. 3. Oulu ICT Platform provides an open interface for activating offered flexibilities at the PED level.

3 Urban Data Platform

The Urban Data Platform of city of Oulu consist of Oulu home page and several application programming interfaces that have been developed to provide citizens with means to get information and provide feedback. In particular, City of Oulu has been setting-up an Urban Data Platform in 6Aika spearhead project. The objectives of the project have been to:

- Boost development of smart applications and services that improve quality of life
- Create a wider market for apps and services
- Meet citizens' demands for 24/7 digital services
- Engage with developers and citizens
- Harness the potential of data harmonization and open interfaces
- Make better use of other cities' know-how and resources by implementing proven APIs

To this end, the project has developed following open APIs for citizen empowerment:

- The Issue Reporting API enables citizens to easily report problems that need attention directly to the city's feedback system.
- The Linked Events API enhances the discoverability of nearby events by providing events data in a harmonized format.
- The Open Decision API makes it easier for citizens to access city decisions by providing the decision data in a structured and harmonised format.
- The Resource Reservation API enables 3rd parties – citizens and companies – to reserve resources managed by a city, making their use more effective.
- The Linked Data API facilitates getting around by making public transport data more easily available. The Tourism API enriches the visitor experience by enabling access to tourism-related data via a range of handy applications.

In Oulu, following two APIs have been implemented into the existing Urban Data Platform:

- Issue Reporting API: Issue Reporting API allows citizens to send a wide variety of issue reports from external services directly to a city's feedback system, complete with images and location details. The API provides a much more efficient way to gather data and greatly increases engagement by providing two-way communication between citizens and civil servants: citizens can not only report issues to the city, but also track their progress.
- Open Decision API (test-use): The Open Decision API makes municipal decisions and decision-making processes more transparent and accessible to the citizens. For example, city council, committee and board agendas and records can be published along with their attachments as open data. The data can be filtered by date, keywords, and location for easy access. The API also enables combining the information with data from other sources.

As can be seen, the APIs provided by existing Urban Data Platform focus on different use cases than the MAKING-CITY project. The MAKING-CITY project requires an Energy Monitoring and Management Platform that can:

- Provide data for KPI and SCIS calculations.
- Increase the energy awareness among citizens.
- Provide building-level energy-efficiency and flexibility management.
- Services for energy management at the PED area level.

For most of these functionalities it does not make sense to link them to the existing Urban Data Platform as their scope is quite different from the Urban Data Platform (i.e., the Urban Data Platform is designed to provide ways to engage with citizens whereas many of the MAKING-CITY use cases focus on energy and flexibility management). For this reason, the EMM platform designed for Oulu PED area is implemented as an individual platform. However, the platforms are connected through hyperlinks for features that make sense in the context of existing Urban Data Platform. For example, a link to the web user interface that provides visualizations of energy balance and efficiency in Oulu PED is available in the existing Urban Data Platform so that citizens can easily access it. The Energy Monitoring and Management Platform is described in section 4.

4 Energy Monitoring and Management Platform

This section represents software architecture of the Energy Monitoring and Management Platform for Oulu PED area. In general, the term software architecture refers to a high-level structure of a software intensive system. Although software systems have been around for ages is no official definition for the term software architecture [2]. A widely used definition depicted by Kruchten [3] is formulated as follows: "*Software architecture encompasses the set of significant decisions about the organization of a software system including the selection of the structural elements and their interfaces by which the system is composed; behavior as specified in collaboration among those elements; composition of these structural and behavioral elements into larger subsystems; and an architectural style that guides this organization. Software architecture also involves functionality, usability, resilience, performance, reuse, comprehensibility, economic and technology constraints, tradeoffs and aesthetic concerns.*" In ISO/IEC/IEEE 42010 [1] the term "architecture" in the context of software intensive systems is defined as follows: "*fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution*."

In order to successfully express and communicate software architectures there is a need for architecture descriptions [4] that document the architecture in form of diagram(s). It is very difficult to draw a single model that would address all the concerns of the system, represent all relationships relevant for the system in detail, and at the same time would be easily understood and communicated to the different stakeholders [5]. To address this challenge various view-based models for documenting software architectures have been proposed. As the name implies, an architecture view expresses the software architecture from a specific viewpoint. In this deliverables following viewpoints are utilized for documenting the Oulu Energy Monitoring and Management Platform: *context view*, *functional view* and deployment view.

4.1 Context View

The context view represents the overall scope of the system. In practice, it introduces relevant stakeholders and external systems, and depicts how the system of interest interfaces with them. Figure 1 illustrates the context view of the Oulu PED Energy Monitoring and Management Platform, referred to as the Platform in this deliverable. The interaction between the Platform, stakeholders and the external systems is represented in terms of information exchange. The services of the Platform are thus represented as the information provided by the Platform to the different stakeholders

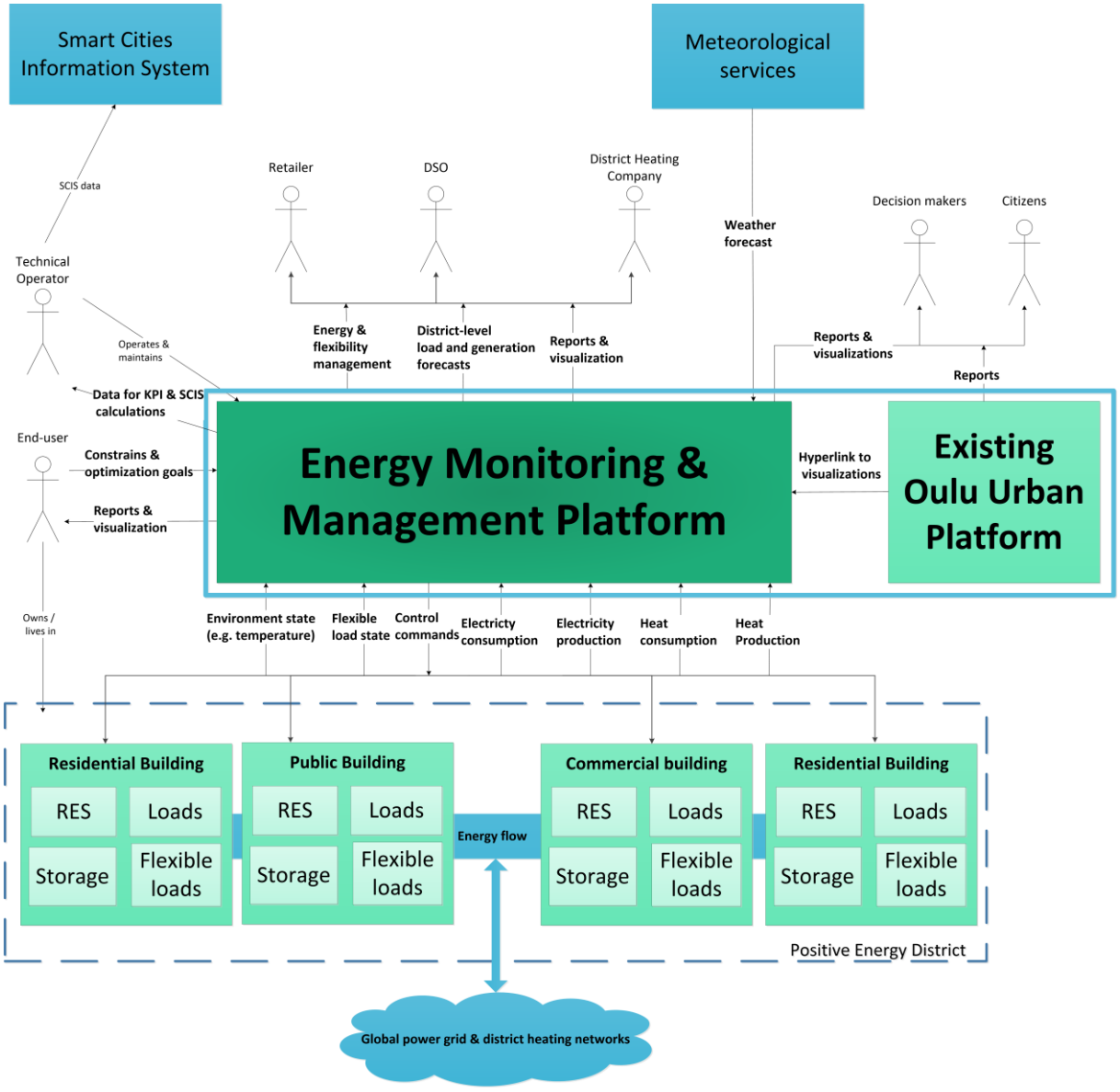

Figure 1: Context view of the Oulu PED Energy Monitoring and Management Platform.

As the name implies the Energy Monitoring and Management Platform is designed to provide ICT services for energy monitoring and management within the Oulu PED area. There are seven type of stakeholders interacting with the Platform: End-user, Retailer, Distribution System Operator (DSO), District Heating Company, Decision makers, Citizens and Technical Operators.

End-user's are stakeholders that live and/or own buildings in the Oulu PED area. It is their interest that the energy services provided by the Platform meet their needs. In practice, this means two things for the services provided by the Platform. First, it means that the Platform makes sure that the environmental conditions (e.g. ambient temperature, CO2, humidity, lighting, etc.) are kept within the limits desired by the End-users. Second, it means that the Platform manages energy according to the End-user wishes with respects to the costs and the environmental footprint. In terms of interaction and information exchange, the End-user provides the Platform with constrains and optimization targets, which specify the aforementioned requirements. The Platform in turn provides the End-users with various reports and visualizations about the energy consumption, related costs and environmental aspects. The details on these services are presented in D2.6 - Positive District Energy Flows.

There are three type of stakeholders whose business is focused on energy and power management: Retailer, Distribution System Operator and the District Heating Company. The Energy Monitoring and Management Platform provides these stake holders with means to manage the aggregated energy and flexibility in the PED area. In practice, the Platform provides forecasts on the available flexibility for a configurable time horizon and provides interface for activating the aggregated flexibilities. The energy aggregation and management service is based on bottom-up based approach where the flexibilities are first modelled at building level and then aggregated at the PED-level. The building-level modelling and control is presented in D2.5 - Smart Energy Systems in Oulu. The details of the aggregation approach in turn will be presented in D2.6 - Positive District Energy Flows. In addition to the energy and flexibility aggregation service, the Platform provides these stakeholders with forecasts on consumption and production within the PED area, as well as, various reports and visualizations on historical performance of the PED area.

The Citizen stakeholder refers to citizen in Oulu and neighbouring areas who do not live or own buildings in the PED area, but are still interacting with it e.g. through occasional visits in the area. For them the main services provided by the Platform include various reports and visualizations about the pilot. This information is also provided for the Decision makers who can influence how similar experiments will be executed in other areas and cities in the future.

Finally, Technical Operator role refers to the stakeholders that maintain and operate the Energy Monitoring and Management platform. It is also the responsibility of this stakeholder to report the relevant data into the Smart Cities Information System (SCIS). To this end, the Energy Monitoring and Management Platform provides her/him with relevant parameters for SCIS calculations.

In addition to the stakeholders, the role of the context view is to introduce relevant external systems for the EMM platform. These external systems include the buildings in the PED area, existing Oulu Urban Platform, and a meteorological service. The PED area buildings and associated energy management systems (in part deployed within the project) provide the Platform with various energy and environmental data, as well as, enable control of various energy resources within the buildings. A meteorological service such as the Finnish Meteorological Institute (FMI) provides the Oulu ICT Platform with weather forecast data.

As already elaborated in section 3, the scope of the EMM platform is different from the existing Oulu Urban Platform. Because of this, the EMM platform is designed and implemented as a standalone platform. The user interface providing various visualizations about the Oulu PED area is made accessible for citizens via the existing Oulu Urban Platform. In practise, this is done by adding hyperlinks to the EMM platform's user interfaces into the Oulu Urban Platform web pages. This makes is possible for citizens browsing the Urban Data Platform to easily find information about the Oulu PED area.

4.2 Functional View

The functional view decomposes a system into logical functional components and represents their responsibilities and main interactions. The Energy Monitoring and Management Platform consist of following main functional components, which hare further divided into sub-modules: District-level Monitoring Service (DMS), District-level Energy Manager (DEM) and Building-level Energy Management System (BEMS). The functional view of the Oulu Energy Monitoring and Management Platform is depicted in Figure 2.

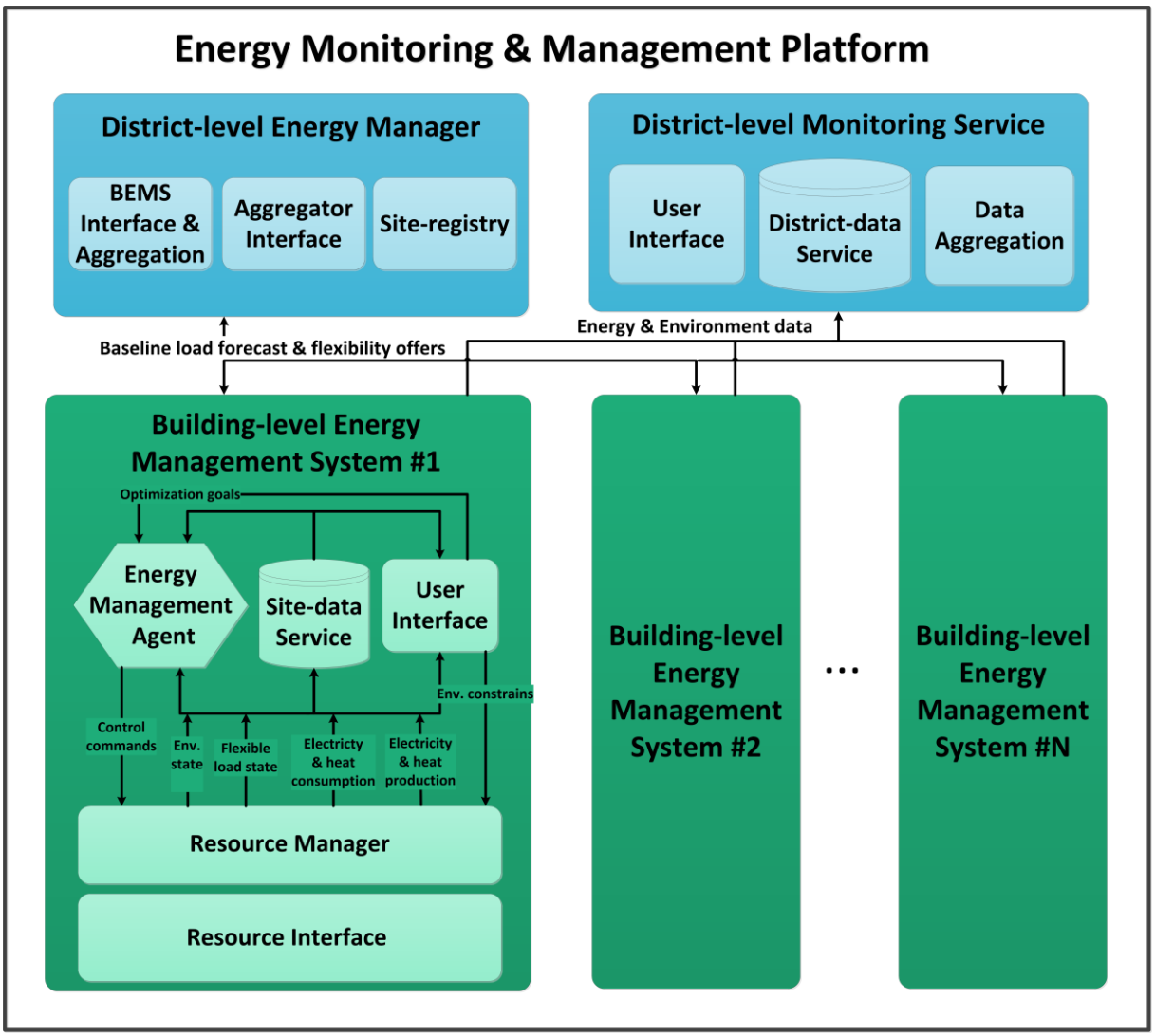

Figure 2: Functional View of the Oulu PED Energy Monitoring and Management Platform.

The Building-level Energy Management System component is responsible for managing energy within a single building in the PED area. It addresses the use cases UC_OULU_03 and UC_OULU_04 that focus on the building level energy and flexibility management, as well as, the UC_OULU_02 as it provides user interfaces for the people living in the Oulu PED area. Internally, the functional component consist of five subcomponents: Energy Management Agent, Site-data Service, User Interface, Resource Manager and Resource Interface. The energy management approach investigated in the Oulu PED area is based autonomous Energy Management Agents implemented with Artificial Intelligence (AI) technologies. In practice, the role of the Energy Management Agent is to learn the dynamics of a building in order to expose its flexibility for the PED area level energy management. The Site-data Service is a logical

component storing site-specific energy and environmental data. The User Interface component provides End-users with means for monitoring site data, as well as, managing optimization targets and environmental constrains. The Resource Interface component provides interaction with building management and energy monitoring systems deployed in the PED buildings. The Resource Manager component manages resource access and data on environmental constrains. Additionally, the Resource Manager is responsible for making sure that the control commands issued by the Energy Management Agent respect the environmental constrains set by the user. The full details on the building-level energy management will be presented in D2.5 - Smart Energy Systems in Oulu.

The District-level Monitoring Service manages data at the whole PED-level. It addresses the use cases UC_OULU_01 and UC_OULU_02. The District-level Monitoring Service is responsible for collecting data required for PED level monitoring and evaluation (i.e. SCIS and KPI calculations). It provides also open interfaces, as well as, visualizations about the energy consumption and production at the building and district levels. These visualizations can be accessed both residents of the Oulu PED area as well as citizens and other stakeholders. Internally the DMS consist of Data Aggregation, District-data Service and User Interface components. The District-level Monitoring Service and these components are presented in detail in D2.6 - Positive District Energy Flows.

The District-level Energy Manager is an aggregation service that aggregates and manages district heating and electricity within the PED area. I.e., it is the functional component responsible for the use case UC_OULU_05. The DEM component consist of following subcomponents: BEMS Interface & Aggregation, Site-registry and Aggregator Interface. The BEMS Interface & Aggregation component interacts with the BEMS functional components in order to aggregate the building level loads and flexibilities both for district heating and electricity. The Site-registry stores necessary information about the buildings in the PED area. The Aggregator Interface component is response for providing interface to aggregators such as DH companies, retailers, and energy suppliers. The details of the district-level energy management approach are presented in detail in D2.6 - Positive District Energy Flows.

5 Conclusions

This deliverable documented the Oulu ICT Platform that extends the existing Oulu Urban Platform with services for energy monitoring and management in PED area. This deliverable provided the main use cases for the Oulu ICT Platform and briefly summarized the functionality provided by existing Oulu Urban Data Platform. The existing Oulu Urban Data Platform is designed for different use cases than required by the Oulu PED area. For this reason, a standalone Energy Monitoring and Management Platform is designed and implemented in the project. The software architecture of the Oulu ICT Platform that combines the Energy Monitoring and Management Platform and the Oulu Urban Platform is documented using a standard viewpoint approach. Context view and functional view were documented in this deliverable. Further details about the Oulu ICT Platform are presented in associated deliverables. Detail about the implementation, deployment and application programming interfaces of the Platform are provided in D2.8 - Adaptation of Oulu ICT Platform. Details about the Building-level Energy Management Systems are documented in D2.5. The D2.6 describes details about the District-level Energy Monitoring and Management Solutions.

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