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D2.17 Interoperability plan and testing

WP2/3/4, Task 2/3/4.6

# Transition of EU cities towards a new concept of Smart Life and Economy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

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| Project Acronym | mySMARTLife | | |
| Project Title | **Transition of EU cities towards a new concept of Smart Life and Economy** | | |
| Project Duration | 1st December 2016 – 30th September 2022 (66 Months) | | |
| Deliverable | D2.17 Interoperability plan and testing | | |
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| Work Package | WP2 | | |
| Lead beneficiary | CAR | | |
| Contributing beneficiary(ies) | NAN, ENG, HAM, TSY, HEL, FVH | | |
| Task description | In this second cross-cutting task, an interoperability test plan will be established from a harmonised approach in the three demos. It will be demonstrated that the new modules developed to improve the Urban platforms interact in an appropriate manner with the other platforms/software or software components and that information is exchanged correct and valid. | | |

| Date | Version | Author | Comment |
|---|---|---|---|
| 12/07/2017 | 0.1 | CAR | Table of contents and responsibilities |
| 19/10/2017 | 0.2 | FVH | Additions in Chapter 3 |
| 20/10/2017 | 0.3 | ICT HAM | Contribution to chapter 3 |
| 30/10/2017 | 0.4 | CAR | Contribution to sections 1 and 3 |
| 16/11/2017 | 0.5 | FVH | Contribution to the use cases |
| 21/11/2017 | 0.6 | All | Contributions to the use cases and interoperability |
| 22/11/2017 | 0.7 | FVH | Review of semantic interoperability |
| 26/11/2019 | 0.8 | All | Definition of use cases for interoperability and indicator for final evaluation |
| 25/11/2020 | 0.9 | All | Test plan for the interoperability testing |
| 27/01/2022 | 0.10 | All | Final use cases and interoperability plan |
| 04/02/2022 | 0.11 | All | Reporting the results of the tests |
| 08/02/2022 | 0.12 | All | Documentation of final use cases and results |
| 12/02/2022 | 0.13 | NAN, ENG | Test cases of the Nantes urban platform |
| 22/02/2022 | 0.14 | All | Final inputs about interoperability lessons learnt |
| 25/02/2022 | 1.0 | CAR | Final review and typos correction |



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# Abbreviations and Acronyms

| Acronym | Description |
|---|---|
| API | Application Programming Interface |
| BACnet | Building Automation and Control Networks |
| CIM | Common Information Model |
| CityGML | City Geography Markup Language |
| CKAN | Comprehensive Knowledge Archive Network |
| CSV | Comma Separated Values |
| CSW | Catalogue Service for the Web |
| EJB | Enterprise JavaBean |
| ESPRESSO | systemic Standardisation approach to Empower Smart citieS and cOmmunities |
| FTP | File Transfer Protocol |
| FTPS | FTP SSL (Secure Socket Layer) |
| GDPR | General Data Protection Regulation |
| HVAC | Heating, Ventilation, and Air Conditioning |
| IEC | International Electrotechnical Commission |
| ISO | International Organization for Standardization |
| IT | Information Technology |
| JSON | JavaScript Object Notation |
| mySMARTLife | Transition of EU cities towards a new concept of Smart Life and Economy |
| OCPP | Open Charge Point Protocol |
| OGC | Open Geospatial Consortium |
| PPI | Pivotal Point of Interoperability |
| REST | Representational State Transfer |
| SDK | Software Development Kit |
| SensorML | Sensor Model Language |
| SFTP | Secure FTP |
| SOAP | Simple Object Access Protocol |
| STA | SensorThings API |



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| | |
|---|---|
| TimeseriesML | Timeseries Model Language |
| XML | eXtensible Markup Language |
| WFS | Web Feature Service |
| WMS | Web Map Service |
| WP | Work Package |



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# 0. Executive Summary

Interoperability is a pivotal aspect in the implementation of services and urban platforms. Its lack is a major obstacle to progress on the digitalization and the increase of knowledge in terms of data sharing. In this way, the use of standards and common definitions support the assurance of interoperability. Nowadays, the importance of data exchange between entities is critical in order to generate more businesses and services. Due to this growing importance, **this document tries to validate an interoperability test plan,** concept that is developed within mySMARTLife project and applicable for other platforms.

In this sense, two interoperability levels are established with the aim to:

1) allow the insertion of new data from additional data sources (southbound interoperability),
2) use of already-existing services from one platform to another by simply making use of implemented open APIs (northbound interoperability).

This document is mostly focused on the northbound level so as to assure the capability of interchange services from platform to platform. For this purpose, several use cases throughout the project actions are used to verify the open data and open API interfaces. The selection of the use cases is based on the data availability in the three urban data platforms so as to check the data exchange mechanisms are functional according to the common data model that is established within the project.

Finally, the target group of this deliverable points the ICT (Information and Communication Technologies) experts (i.e. developers, integrators, maintainers…). The output of this report aims at highlighting how the assurance of the interoperable services could guide further developments in the urban data platforms to assure this feature is ensured. As well, it describes how the usage of SensorThings API makes the developments compliant with INSPIRE Directive to further implement or extend services following standards.



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# 1. Introduction

## 1.1 Purpose and target group

As extracted from the description of the task, the objective of this deliverable is to establish **an interoperability test plan in a harmonized way for the urban platforms developed in the three lighthouse cities**. The main intention of the work within this deliverable and task is to demonstrate that the modules / services of the urban platforms are interoperable across urban platforms and they are able to interact and exchange data. Then, thanks to the interoperability testing plan, the capability of the services to be exchangeable is increased and validated from software-to-software components.

The lack of interoperability is a major obstacle to progress on the digital single market. Hence, interoperability is one of the most important topics when developing and/or improving urban platforms. Interoperability should be guaranteed in a sustainable way and not as a one-off target or project. Therefore, mySMARTLife does not intend to fix this feature within the urban platform, but to define a set of requirements that deal with the interoperability aspect abroad the project. That is why, similar to the European Interoperability Framework definition, it is pivotal to establish interoperability agreements in all layers, complemented by operational agreements and change management procedures. Thus, this deliverable tries to answer these “questions” in terms of interoperability layers within the common framework, as well as the data exchange mechanisms.

Related to organization of the task, this is one of the two transversal tasks that affect the work packages dedicated to the demonstration activities in the lighthouse cities. More in particular, Figure 1 represents the schema about how these tasks are cross-cutting WP2, WP3 and WP4. All are related to a common open framework definition to guide the implementation of the new services within the urban platforms, ensuring the interoperability between these services.

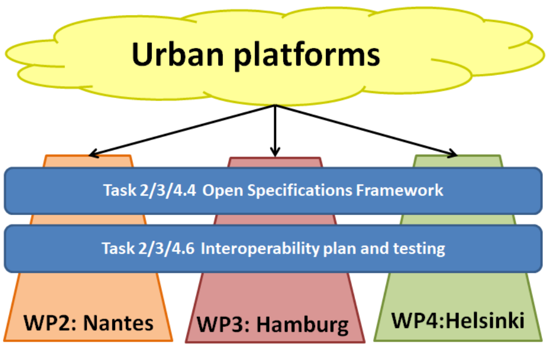


Figure 1: Interoperability task within the work programme

As mentioned before, the objective of this deliverable is to establish a set of guidelines in terms of interoperability aspects in the new implementations under the mySMARTLife umbrella, but also out of the project, with other platforms and frameworks. Therefore, the target group is any stakeholder involved in



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the urban platform context, i.e. ICT experts. This target group is the one with capabilities of understanding the usage of APIs, how to establish the information exchange mechanisms and developing new urban platform features. Not only the ICT experts of the three urban platforms of the projects are targeted, but also third parties with the aim of making use of data to generate new businesses and knowledge around the urban platforms. For instance, entrepreneurs being able to develop and deploy new services at top of the urban platforms would need to know the interoperability requirements and connection methods to the multiple open APIs.

Finally, the distribution of the deliverable gives firstly an overview about what interoperability is in the mySMARTLife context and the levels of interoperability that are defined in the project. Secondly, the use cases, which are used for demonstrating the interoperability, are defined. Next, the interoperability test plan is established where the objectives and the procedure are explained. Finally, the results are documented.

## 1.2 Contributions of partners

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

Table 1: Contribution of partners

| Participant short name | Contributions |
| --- | --- |
| CAR | Task and deliverable leader. Contributor to the interoperability definition, as well as testing planning. |
| NAN | Main contributor to the Nantes use cases, as well as the templates for use cases definition. |
| ENG | Contributor to the Nantes urban platform use cases and definition of test plans and results in the case of Nantes. |
| HAM | Similar to city of Nantes, but in the case of Hamburg. |
| TSY | Contributor to the interoperability tests and results for Hamburg platform. |
| HEL | Similar to city of Nantes, but in the case of Helsinki. |
| FVH | Contributor to the interoperability tests and results for Helsinki platform. |

## 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 mySMARTLife project and that should be considered along with this document for further understanding of its contents.



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Table 2: Relation to other activities in the project

| Deliverable Number | Contributions |
|---|---|
| D2.16 | This deliverable provides the common open specifications framework definition where the multilayer conceptual framework is explained and, from which, interoperability aspects are defined. |
| D2.8 | The deliverable is focused on the improved services in Nantes urban platform and these services need to be tested from the interoperability point of view. |
| D3.5 | The developments of the new concepts for urban platform in Hamburg include the interoperability concept and, therefore, related to this deliverable. |
| D3.6 | This deliverable determines the open data and open APIs in Hamburg, which are key points for the interoperability. |
| D4.9 | This deliverable contains the explanations related to the Carbon Neutral Me, which is a new service in the Helsinki urban platform and, hence, part of the interoperability testing phase. |
| D4.10 | Description of the features for new services in the platform, then, again, interoperability aspects. |
| D4.11 | Description of IoT services that are pivotal points for interoperability. |
| D4.13 | Similar to previous cases, this deliverable is dedicated to open data and open APIs, being pivotal for assuring interoperability. |
| D5.3 | Related to the actions, this deliverable contains the monitoring programs for these actions and, within them, monitoring should be integrated in the platforms, which is interoperability at data collection level. |
| D5.4 | Data collection should be integrated in the platforms, therefore, interoperability for gathering information must be ensured, as well as data models should be ready to share information. |



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# 2. Glossary

Before starting with the development of the technical content related to the interoperability testing, it is important to provide a definition of several concepts which are sometimes misunderstood. In this sense, similar to D2.16, the glossary of terms is explained at the beginning to help the reader to understand the concepts included in the document. The critical terms are introduced in Table 3.

Table 3: Glossary of terms

| Term | Definition used |
|---|---|
| | Stakeholders |
| Platform provider | Stakeholder who:<br>- "*MAINTAINS the eco-system of data, services, and users. DEFINES standards, licenses and regulations and provides terms and conditions for platform usage and the commercial exploitation of data and services. DECIDES WHO is allowed to join the value network of data and services providers.*" [1] |
| Data publisher | Stakeholder who:<br>- "*PUBLISHES open and proprietary data into the platform.*<br>- *MANAGES AND MAINTAINS RESOURCES in the platform accordingly to terms and conditions.*" [1] |
| Data consumer | Stakeholder who:<br>- "*CONSUMES open and proprietary data provided in the platform. USES open and commercial data services provided in the platform. PROVIDES FEEDBACK on data and services provision.*" [1] |
| Service provider | Stakeholder who:<br>- "*DEPLOYS open and commercial data services into the platform (e.g. data visualisation, data cleansing, and data integration tools). MANAGES AND MAINTAIN RESOURCES in the platform according to the terms and conditions.*" [1] |
| Final stakeholder | Stakeholder who ultimately beneficiates from the Urban Platform.<br>First of all, and the most important stakeholder, the citizens. They are the main focus of the urban platform by means of available services. Nevertheless, city managers, city council, etc. make use of the urban platform to make decisions based on data and indicators that the urban platform provides. |



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<table>
<tr><th>Term</th><th>Definition used</th></tr>
<tr><td></td><td>Processing steps</td></tr>
<tr><td>Collect</td><td>Processing step #1 (sensing layer / field layer):<br>- At field level, field information (heat, pressure, power, consumption…) are collected and converted into IT data. This step may be under the responsibility of the sensors' owner, i.e. the Data publisher.</td></tr>
<tr><td>Publish</td><td>Processing step #2 (sensing layer / field layer):<br>- The Incoming Data are made available to the Urban Platform by the Data Publisher in the Data Publisher's format: original or specific or transformed into an open standard format to ensure interoperability.<br>- Access rights (right to publish) are verified at this step.<br>- It is the Data Publisher's responsibility to ensure that the published data meet quality requirements.<br>- Publish – Push:<br>o The Data Publisher sends the data to the Urban Platform; the Urban Platform provides services to receive the data and the according Service Contract.<br>o Example: IoT measurements are sent to the urban platform.<br>- Publish – Pull:<br>o The Urban Platform IT Core fetches the Incoming Data; the Data Publisher provides services to retrieve the data and the according Service Contract.<br>o Example: Weather information is fetched by the urban platform periodically (poll mechanism).</td></tr>
<tr><td>Import</td><td>Processing step #3 (data layer / drivers' layer):<br>- The Incoming Data Service Contract is verified.<br>- The Incoming Data is stored in a staging data container to be ready for the next step.</td></tr>
<tr><td>Integrate</td><td>Processing step #4 (data layer / drivers' layer):<br>- The Incoming Data is transformed from the Data Publisher's format into the target data format and stored in the Work Data container.<br>- The data is ready for either being made public ("Expose" step) or being used for a transformation.</td></tr>
</table>



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| Term | Definition used |
| --- | --- |
| Transform | Processing step #5 (business layer / knowledge layer):<br>- Service Providers provide transformation services and the according Service Contracts.<br>- The transformed data must be in target format, i.e. do not require any other Integration step.<br>- Transformation can be of various types: e.g. aggregation, anonymization, calculation, analysis, forecast, cross-referenced with other data…<br>- Not all data require to be transformed prior to exposition. |
| Expose | Processing step #6 (business layer / interoperability layer):<br>- The Data in target format is tagged as ready to be exposed, either to the public or to a restricted list of Data Consumers.<br>- Only data tagged as "exposed" can be consumed by an actor, which is neither the Platform Provider nor a Service Provider. |
| Distribute | Processing step #7 (IT enabled services layer / intelligent services layer)<br>- The Data is transferred from the Urban Platform to Data Consumers. Typically, this step can be carried out by an open data portal.<br>- Access rights (data access rights) are verified at this step. |
| Consume | Processing step #8:<br>- The Data consumers make use of the distributed data. |
| | Openness |
| Open data | "*Open data is the idea that some data should be freely available to everyone to use and republish as they wish, without restrictions from copyright, patents or other mechanisms of control.*" [2] |
| Open specification | The documents fully describing the functional perimeter and the integration details (including the service contract) are free for access. |
| Open API | "*An open API, also known as a public API, is an application programming interface that allows the owner of a network-accessible service to give universal access to consumers of that service, such as developers. An API is a software intermediary that makes it possible for application programs to interact with each other and share data.*" [3]<br>The API is available to any user for free.<br>Authentication may be required, depending on the Platform Provider policy. |



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| Term | Definition used |
|---|---|
| Open SDK | Either:<br>a) Technical components, available to third-party users for free, which allow developers to implement components, which would be executed within the Urban Platform without using the Open API.<br>Or:<br>b) Technical components, available to third-party users for free, which allow third parties to use the open APIs.<br>For mySMARTLife, Open SDK will be implemented by open source tools, which apply to the interoperable web services provided at field and API level. |
| | Interoperability |
| Interoperability | "*Ability for products/services/systems to exchange data with other products/services/systems in a harmonized and homogeneous way by using open and standard formats and/or protocols.*" [3] |
| Data format | Structure, cardinality, field formats and field of extent, which together represent in an unambiguous way a piece of information. |
| Service contract | Document, which defines an interaction between two IT systems. It contains or refers to:<br>- an Interface Contract (cf. definition),<br>and also refers to:<br>- the time windows and/or schedule during which the service is due to be available,<br>- the estimated and/or maximum amount of data involved,<br>- the periodicity at which new data are available or recalculated,<br>- the minimum and maximum latency, i.e. the amount of time before new data are made available through the service or the indication that there is no commitment in this matter,<br>- the rules and regulations applicable to the use of the service. |



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| Term | Definition used |
|---|---|
| Interface contract | Technical document, which defines:<br>- Service protocol: file-based (e.g. FTP, SFTP, FTPS…), service-based (e.g. REST, SOAP, EJB…),<br>- Service signature (methods names, arguments names, return values, exceptions),<br>- Data format (e.g. JSON, XML, CSV…),<br>- Data structure: fields and cardinality,<br>- Field information: type (e.g. other data, string, integer, double, date…), format (e.g. length, number of digits…), list of accepted values (e.g. "Y", "N", "ON", "OFF"…).<br>- An explanation of the data and fields, their meaning and any information and/or reference, which helps to understand what the service and data are about and how to use it.<br>- Data related specifications should be as close as possible to existing standards, if not directly refer to it. |
| | Other definitions |
| Urban Platform | It is "*the implemented realization of a logical architecture/content/design that brings together (integrates) data flows within and across city systems and exploits modern technologies (sensors, cloud services, mobile devices, analytics, social media etc.)*" [4].<br>It provides "*the building blocks that enable cities to rapidly shift from fragmented operations to include predictive effective operations, and novel ways of engaging and serving city stakeholders in order to transform, in a way that is tangible and measurable, outcomes at local level (e.g. increase energy efficiency, reduce traffic congestion and emissions, create (digital) innovation ecosystems)*". [4]<br>An urban platform integrates various verticals and enables data exchange between verticals and data analytics regarding the combination of services. It forms a system of systems. |
| Framework | For software point of view, it refers to a reusable set of libraries or classes for a software system. It represents a common, reusable and open abstraction of the software architectures. It is basically a structure, a logical way to classify, segment and categorize functionalities. |
| Architecture | It refers the process of defining a structured solution that meets all of the technical and operational requirements, while optimizing common quality attributes such as performance, security, and manageability. The software architecture of a program or computing system is the structure or structures of the system, which comprise software elements, the externally visible properties of those elements, and the relationships among them. |
| Sensor | Sensor is a simply measurement device, for instance, a temperature sensor. A device is any equipment sending data, either composed by a single value (single sensor) or multiple values (i.e. multi-sensor, for example, a data collector that sends several values once). |



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| Term | Definition used |
|---|---|
| Service | A service is a high-level functionality within any of the defined verticals that allow citizens, city planners, city managers, public administration, etc. to interact with the urban platform via applications (web, mobile...). |
| Dataset | A dataset is a representation of a collection of data in an established format. |



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# 3. Interoperability concept

## 3.1 Interoperability under mySMARTLife context

In information systems, interoperability describes the extent to which systems and devices can exchange data and interpret the shared data. For two systems to be described as interoperable, they are expected to exchange data and subsequently present that data in a way that can be understood by a user on either system. That is to say, it establishes how a system is capable of working with another system.

Interoperability of information systems has been researched closely in various areas, especially in healthcare. The definitions such as the following three concepts of interoperability are however universal and can also be adopted in mySMARTLife project [5]:

- **Foundational** interoperability allows data exchange from one information technology system to be received by another and does not require the ability for the receiving information technology system to interpret the data.
- **Structural** interoperability is an intermediate level that defines the structure or format of data exchange (i.e. the message format standards) where there is uniform movement of data from one system to another such that the operational purpose and meaning of the data is preserved and unaltered. Structural interoperability defines the syntax of the data exchange. It ensures that data exchanges between information technology systems can be interpreted at the data field level.
- **Semantic** interoperability provides interoperability at the highest level, which is the ability of two or more systems or elements to exchange information and to use the information that has been exchanged. Semantic interoperability takes advantage of both the structuring of the data exchange and the codification of the data including vocabulary so that the receiving data systems can interpret the data in an intended way.

According to these three concepts of interoperability and taking the pivotal points of interoperability (PPI) defined by ESPRESSO [5] into account, as reference framework for the urban platforms' implementation, two levels of interoperability are basically defined in mySMARTLife, but covering the three aforementioned aspects. First of all, it is important to highlight that the PPIs try to find a consensus between standardized interfaces that deal with composition of cyber-physical systems without constraining innovation [5][6]. In this way, Figure 2 represents the PPIs between the field equipment, data zone and applications/services. As observed, data gathering should be interoperable in terms of allowing data collection from sensor devices. In this way, any third party with the commitment of sharing information through the urban platform may connect their sources in a "standardized" way. Similar it is happening in the applications where the services make use of data from data lake and, hence, they need to access data, being necessary the



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interoperability. Last but not least, in the data lake itself, the use of standard data formats and semantics (including metadata) put in favour the interoperability of data.

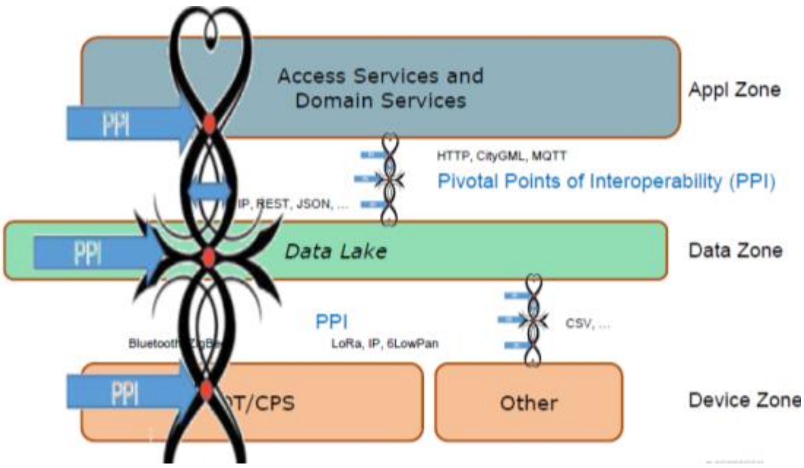


Figure 2: Pivotal Points of Interoperability

For mySMARTLife project, the concept has been taken and it has been already explicitly included in the definition of the common open specifications' framework. As it is highlighted in Figure 3 [7], there is a specific interoperability layer to ensure the application PPI, while drivers' layer contains a module for interoperability in terms of PPI for the device zone. Related to the data zone, it is not included in the framework, but the use of standards for data models and metadata applies for the data lake interoperability, as well as the aforementioned semantic interoperability. In the mySMARTLife scope, the interoperability layer is named "**Northbound**" and drivers' level is "**Southbound**".

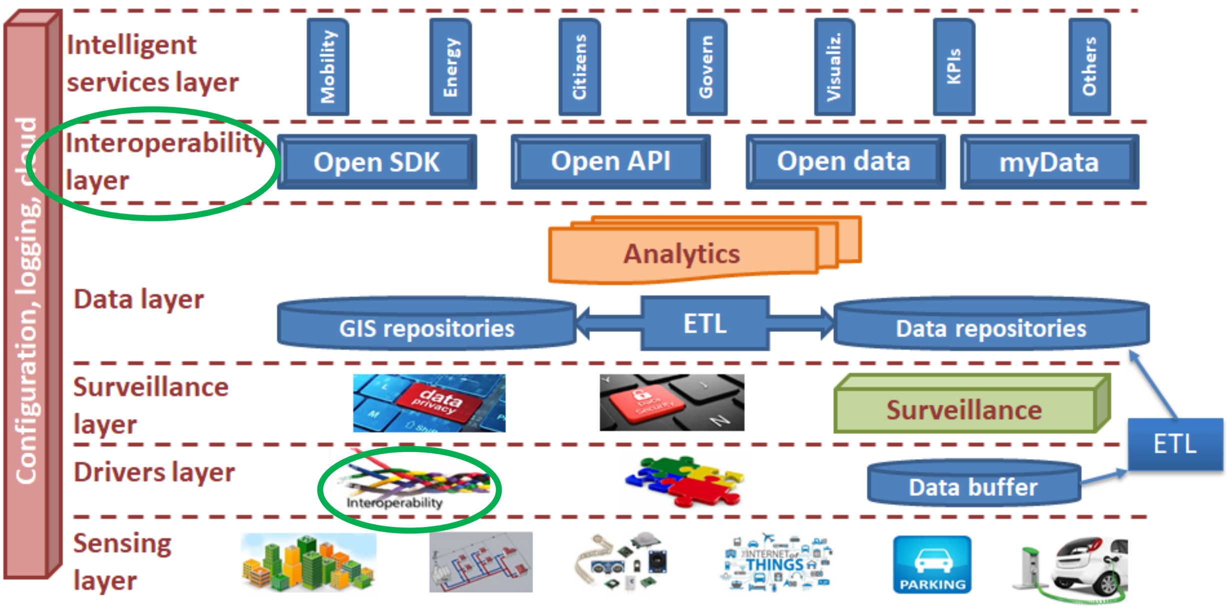


Figure 3: Interoperability levels in mySMARTLife



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This **northbound and southbound** interoperability definition may be also looked up Figure 4 where the red line establishes the interoperability requirements within mySMARTLife project. First of all, and as explained above, the applications or services (A1 and A2) require of interoperability, open data and open APIs to ensure its proper operation. Secondly, related to the sensors, data need to be integrated in the urban platforms to render analytics, provide open data and supply data to the high-level services. Last but not least, in the picture, there are some lines among the urban platforms (OUP – Open Urban Platforms). While the two first points refer to the interoperability in a single urban platform, this case refers to the usage of the same services upon different urban platforms, which is the main objective of this deliverable. In this sense, interoperability between platforms is dedicated to the usability of services from platform-to-platform, thus, increasing the interoperability of the developments.

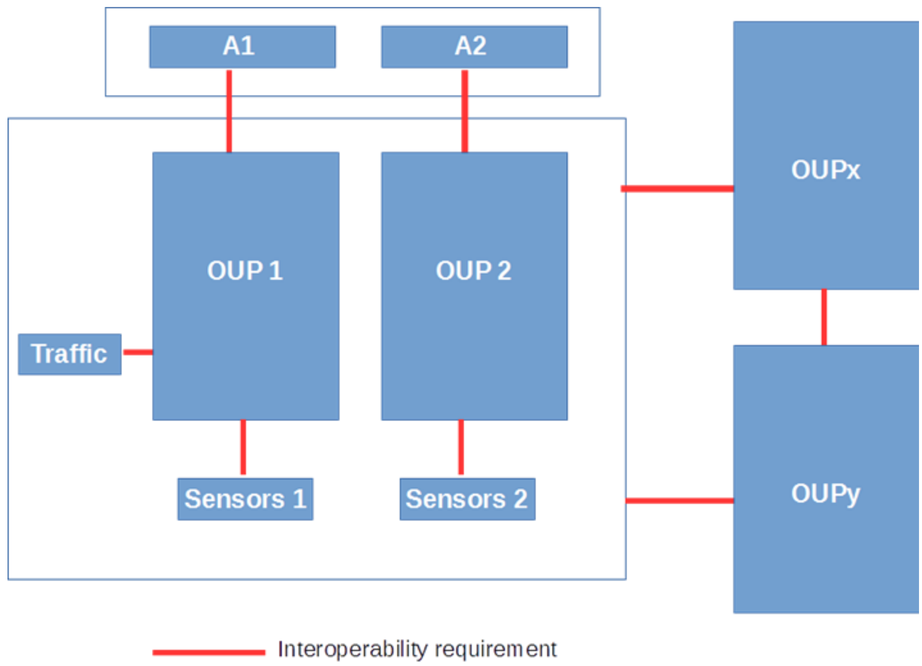


Figure 4: Interoperability requirements for the urban platforms

## 3.2 Southbound Interoperability: sensors and drivers' layer

As it has been stated before, southbound interoperability is established in the drivers' layer of the framework in order to ensure interoperability in data collection. The great advantage of assuring this level of interoperability lies in allowing further integration of data by third parties when complying with the requirements and protocols described here.

Within mySMARTLife, the common approach for the three urban platforms in terms of sensor API is the use of SensorThings API (STA) from Open Geospatial Consortium (OGC) as common data model. The STA is seen to support the types of sensors the project activities require and even more. It does not



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restrict the use of data model so there is no need to define a common set of metadata elements. The SensorThings API Standard Specification (OGC 15-078r4) can be found in [1].

Nevertheless, there is no STA-compliant sensors, which require a transformation from the communication protocols (either standard, open or proprietary). mySMARTLife, under the open specifications' framework, defines the drivers' layer in charge of this accommodation of data. Drivers to ingest data are fully used in the data platforms development, which is a common practice and, therefore, it not the objective of this deliverable.

The compliance of implemented interface meeting the basic requirements of the SensorThings API can be verified using the testing framework provided by OGC, available in [2].

## 3.3 Northbound Interoperability: services, apps and 3D city models

The northbound interfaces are in mySMARTLife project mostly intended for services such as visualization, dashboards, mobile apps and other services i.e. third parties who themselves develop new services for the city. For these use cases, APIs are exposed to the northbound. In the Urban Data Platforms of Helsinki, Nantes und Hamburg API definitions, provided by the OGC, are used. The northbound API shall support i.e. the SensorThings API and its query options (including spatial data queries). The cities that already use CKAN as a data catalogue can extend its use to provide metadata of the APIs. In the case of Hamburg a metadata catalogue (https://www.metaver.de) is used which uses the OGC CSW standard which allows an automatic integration into other meta catalogues like i.e. the European data catalogue (https://data.europa.eu/). Other northbound APIs are i.e. WFS, WMS or OAF (https://api.hamburg.de/datasets/v1).

A specific type of visualization service is the 3D City Model. This data model is based on the CityGML version 2.0 standard from Open Geospatial Consortium. It is expected that the urban platform would have the role of providing information for the 3D city model, thus supporting the CityGML format would be recommended.

## 3.4 Semantic interoperability: metadata

As established in D2.16, metadata is one of the topics to be addressed within the urban platforms. This is a key aspect of interoperability as it provides semantic information at API level. In this way, metadata acts as a provider of meaningful information to understand the open data-sets. Following this approach, discussions have treated static datasets, at least the capability of providing JSON file, and XML for specific formats (e.g. OGC standards WFS and WMS).

[1] https://portal.opengeospatial.org/files/?artifact_id=64146

[2] http://cite.opengeospatial.org/te2/about/sta10/1.0/site/



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In terms of metadata information, there are several standards like SensorML, OCPP, BACnet, TimeseriesML, ISO/IEC 15118, CIM, CityGML, IEC 61672, etc. Figure 5 illustrates an example about how a data observation is mapped into the context of semantic and ontologies according to some ISO classes.

In this way, Project Haystack [8] proposition has been analysed as one possible approach for semantic interoperability in the building automation and energy related initiatives. Basically, the project is "*an open source initiative to streamline working with data from the Internet of Things. They standardize semantic data models and web services with the goal of making it easier to unlock value from the vast quantity of data being generated by the smart devices that permeate our homes, buildings, factories, and cities. Applications include automation, control, energy, HVAC, lighting, and other environmental systems*". Therefore, it provides a standard language that allows the interpretation of the information. Nevertheless, during the evolution of the project, other possibilities will be studied. Also, the possible requirement of specific ontologies will be studied later on. In semantic interoperability the maturity and quality of external data services may be an issue, especially in a project that combines together energy, mobility and environmental observations in a way that mySMARTLife does.

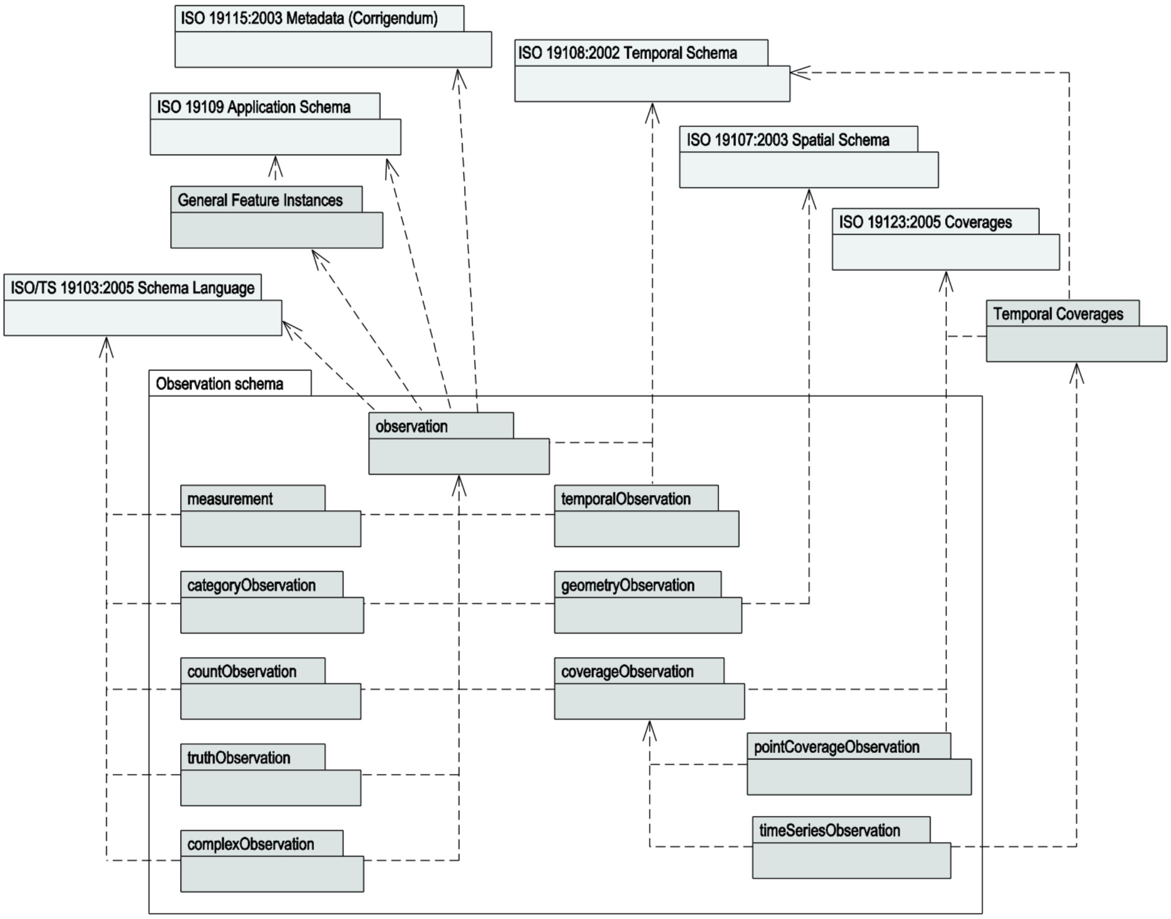


Figure 5: Example of standard connection for observations



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# 4. Use cases definition

Standards and specifications are fundamental to ensure interoperability. There are six steps to managing them appropriately:

1) identifying candidate standards and specifications based upon specific needs and requirements;
2) assessing candidate standards and specifications using standardised, transparent, fair and non-discriminatory methods;
3) implementing the standards and specifications according to plans and practical guidelines;
4) monitoring compliance with the standards and specifications;
5) managing change with appropriate procedures;
6) documenting standards and specifications, in open catalogues, using a standardised description.

In this sense, this section identifies the use cases that are used for demonstrating and validating the interoperability.

## 4.1 Use cases format

ESPRESSO is one of the references that has been used for the definition of the framework and it provides very helpful information. In this way, it also establishes ways how to test interoperability. Hence, ESPRESSO is also taken as reference for the definition of the use cases and definition of the test plans.

With this purpose, a set of use cases is necessary in order to define the methodology by means of which interoperability is tested. In fact, use case is defined as a list of actions or steps, typically defining interactions between a role and a system, in order to achieve a specific goal. Nevertheless, it is important to highlight that the use cases may be diverse. That is the reason why, within mySMARTLife, a use case description format is envisaged with the aim of providing a unified view of the use cases and having a common understanding between all the stakeholders.

ESPRESSO has been selected as reference. In particular, table 1 of the use cases document from ESPRESSO [9] has been taken. This template has been used as a reference, but it has been simplified as the goal within ESPRESSO is to define software use cases, while, within mySMARTLife focuses on interoperability, hence, there are some of the fields that are not applicable (e.g. UML - Unified Modelling Language schemas).

## 4.2 Use cases selection for interoperability

Before the description of the use cases, a prior step is to determine which use cases are the best positioned to be analysed. As mySMARTLife is a city-driven project, this means that the interventions proposed in the three lighthouse cities of the project are tailored to solve real city demands. So, the interventions in the three cities are not the same and a necessary analysis of the use cases is necessary.



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Then, the selection of the interoperability use cases relies on the services that are developed and deployed in the urban platforms developed in Nantes, Hamburg and Helsinki. As aforementioned, the ICT activities in the project focused on real demands from the cities and their citizens, thus services differ one from each other and data requirements are diverse. That is to say, fully compliance on the data availability is complex as data collection approaches are not similar from city to city. Hence, interoperability use cases or services should be selected taking this constraint into account. In other words, data are essential for interoperability, therefore, it would not make sense to select a service where data are related to mobility for an energy service.

Therefore, Table 4 has been used as template for the data requirements compilation from the cities. This table contains a short description of the use case, the data-sets that are required for the proper functionality, minimum frequency of the data collection for a proper and a simple Yes/No tick in order to determine whether the lighthouse city complies with these requirements.

Table 4: Template for the use cases compilation

| Use case | | Nantes | Hamburg | Helsinki |
|---|---|---|---|---|
| Description of the use case | | | | |
| Data requirements | Min data frequency | | | |
| Data-set #1 | Seconds | Yes or not | Yes or not | Yes or not |
| Data-set #2 | Minutes | Yes or not | Yes or not | Yes or not |
| Data-set #3 | Hours | Yes or not | Yes or not | Yes or not |

By using the aforementioned template, the cities have fulfilled their proposed use cases. Starting with Nantes, three use cases are proposed, as shown in Table 5. For Hamburg, other two are established as Table 6 shows and three additional ones from Helsinki (Table 7).

Table 5: Nantes proposed use cases

| Use case #1 | | Nantes |
|---|---|---|
| Optimization of public buildings electrical contracts | | |
| Data requirements | Min data freq. | |
| Electricity meters 10 min consumption | 10 min | Yes |
| Electricity meters daily consumption | 1 day | Yes |
| Yearly consumption | 1 year | Yes |
| Electrical contract power | 10 min | Yes |
| KPI: electrical contract versus consumption | 1 day | Yes |
| Use case #2 | | Nantes |
| Street lighting monitoring / detection of failure | | |



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| | | |
|---|---|---|
| Data requirements | Min data freq. | |
| Street lighting cabinet power consumption | 30 minutes | Yes |
| Use case #3 | | Nantes |
| Monitoring of electric charging stations | | |
| Data requirements | Min data freq. | |
| Charging stations | Per charging event | Yes |
| Charging sessions data (energy, times, usage) | Per charging event | Yes |
| KPIs on energy (as D5.1) | 1 day | Yes |
| KPIs on times (as D5.1) | 1 day | Yes |
| KPIs on usage (as D5.1) | 1 day | Yes |

Table 6: Hamburg proposed use cases

| Use case #1 | | Hamburg |
|---|---|---|
| Monitoring of electric charging stations | | |
| Data requirements | Min data freq. | |
| Charging stations | Per charging event | Yes |
| Charging sessions data (times, usage) | Per charging event | Yes |
| KPIs on times (as D5.1) | 1 day | Yes |
| KPIs on usage (as D5.1) | 1 day | Yes |
| Use case #2 | | Hamburg |
| Monitoring of PV Energy at HAW-Energy-Campus | | |
| Data requirements | Min data freq. | |
| Monitoring of produced PV-Energy (3 day back) | 1 day | Yes |

Table 7: Helsinki proposed use cases

| Use case #1 | | Helsinki |
|---|---|---|
| Environmental Noise (Action 48) | | |
| Data requirements | Min data freq. | |
| Peak noise level | 1 second | Yes |
| Daily aggregated values | 2 / day | Yes |
| Use case #2 | | Helsinki |
| Viikki Solar Panel Production (48) | | |
| Data requirements | Min data freq. | |
| Energy kWh | 1 hour | Yes |
| Use case #3 | | Helsinki |
| EV Charging (Action 26) | | |



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| Data requirements | Min data freq. | |
|---|---|---|
| Energy kWh | 1 hour | Yes |

### 4.2.1 Analysis of the candidate use cases and selection

As observed before, there are already some use cases that are overlaid (e.g. charging stations), being possible candidate use cases to demonstrate the interoperability. This section crosses the candidate use cases among the three cities to check if the minimum data requirements are also satisfied in the other two cities.

For that purpose, two additional columns were included in the use cases data requirements to determine data availability in the other cities. Figure 6, Figure 7 and Figure 8 show the analysis of the compliance of data availability requirements from one city to the other two urban platforms.

| NANTES CANDIDATE USE CASES | | | | |
|---|---|---|---|---|
| **Use case** | | **Nantes** | **Hamburg** | **Helsinki** |
| Optimization of public buildings electrical contracts | | | | |
| **Requirements** | **Min data frequency** | | | |
| Electricity meters 10 min consumption | 10 min | Yes | No | No |
| Electricity meters daily consumption | 1 day | Yes | No | No |
| Yearly consumption | 1 year | Yes | No | No |
| Electrical contract power | 10 min | Yes | No | No |
| KPI: electrical contract versus consumption | 1 day | Yes | No | No |
| **Use case** | | **Nantes** | **Hamburg** | **Helsinki** |
| Street lighting monitoring / detection of failure ? | | | | |
| **Requirements** | **Min data frequency** | | | |
| Street lighting cabinet power consumption | 30 minutes | Yes | No | No |
| **Use case** | | **Nantes** | **Hamburg** | **Helsinki** |
| Monitoring of electric charging stations | | | | |
| **Requirements** | **Min data frequency** | | | |
| Charging stations | Per charging event | Yes | Yes | Yes |
| Charging sessions data (energy, times, usage) | Per charging event | Yes | Yes | Yes |
| KPIs on energy | 1 day | Yes | No | Yes |
| KPIs on times | 1 day | Yes | Yes | Yes |
| KPIs on usage | 1 day | Yes | Yes | Yes |

Figure 6: Analysis of data availability in Hamburg and Helsinki for the Nantes use cases



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| HAMBURG CANDIDATE USE CASES | | | | |
|---|---|---|---|---|
| **Use case #1** | | **Nantes** | **Hamburg** | **Helsinki** |
| Monitoring of electric charging stations | | | | |
| **Requirements** | **Min data frequency** | | | |
| Charging stations | Per charging event | Yes | Yes | Yes |
| Charging sessions data (times, usage) | Per charging event | Yes | Yes | Yes |
| KPIs on times | 1 day | Yes | Yes | Yes |
| KPIs on usage | 1 day | Yes | Yes | Yes |
| **Use case #2** | | **Nantes** | **Hamburg** | **Helsinki** |
| Monitoring of PV Energy at HAW-Energy-Campus | | | | |
| **Requirements** | **Min data frequency** | | | |
| Monitoring of produced PV-Energy (3 day back) | 1 day | Yes | Yes | Yes |

Figure 7: Analysis of data availability in Nantes and Helsinki for the Hamburg use cases

| HELSINKI CANDIDATE USE CASES | | | | |
|---|---|---|---|---|
| **Use case** | | **Nantes** | **Hamburg** | **Helsinki** |
| Environmental Noise (Action 48) | | | | |
| **Requirements** | **Min data frequency** | | | |
| Peak noise level | 1 sec | No | No | Yes |
| Daily aggregated values | 2 / day | No | No | Yes |
| **Use case** | | **Nantes** | **Hamburg** | **Helsinki** |
| Viikki Solar Panel Production (48) | | | | |
| **Requirements** | **Min data frequency** | | | |
| Energy kWh | hour | Yes | Yes | Yes |
| **Use case** | | **Nantes** | **Hamburg** | **Helsinki** |
| EV Charging (Action 26) | | | | |
| **Requirements** | **Min data frequency** | | | |
| Energy kWh | hour | Yes | No | Yes |

Figure 8: Analysis of data availability in Nantes and Hamburg for the Helsinki use cases

From the previous snapshots, it can be concluded, there are **3 use cases where interoperability aspects can be tested**:

- Monitoring of electric charging stations
- Monitoring of PV Energy at HAW-Energy-Campus
- Viikki Solar Panel Production (48)

Next chapters describe the use cases in detail, prepare the interoperability plans and, then, validate interoperability according to the KPI in section 5.2. Furthermore a 4$^{th}$ test case, not identified before, has been included related to the use of SensorThings API as common data model.



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## 4.3 Use case 1: Monitoring of electric charging stations

The first use case is the monitoring of electric charging stations, which is common in the three cities. Full description of the use case is presented in Table 8, according to the simplified template from ESPRESSO.

Table 8: Monitoring of electric charging stations use case

| GENERAL INFORMATION ABOUT THE USE CASE | |
|---|---|
| Monitoring of electric charging stations | |
| Domain | Electric mobility |
| Subdomain | Charging stations for electrical vehicle |
| Objectives / benefits of the use case | Data collection from the eV charging stations |
| Description | |
| User story description | Use case compiles data when a charging event is launched, then, time on usage and supplied energy are collected to determine charging point statuses and availability. |
| Scope | |
| This use case aims at collecting data from the charging stations, both supplied energy and usage. Furthermore, the use case calculates a set of KPIs related to the times on usage. | |
| Objectives | |
| Monitor and calculate KPIs for the performance and availability of charging stations. | |
| Actor List and Requirement | |
| Actors identified | Urban platform maintainers, mobility experts, citizens. |
| Requirements (from actor's perspective) | Availability of data from the charging points. |

| AVAILABLE DATA AT THE PILOT SITE AND OPEN PORTALS | | |
|---|---|---|
| Data | Technical Description | Standards applied |
| Which are the available data at the pilot site for this use case? | Charging station status<br>Charging station energy<br>KPIs on times<br>KPIs on usage | SensorThings API |
| Which are the available and useful data coming from Open Portals? | All from previous row | SensorThings API, CKAN, CSW |

## 4.4 Use case 2: Monitoring of PV Energy at HAW-Energy-Campus

Second use case refers to the PV plant deployed at the Energy Campus in Hamburg, which requires the energy that is produced by the PV plant. As observed previously, although the use case is specific on Hamburg, the other cities can provide data related to any other PV plan. Details of the use case are presented in Table 9.

Table 9: Monitoring of PV Energy at HAW-Energy-Campus use case

| GENERAL INFORMATION ABOUT THE USE CASE | |
|---|---|
| Monitoring of PV Energy at HAW-Energy-Campus | |
| Domain | Energy |
| Subdomain | Renewable energy production |



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| | | |
|---|---|---|
| Objectives / benefits of the use case | Data collection of the generated energy from a PV plant. | |
| Description | | |
| User story description | The use case just collects the instantaneous energy that is generated by a PV plant, in this case, the case of Energy Campus in the city of Hamburg. | |
| Scope | | |
| The scope is monitoring and data collection for PV plant generation. | | |
| Objectives | | |
| Monitor and determine the level of renewable that is used for self-consumption. | | |
| Actor List and Requirement | | |
| Actors identified | Urban planners, energy experts, citizens. | |
| Requirements (from actor's perspective) | Availability of data from the PV plant. | |
| AVAILABLE DATA AT THE PILOT SITE AND OPEN PORTALS | | |
| Data | Technical Description | Standards applied |
| Which are the available data at the pilot site for this use case? | Supplied energy | SensorThings API |
| Which are the available and useful data coming from Open Portals? | Supplied energy | SensorThings API, CSW |

## 4.5 Use case 3: Viikki Solar Panel Production (48)

Next is the case of Viikki solar plant production, which is pretty much similar to the use case #2 as the objective is to collect data from solar generation. Details are compiled in Table 10.

Table 10: Viikki Solar Panel Production use case

| GENERAL INFORMATION ABOUT THE USE CASE | |
|---|---|
| Viikki Solar Panel Production use case | |
| Domain | Energy |
| Subdomain | Renewable energy production |
| Objectives / benefits of the use case | Data collection of the generated energy from a solar plant. |
| Description | |
| User story description | The use case just collects the instantaneous energy that is generated by a solar plant, in this case, deployed in Viikki building in the city of Helsinki. |
| Scope | |
| The scope is monitoring and data collection for solar plant generation. | |
| Objectives | |
| Monitor and determine the level of renewable that is used for self-consumption. | |
| Actor List and Requirement | |
| Actors identified | Building owners, energy experts. |
| Requirements (from actor's perspective) | Availability of data from the solar plant. |
| AVAILABLE DATA AT THE PILOT SITE AND OPEN PORTALS | |



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| Data | Technical Description | Standards applied |
|---|---|---|
| Which are the available data at the pilot site for this use case? | Supplied energy | SensorThings API |
| Which are the available and useful data coming from Open Portals? | Supplied energy | SensorThings API, CKAN |



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# 5. Interoperability test plan

## 5.1 Objectives of the plan

As it has been stated across the document, the objective of the interoperability test plan is to demonstrate and validate the capability of reusing the services from one platform to another, providing interoperable services. Anyway, at this stage of the project, the full definition of the data-sets, metadata and data models are being determined and full details will come in next iterations.

## 5.2 Interoperability indicator

The question that still remains from the objectives is how to measure them. In this sense, it has been selected the standard **ISO 37151:2015** [10], which **establishes metrics for measuring the performance in Smart Community infrastructures**. Among them, it might be found the Urban Platforms and their related services. "*ISO/TS 37151:2015 gives principles and specifies requirements for the definition, identification, optimization and harmonization of community infrastructure performance metrics. Also, it gives recommendations for analysis, including: smartness, interoperability, synergy, resilience, safety, and security of community infrastructures*" [10].

Having said that, it is clear that one of the measurement parameters is the interoperability, which is re-used here to evaluate the final interoperability, where the community infrastructure in our case is the urban platform (being ICT in the ISO standard). For that end, the definition within CITYKEYS is selected. In this case, the indicator is "Improved interoperability", measured in a likert scale. Its definition is "*the extent to which the project has increased interoperability between systems*" [11]. The likert scale goes from 1 to 5 (from not at all to excellent) and the values are provided as follows:

1. **Not** at all: the project does not increase interoperability.
2. **Poor**: the project does little to increase interoperability.
3. **Somewhat**: the project somewhat increases interoperability.
4. **Good**: the project increases interoperability sufficiently.
5. **Excellent**: the project increases interoperability extensively.

Next question is how to evaluate this scale. Firstly, according to CITYKEYS, several considerations should be taken into consideration:

- **Project documentation**, which is applicable in this case based on the deliverables generated for the urban platforms (Open APIs), as well as the definition of the use cases above.



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- Expected **data availability** that sets how information should be available in case the interoperability is an impact. This data availability is described in the next section.
- In terms of **reliability**, it should be highlighted the subjectivity aspects that are included. Therefore, it cannot be considered as 100% reliable.
- Information should be **accessible** if interoperability is an impact.

With these requirements in mind, mySMARTLife does not only take the definition into consideration, but it also provides a more objective way to determine the indicator. The reason is because it is difficult to determine what means interoperability extensively or any other definition. For this aim, mySMARTLife establishes the criteria as in Table 11.

Table 11: mySMARTLife mapping for interoperability indicator criteria

| Interoperable likert value | mySMARTLife criteria |
|---|---|
| Not at all | No one service is able to consume and use data for presenting the functionality. |
| Little increase | A subset of the services is able to operate, but other are not running. |
| Somewhat | Services work but they present some problems with the data consumption and/or functionality that is offered. E.g. not all the required data are available. |
| Sufficiently increase | Almost all the services are working as expected, consuming data and providing the results. Minor bugs and/or errors are allowed, but without affecting the overall functionality. |
| Extensively increase | All the services are interoperable from platform to platform. They consume data as expected and provide the expected functionality without errors. |

It should be remarked the indicator is not included within WP5 and the evaluation plans (ICT pillar) because this task and deliverable are directly leading the interoperability assessment. Therefore, it does not make sense to repeat the assessment process in two different tasks.

## 5.3 Available data

The way to demonstrate the interoperability is making use of data. Then, this deliverable relies on the monitoring programmes (D5.3) [12] and data collection approach (D5.4) [13]. Within D5.3, the monitoring programmes are established according to the requirements for KPI calculation and establish the measurements that are taken from the actions/interventions. In this sense, the services are implemented following the actions/interventions, hence, gathered data from the monitoring programmes are aligned with the services.

However, data availability is not only monitoring, but also completeness and consistency. This is part of what D5.4 measures. Data collection approach aims the assessment of the monitoring data quality. That is to say, determining the quality, in terms of completeness (i.e. data gaps) and coherency (i.e.



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measurements within the expected measurement range), of the variables that are included in the monitoring programmes.

Even though services are developed in accordance to the monitoring data from monitoring programmes, actions do not need to be common from city to city. For instance, district heating or public lighting are common interventions across the three lighthouse cities, but other actions differ. Hence, there could exist some cases where data are not collected within the specific intervention (e.g. ice cooling storage in Hamburg, which is a very specific action).

Finally, it should be considered the data that is generated within the project is exposed via open data portals and open APIs. mySMARTLife actions include the publication of the monitoring data (aggregated, KPI calculations or even raw data when no GDPR conflicts exist). Then, the interoperability test plan described in this deliverable relies on these available open data-sets to run the experiments.

## 5.4 Test plan

The test plan is a **description of the strategy to verify and ensure that the interoperability requirements are fulfilled at the end of the developments and deployments**. In this way, the objective, the tests, pass/fail criteria and responsibilities are necessary.

First of all, it is convenient to define the concept of interoperability testing. Although, it has been previously introduced, it can be said that interoperability testing "*is a software testing that checks whether the software can interact with other software components and systems*" [14]. According to this sentence and as stated before, the ultimate goal is to ensure the software product (in this case, data management and services translated into interoperability use cases) has the capability to communicate with other software instances and, therefore, being compatible.

Interoperability testing is defined as an end-to-end functionality that starts with the data collection, data exchange and sharing from system to system or software to software. Recalling the data management procedure from D2.16 [7] and depicted in Figure 9, the interoperability testing, in this case, is focused on the API level interoperability (expose and distribute). This covers both northbound and semantic interoperability. Northbound as data final consumer and semantic due to data model. Nevertheless, southbound interoperability is not part of the interoperability testing as this is specific for the urban platforms and is assured via the field level communication drivers.



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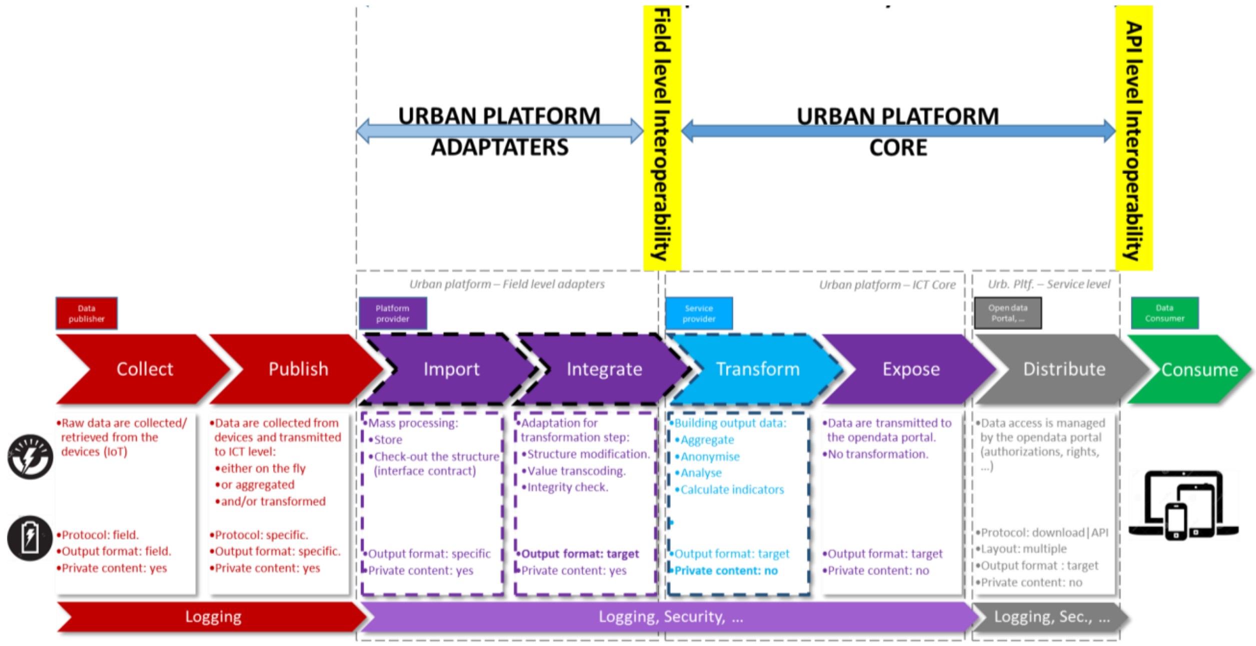


Figure 9: Data management procedure

Then, the capability of the services for consuming data from platform to platform is highlighted, where the risks that should be avoided are listed below:

- **Loss of data**, linked to semantic interoperability, where data can be not correctly exchanged due to incompatibility of data formats.
- **Unreliable performance** due to the lack of compatibility of data. The service would not operate as designed and, therefore, providing limited and/or unexpected performance
- **Unreliable operation** if data are not properly managed. The service could not operate as expected, dealing with unreliable operation.
- **Incorrect operation**, linked to the previous two bullets.
- **Low maintainability**, which is a direct consequence of non-interoperable services. When interoperability is not provided, adaptations, changes and modifications in software code are necessary, complicating the maintainability of services.

Having explained the interoperability testing concept, next stage is to define the test plan. The next chapter enters into details about how to test interoperability (or how this will be performed in mySMARTLife during the last stage of the project).



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### 5.4.1 Definition of the test plan for mySMARTLife services

Test plans are usually run in several stages or steps:

1. Launch the project where the infrastructure and set-up are established. This is out of scope of the present deliverable as the infrastructure and set-up are part of other tasks of the project. This infrastructure is realised through the urban platforms' development, specifically in each lighthouse city, to ingest actions/interventions data.
2. Set up the lab test, which, in this case, goes a step forward as it is not lab, but real environment with real data and urban platform instances. Within this step, there are several sub-steps to be considered:
    a. Make sure all required skill and automation tools are set up for test activities. Within mySMARTLife, the ICT responsible for the urban platforms is involved, therefore, covering the ICT skills to run automatic scripts to connect the APIs;
    b. Use automation tools for minimizing test cases and re-use test cases, which is implemented by the services and API endpoints available on the project;
    c. Maintain a database of configuration files, where the urban platform is deployed, configured and consuming data;
    d. Record and analyse metrics for project, as one of the objectives of the test;
    e. Record configuration from unsuccessful tests for reference and analysis.
3. Develop the test plan itself with the use cases and procedures, which has been defined previously, within section 4 and complemented with the list of tests detailed further in this section.
4. Execute test plan.
5. Document results, which will be documented in section 6.
6. Release the resources to continue with the normal operation. This is done by liberating the open API connection by the services.

There are five interoperability testing types, but not all are considered within mySMARTLife. The list is "data type", "semantics", "physical", "protocol" and "data format". The only one that is not covered is "physical", as explained before, the data ingestion is covered within the monitoring programmes and data collection approaches followed in each specific urban platform.

Then, the interoperability testing plan is composed by a set of test cases or functionalities that need to be tested. In this sense, a test case scenario is a well-established functionality that the service needs to run for providing the expected operation. Usually, the test cases split the service global operation into sub-functionalities that need to be checked in order to ensure a proper execution. They are defined by an

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objective or description of the test case, the success criteria and the test type. Table 12 includes the test cases or functionalities to be tested for assuring interoperability, which will be rendered within mySMARTLife according to the interoperable use cases defined before.

Table 12: Interoperability test functionalities

| Functionality | Description | Success criteria | Interoperability testing type |
|---|---|---|---|
| API connection | The service is able to connect the API that provides data in the designed protocol for data exchange. | API response 200 | Protocol |
| Data consume | The service is able to consume and read data from the connected API independently the format. | API data ingested | Data type |
| Data transfer | Data are interpreted correctly without inconsistencies and being reliable for the final consumer (i.e. service). | Data formatted | Data format and semantics |
| Algorithm execution | Once data are ingested, it needs to be checked that the data are completed and the algorithm (can be a simple calculation) runs as designed without data gaps and/or inconsistencies. | Result of algorithm as designed | Data type |
| Data presentation | Results are printed and visualized as the original service. | Data visualisation | Data format |
| Data push | If required by the service, the result could be transmitted into the lower levels of the urban platform to be stored in persistent ways. Then, the communication should be established not only in the reading direction, but also writing. | API response 200 | Protocol |
| Data storage | After connection, data should be transmitted for final storage. | Results storage | Data format and semantics |

When any of the previous functionalities does not work as expected (i.e. fail), the reasoning will be obtained to determine if the cause is a software bug, a non-implemented functionality or an interoperability issue. In contrast with other test plans where the error is solved or tried to be solved, here, this feedback will serve to determine the interoperability level according to the indicator described above and the requirements that are necessary to comply with a full interoperability level.

### 5.4.2 Test plan preparation

As it has been already explained, the test plan consists of checking the functionality of the services from urban platform to urban platform. Figure 10 represents the concept of the interoperability testing. The picture shows how one service (i.e. use case) consumes data from two different urban platforms (e.g. service A making use of data from Nantes and Hamburg) with the goal of obtaining the same result (i.e. service operating with different data).



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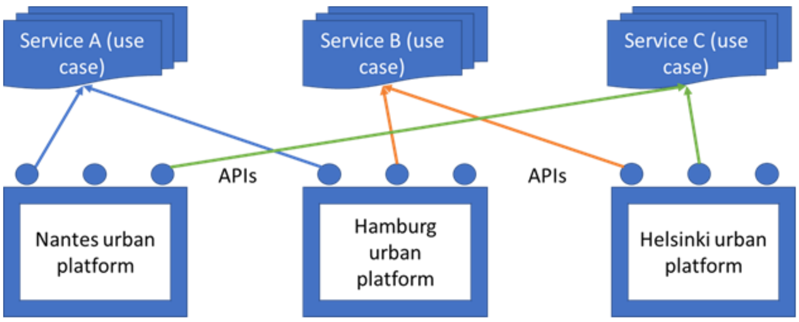


Figure 10: Concept of the interoperability test plan

The way to run the tests is presented in Table 13, where green cells mark the urban platform where the service is currently deployed, orange cells where the service will be tested and blank means no test of such a use case will be tested in the urban platform. It should be remarked the monitoring of electric charging stations is a recurrent use case deployed on the three urban platforms, therefore, the service of each one will be tested in another. That is to say, for instance, Nantes charging station service will be tested in Helsinki API and so on.

Table 13: Services testing plan

| Use case | Nantes | Hamburg | Helsinki |
|---|---|---|---|
| Monitoring of electric charging stations | To be tested | | |
| Monitoring of PV Energy at HAW-Energy-Campus | To be tested | | |
| Viikki Solar Panel Production (48) | | To be tested | |

In order to report the results, comparative snapshots of the results will support the visual evaluation. Complementary, a table will provide details on the reasoning for failing (if this is the case) and recommendations to ensure interoperability. The table will include the functionalities that are described in Table 12, focusing on the results for each one of them, as illustrated in Table 14.

Table 14: Template for documentation of the test results

| | Result of test | Reasons for failing | Recommendations for successful interoperability |
|---|---|---|---|
| API Connection | | | |
| Data consume | | | |
| Data transfer | | | |
| Algorithm execution | | | |
| Data presentation | | | |
| Data push | | | |
| Data storage | | | |



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# 6. Interoperability test results

Once the tests are run, the final part is to document the results, detailing the reasons why a test was failed. This section describes the analysis and conclusions of the tests, splitting chapters per use case to be documented.

## 6.1 Use case 1: Monitoring of electric charging stations

Starting with the first use case, monitoring of electric charging stations, as summarised in Table 13, the service available on Nantes has been tested against data provided by the cities of Hamburg and Nantes. As observed in Figure 11 and Figure 12, the service is showing data from the charging stations in the proper way. Dashboards are drawing expected results and behaviour.

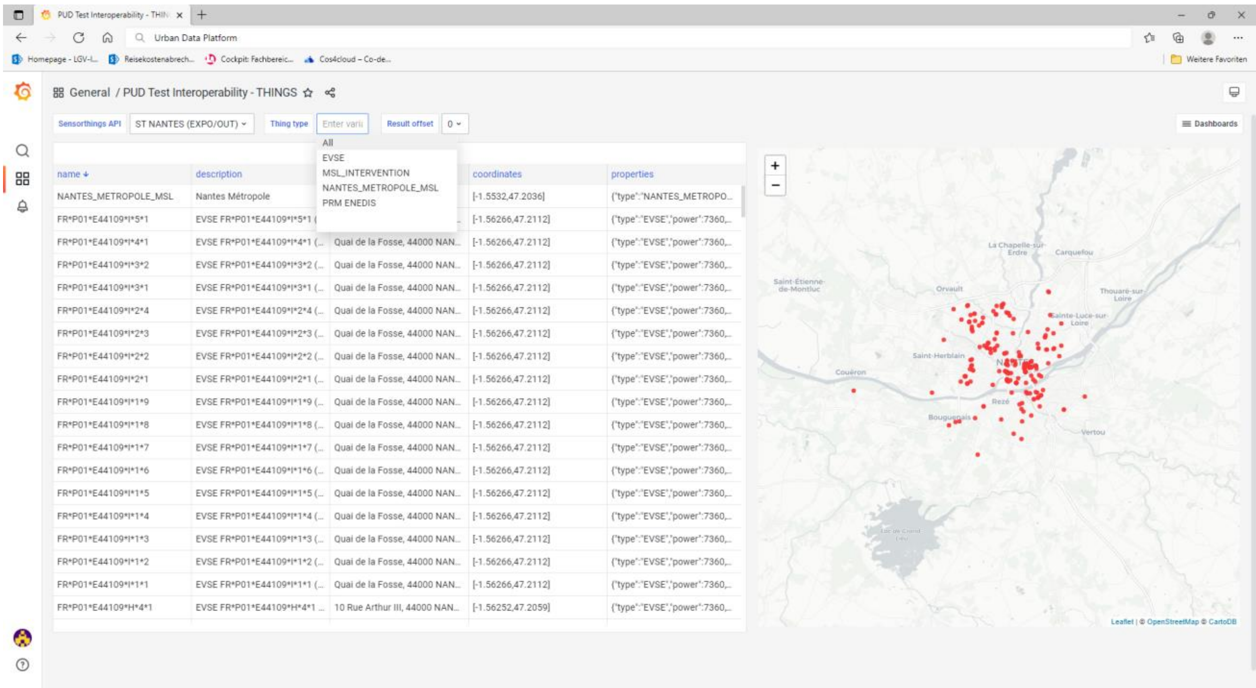


Figure 11: Platform agnostic dashboard for the charging stations with Nantes data



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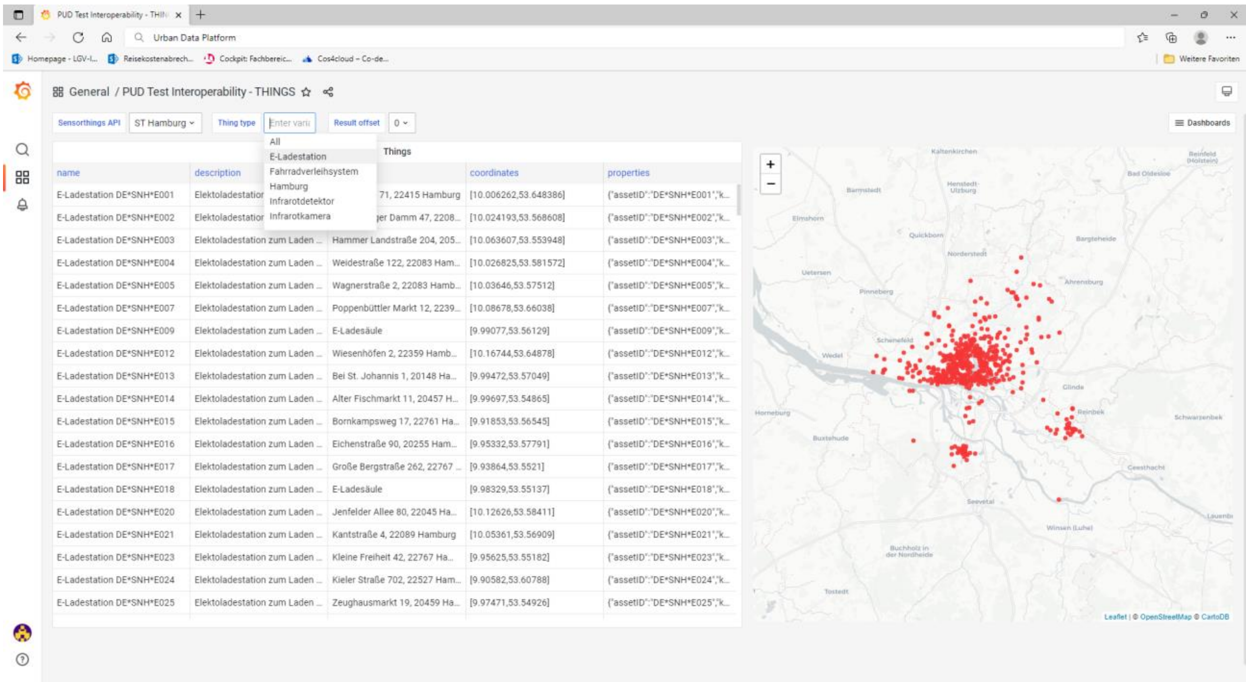


Figure 12: Platform agnostic dashboard for the charging stations with Hamburg

Additionally, results of the interoperability test observations on the use case of eV-charging stations in Nantes vs Hamburg are depicted in Figure 13 and Figure 14.

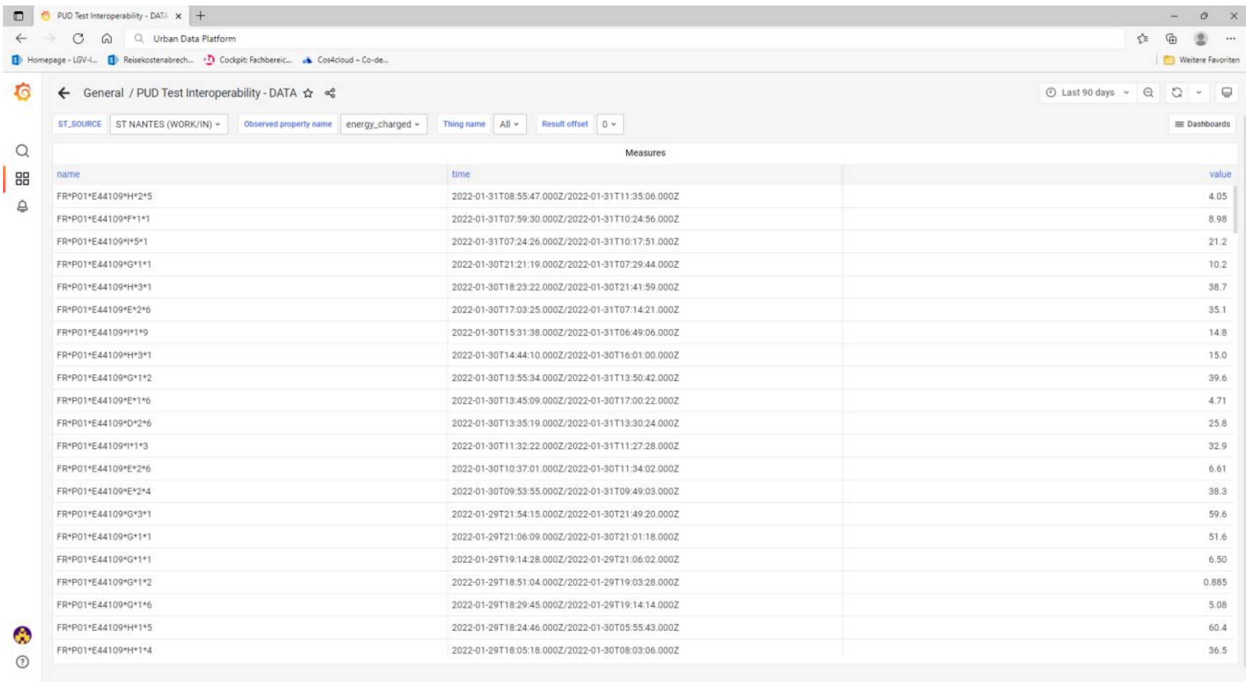


Figure 13: Platform agnostic dashboard with Nantes list of charging points



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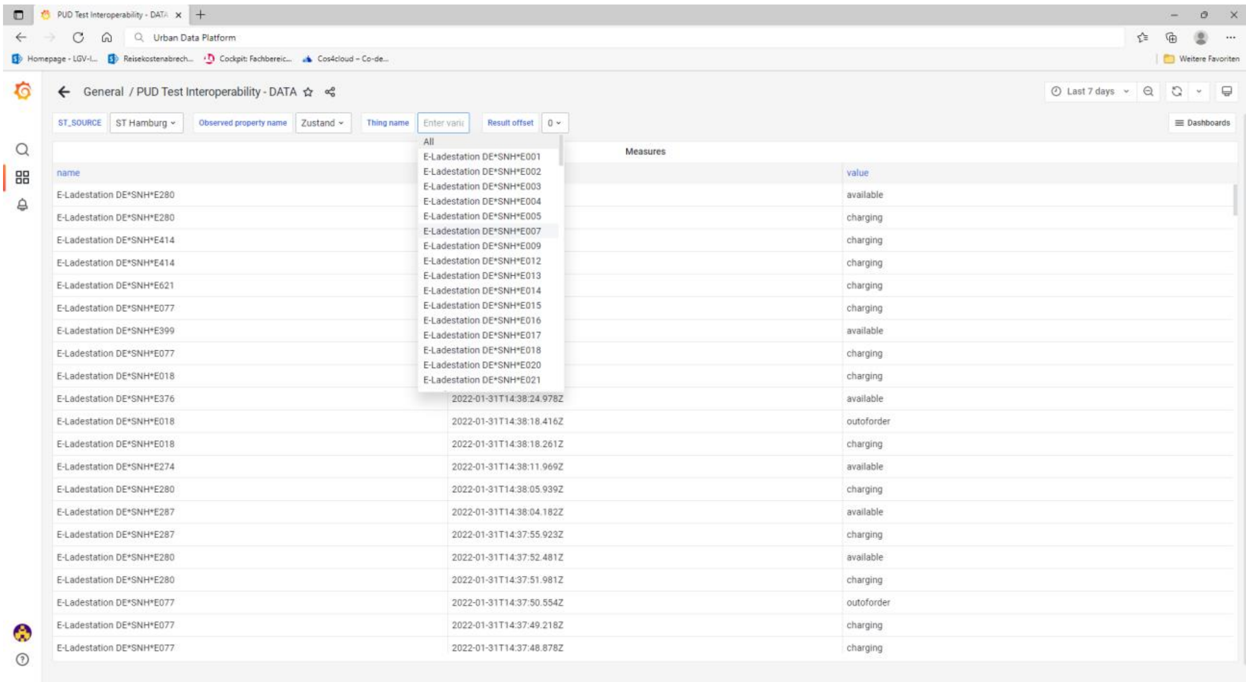


Figure 14: Platform agnostic dashboard with Hamburg list of charging points

Additionally, Table 15 shows the results of the test, which is successful in all the functionalities. Data push and data storage are not possible due to the local restrictions in terms of data expose. Within Nantes urban platform, it is forbidden (due to security and liability reasons). Many cities and territories in France have suffered from cyberattacks and constraints limit this functionality at the moment.

Table 15: Result of the functionalities testing for use case #1 between Nantes and Hamburg

| | Result of test | Reasons for failing | Recommendations for successful interoperability |
|---|---|---|---|
| API Connection | | n.a. | Tests have been successfully passed, but, as recommendation for further developments, one important aspect for success has been the proper definition of a common data model (SensorThings API in this case). Data model concepts have been put in common since design, being the key for success. |
| Data consume | | n.a. | |
| Data transfer | | n.a. | |
| Algorithm execution | | n.a. | |
| Data presentation | | n.a. | |
| Data push | n.a. | n.a. | |
| Data storage | n.a. | n.a. | |

## 6.2 Use case 2: Monitoring of PV Energy at HAW-Energy-Campus

Monitoring of PV energy at Energy campus obtains the production of the renewable sources installed in Hamburg. Figure 15 represents the energy generation of such an installation in the energy campus. The



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generation of PV systems is usually used for self-consumption. This is the case of Nantes, whose electricity load curves are obtained in Figure 16 and Figure 17.

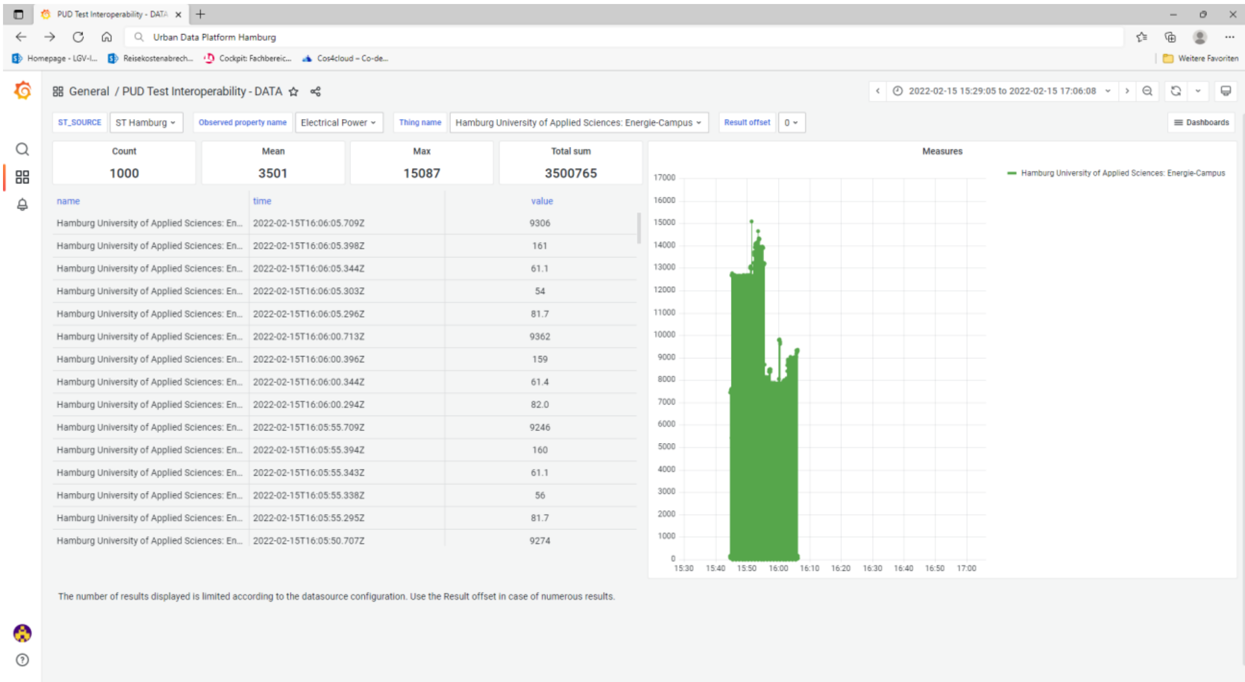


Figure 15: Monitoring of the PV generation with Hamburg urban platform data

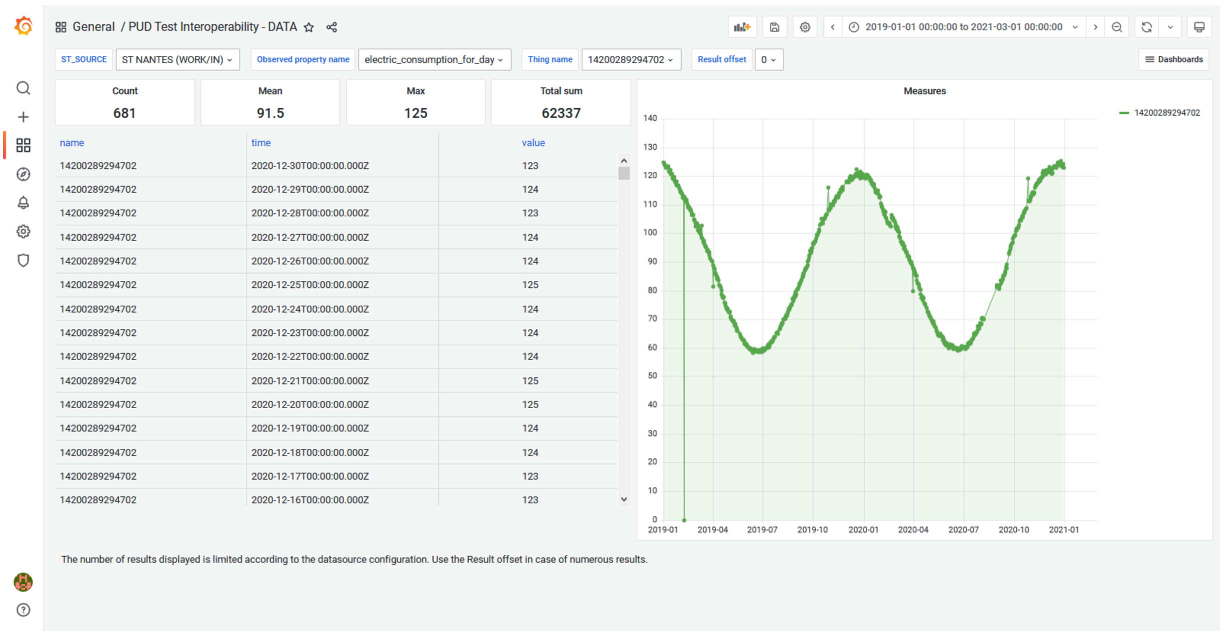


Figure 16: Daily electric consumption in public buildings within Nantes



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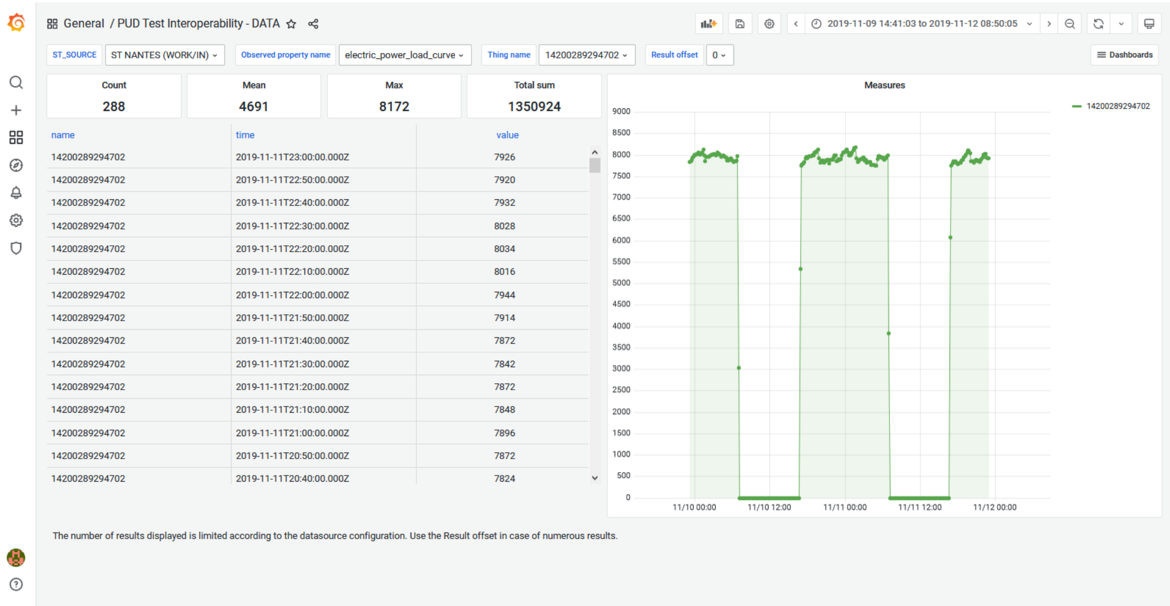


Figure 17: 10mn step electric load curve (electric meter # 14200289294702) in Nantes

This test has not run the full functionality, but how the data coming from different sources can be obtained, interpreted and make them interoperable. That is the reason why Table 16 is limited to the API connection, data consume and transfer.

Table 16: Summary of the results within use case #2

| | Result of test | Reasons for failing | Recommendations for successful interoperability |
|---|---|---|---|
| API Connection | | n.a. | Definition of common and language-agnostic codes, similar to the application in the KPIs to increase the data interpretability and, thus, interoperability. |
| Data consume | | n.a. | |
| Data transfer | | n.a. | |
| Algorithm execution | n.a. | n.a. | |
| Data presentation | | n.a. | |
| Data push | n.a. | n.a. | |
| Data storage | n.a. | n.a. | |

## 6.3 Use case 3: Viikki Solar Panel Production (48)

Third use case is the Viikki solar panel production. In this case, the testing use case has been performed through the Postman software, which allows checking the data accessibility via connecting an API. Figure 18 illustrates the result of the connection, being successful and retrieving the necessary data.



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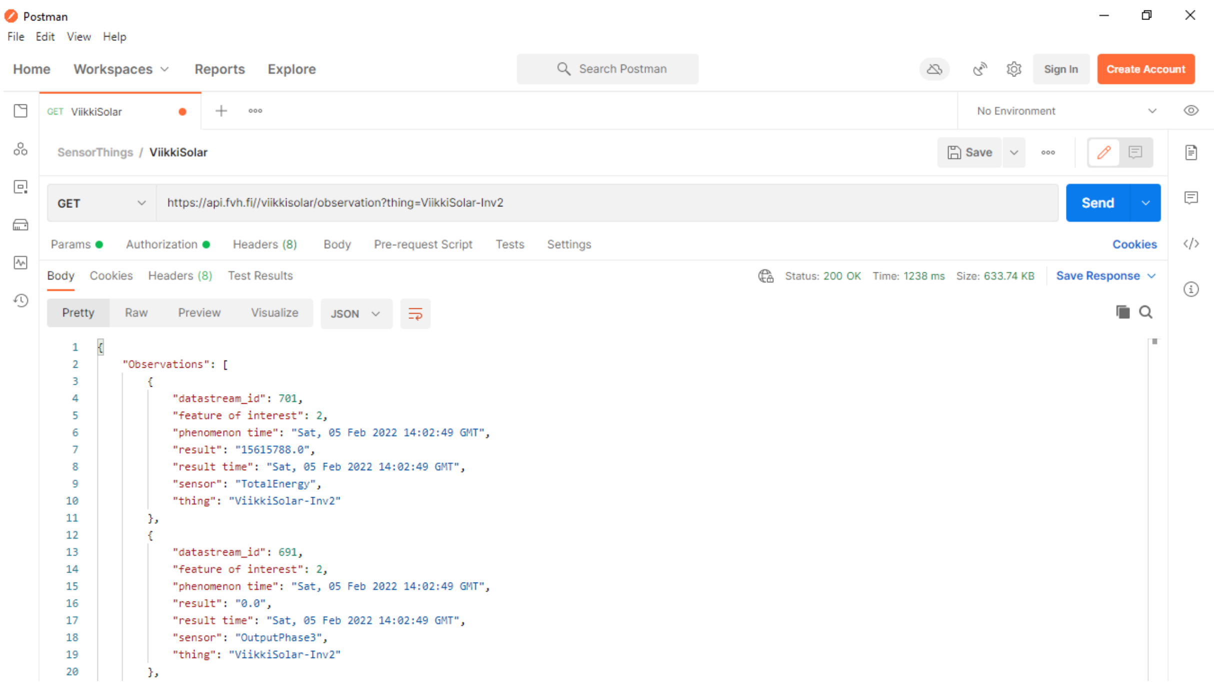


Figure 18: Viikki Solar Panel Production use case test result

Table 17 summarises the results in terms of functionalities of the use case. As observed, owing to the testing phase made via Postman, all the functionalities cannot be evaluated, i.e. execution of the algorithms, data push, storage and presentation. However, as depicted in the previous snapshot, the API is available to connect, data is correctly consumed and the data transfer is properly rendered by providing a JSON format.

Table 17: Result of the functionalities testing for use case #3

| | Result of test | Reasons for failing | Recommendations for successful interoperability |
|---|---|---|---|
| API Connection | | n.a. | Use of standards for data sharing with self-interpretable information makes easier the capability of data expose and interoperability between services. |
| Data consume | | n.a. | |
| Data transfer | | n.a. | |
| Algorithm execution | n.a. | n.a. | |
| Data presentation | n.a. | n.a. | |
| Data push | n.a. | n.a. | |
| Data storage | n.a. | n.a. | |

## 6.4 Use case 4: Things

Additionally, although it was not a test case defined previously, this additional test focuses on the SensorThings API data model used. The intention is to show the results about interoperability and capability of self-discovery. This service is not specific to Nantes or Hamburg or Helsinki or any other



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platform equipped with SensorThings API. In other words, applying the dashboard service to the context of an urban platform and verifying that the data are well displayed shows that the compliant platforms are interoperable. The only restriction is that the API should be public or at least reachable by the dashboard server, which may not be compliant with privacy issues such as those applicable to Helsinki use cases.

The specificities of each platform lie at two levels. The first level is obvious and is at access level: which URL and which security scheme. This access information is stored as a “data source”, the idea being switching data source applies the same dashboard service to a different urban platform. As it is illustrated in Figure 19, the use of SensorThings API allows listing elements from platform to platform. In the example of Figure 20, Nantes urban platform is able to obtain the “things” within Hamburg urban platform.

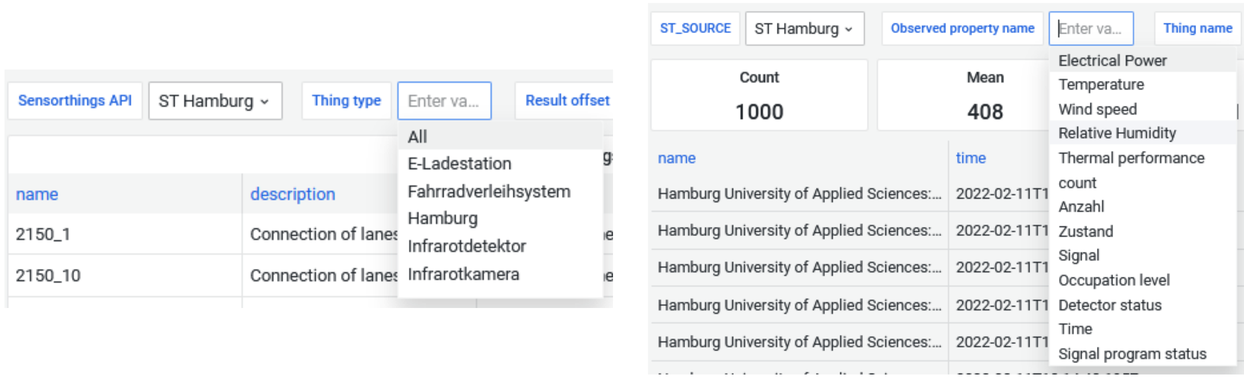


Figure 19: Things discovered from the Nantes urban platform in the Hamburg API

The dashboard service is composed of two dashboards: a “things” dashboard, which explores the repository of the urban platform, and an “observation” dashboard, which explores the data (measurements or KPIs). The “things” dashboard explores the repository of “things” and their “location” as per SensorThings API definitions[3] and shows the retrieved data in tabular and a spatial way. The data can be filtered according to their “type”, which is discussed in the annexes about semantic interoperability. The “data” or “observations” dashboard explores the sensors and KPI data collected by the urban platform under the form of “observation”, “data stream” and “observed property” objects as per SensorThings API definitions. The retrieved data are displayed in tabular and graphical ways. The data can be filtered according to the “type” of the “thing” associated, such “type” is discussed in the annexes.

[3] http://docs.opengeospatial.org/is/15-078r6/15-078r6.html#24



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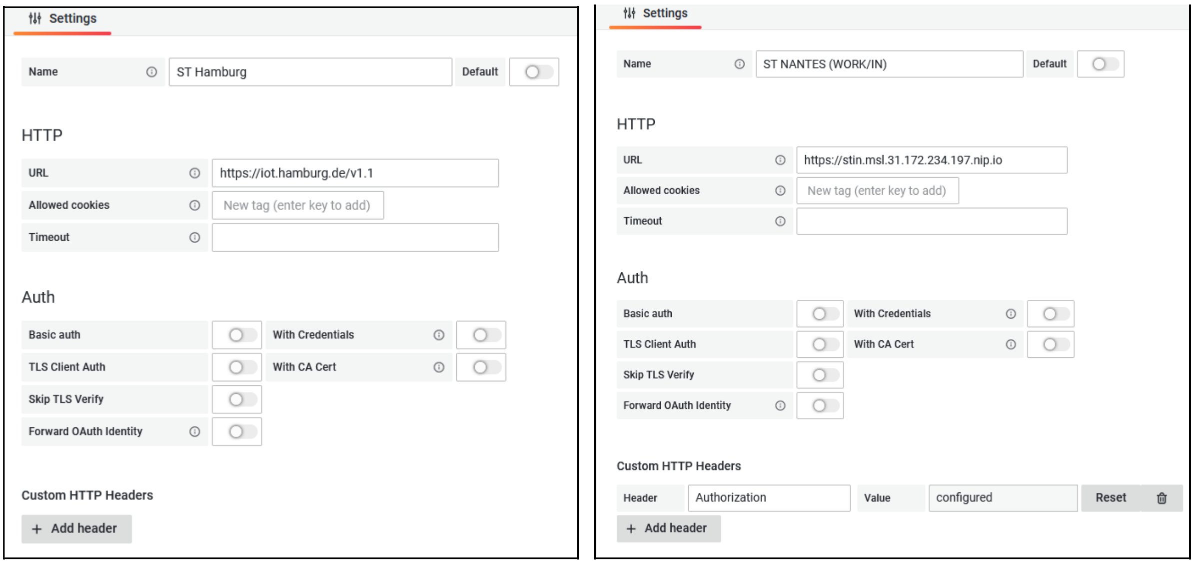


Figure 20: Examples of Hamburg (free access) and Nantes (token-based access) data sources



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# 7. Compliance with the European INSPIRE Directive

The chosen SensorThings API within the mySMARTLife Project by Helsinki, Nantes and Hamburg shows perfect interoperability and the implementation into the Urban Data Platform Hamburg has been selected as a good practice example for the INSPIRE Directive. To date, the OGC Sensor Observation Service (SOS) has been utilised for direct access to measurement data in INSPIRE. In the quest for simpler access methods, use of the OGC SensorThings API (STA) is proposed as an alternative, pertaining both to the data and service specifications. It is shown to be in full compliance with the data requirements ensuing from both the INSPIRE EF Theme as well as the underlying Observational Model from the GCM as described in a dedicated publication.

In order to show the practical applicability of a STA-based INSPIRE download service, several STA systems have been deployed by MS. At present, STA endpoints have been created for multiple following environmental and related domains, thus showing the degree of flexibility available when utilizing STA. While initially designed to bridge the gap between the spatial and IoT domains, the potential for reuse far beyond sensors becomes apparent.

**INSPIRE Components:**

This Good Practice pertains to data encoding as well as to network (download) services, while greatly enabling data sharing.

Pertaining to data encoding, the underlying STA data model, while isomorph to the OGC O&M data model upon which the INSPIRE observational models is built, does have some subtle differences, requiring reconfiguration of the O&M based INSPIRE data specifications. However, due to the isomorphism between these data models, the fact that the STA data model was derived from the O&M model, a lossless transposition of data can be assured.

Pertaining to network (download) service requirements, STA utilises a REST-based API approach modelled on the OData standard. In addition to fulfilling the core requirements laid down by INSPIRE pertaining to download services, the OData approach allows for the formulation of complex queries tailored to the complexity of the underlying data model, thus allowing users more direct access to the data they require than previously possible.

**Relevance & expected benefits:**

The adoption of the OGC SensorThings API standard as an INSPIRE download service would provide a modern approach for the exposure of dynamic geospatial data that adheres to the recommendations of the W3C Data on the Web Best Practices.



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Both implementers of INSPIRE and users of the data would benefit from the powerful, yet simple approach for data sharing.

In contrast to the previously utilised OGC Web services (OWS), deployment of STA is far easier and less resource intensive than SOS, while use of the JSON encoded data is far more in line with modern development paradigms [15].

The knowledge gain in the mySMARTLife project has been shared with the API4INSPIRE within the ELISE - European Location Interoperability Solutions for e-Government action. This leads to the good practice example Urban Data Platform Hamburg where a huge volume of sensor data is now integrated subsequently to the developments carried out in the mySMARTLife project[4]. The provided data extends far beyond the use cases of mySMARTLife namely integration of traffic light data, vehicle and bicycle counting with more than 2500 cameras. These data have been presented at the ITS World Congress 2021 in Hamburg[5].

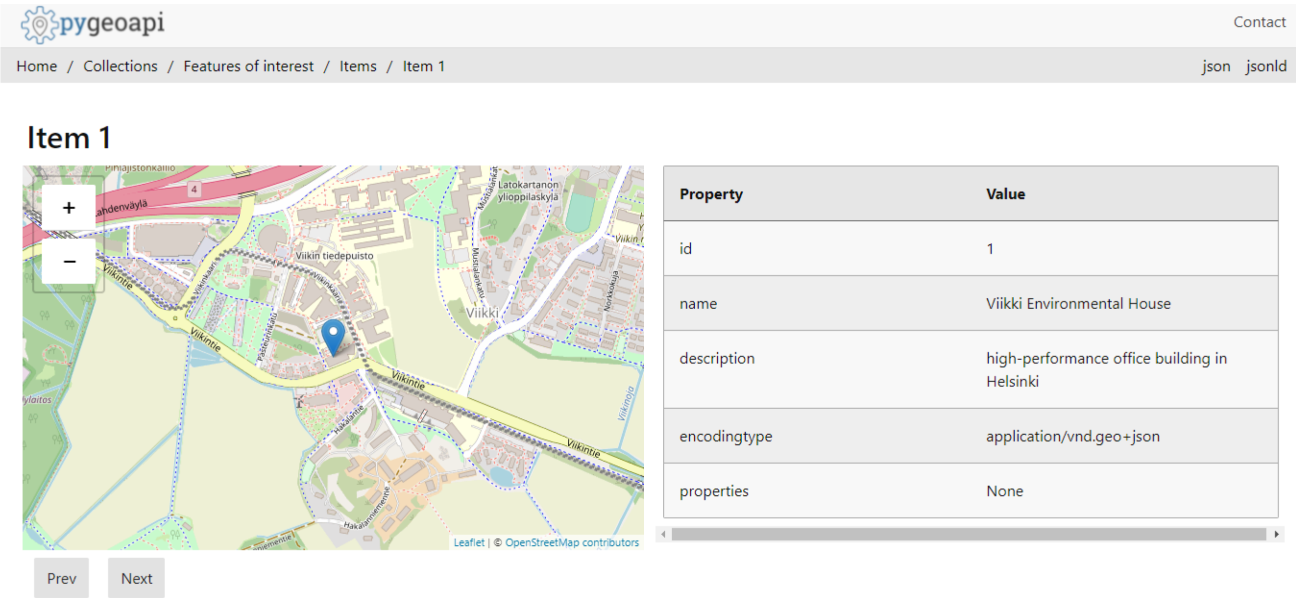


Figure 21: OGC API Features collection in Helsinki: pygeoapi

The SensorThings API also benefits from supporting spatial data infrastructure that provides a controlled source for the definitions of locations in the INSPIRE download service, OGC API Features. The SensorThings API supports the location as context in several ways: as a location or historical location of the Thing -entity, as an observed area of the data stream or as a related feature of interest. Figure 21 shows the mySMARTLife pilot locations of Helsinki as an OGC API Features collection, using the open-source reference implementation of the OGC APIs, pygeoapi.

[4] https://joinup.ec.europa.eu/collection/elise-european-location-interoperability-solutions-e-government/api-inspire

[5] https://itsworldcongress.com/wp-content/uploads/2021/10/211006_ITS_Broschure_eng_final.pdf, page 21



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The benefit from the new generation of the OGC APIs is that the location information is made available in a developer-friendly JSON and JSON-LD format (see Figure 22).

The importance of including the OGC API Features as part of the smart city data acquisition is most significant in environmental monitoring, where the location of the facilities is included in the mandatory types of services in INSPIRE Annex 3.


```json
{
    "type": "Feature",
    "geometry": {
        "type": "Point",
        "coordinates": [
            25.015582,
            60.224904
        ]
    },
    "properties": {
        "id": 1,
        "name": "Viikki Environmental House",
        "description": "high-performance office building in Helsinki",
        "encodingtype": "application/vnd.geo+json",
        "properties": null
    },
    "id": 1,
    "prev": "1",
    "next": 2,
    "links": [
        {
            "rel": "self",
            "type": "application/geo+json",
            "title": "This document as GeoJSON",
            "href": "https://geo.fvh.fi/features/collections/featureofinterest/items/1?f=json"
        },
        {
            "rel": "alternate",
            "type": "application/ld+json",
            "title": "This document as RDF (JSON-LD)",
            "href": "https://geo.fvh.fi/features/collections/featureofinterest/items/1?f=jsonld"
        },
        {
            "rel": "alternate",
            "type": "text/html",
            "title": "This document as HTML",
            "href": "https://geo.fvh.fi/features/collections/featureofinterest/items/1?f=html"
        },
        {
            "rel": "collection",
            "type": "application/json",
            "title": "Features of interest",
            "href": "https://geo.fvh.fi/features/collections/featureofinterest"
        },
        {
            "rel": "prev",
            "type": "application/json",
            "href": "https://geo.fvh.fi/features/collections/featureofinterest/items/1?f=json"
        },
        {
            "rel": "next",
            "type": "application/json",
            "href": "https://geo.fvh.fi/features/collections/featureofinterest/items/2?f=json"
        }
    ]
}
```


Figure 22: Example of JSON and JSON-LD formats for OGC APIs



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# 8. Discussion on the interoperability results

In the beginning of the mySMARTLife project in 2017, the concept of Urban Platform was mainly defined by the EIP-SCC initiative, the ESPRESSO project (GA #691720) and the Synchronicity project (GA #732240), that started parallel in January 2017. As a lighthouse project, mySMARTLife has had the opportunity to follow the development of the concept and also to see the limitations and challenges the adoption in real life city cases has faced. Naturally, five years is a long period in the development of ICT platforms and the innovation project should show agility and responsiveness to meet the demand and have higher impact.

While in all the three cities the developed platform and concept have found real life use as part of the city data services, the requirements for further development have not disappeared. In Helsinki, the city launched a major data initiative in the mobility domain, with the goal of providing situational awareness of the city-wide transportation system. From the data perspective, such ambition means moving from data acquisition towards real-time data stream processing. When the Urban Platform in 2017 was mainly seen as an IoT platform providing sensor data acquisition and dashboards, today the use cases and requirements would be set differently.

The various actions in mySMARTLife have shown the increasing role of data integration. We introduced the role of ETL on the urban platform concept as a generic process to provide data mapping and harmonisation as a part of the data platform. From practical experiments we have seen the need to deal with legacy systems and industry standards, especially in the field of building automation and energy systems. Also, while it would be great to define one smart city data model that covers everything, the cities can also accept the harmonization effort the industry has already made: As an example, being able to support data in the OCPP (Open Charge Point Protocol) 1.6 protocol format in electrical vehicle charging stations already means that the equipment of practically any of the major players in the market can be connected to the urban platform. In the Kalasatama Plot Assignment Stipulations in Helsinki the data requirements were re-defined to accept industry standards as long as they are supported by several major players in the market. The question of which standards to prefer in public procurement remains open. As part of the ESPRESSO project, in certain domains, the group found thousands of relevant standards that could have been adopted. This have further supported the conclusion that the foundation of interoperability in urban platform is not about limiting the supported standards to few, but to be able to be agile, have state-of-the-art data integration capabilities and to rely on newer approaches on context metadata such as the data catalogues and data quality management (DQM) tools.

The role of public procurement in the harmonisation of data models and interoperability is now on the table at the living-in.eu initiative. The key findings from the mySMARTLife project have already been



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disseminated to groups working on the next steps of the European data policy. The Open and Agile Smart Cities and Communities (OASC) group has been active in defining the Minimum Interoperability Mechanism. The original ambition was to have a limited number of MIM's that similar to the PPI's in Espresso. The definition relies on ITU: *The minimal sufficient degree needed to meet a certain requirement for data sharing, use and* reuse. This work relied on previous work on mentioned projects and also the Connecting Europe Facility (CEF) support for interoperability, including the Context Broker and NGSI-LD.

OASC is motivating the shift of focus towards minimal interoperability with feasibility reasoning: Complete interoperability would require compliance with a large number of detailed standards – only possible for cities with significant resources. Their position is that the minimal interoperability is especially needed to enable the many small and medium sized cities and communities to benefit from an open market.

The OASC approach was defined followingly in the CxC webinar in January 2022, with the conclusions presented in Table 18.

Table 18: OASC approach webinar conclusions

| Sufficient interoperability to allow: | Minimal to ensure: | Clearly defined mechanism so that: |
|---|---|---|
| • "Good enough" integration of systems<br>• Development of a viable market – cutting costs, minimising risk and preventing vendor lock-in | • No unnecessary complexity or time-to-implement<br>• Aim for cost for cities to implement (staff time, software, hardware) to be less than, say, €50.000 | • It is easy to determine if a product or service is compliant<br>• It is easy to determine the steps to implement |

The Urban Platform concepts defined in each city as part of the mySMARTLife project were also able to tackle an issue that was not covered by Connecting Europe Facility with their Context Broker and NGSI-LD recommendation: the compliance with the INSPIRE requirements. Some actions in mySMARTLife were already related in presenting the new data products as part of the city 3D model. This not only requires compliance with the geospatial data standards matching with the INSPIRE technical requirements, but also formed the basis for digital twin services for the smart cities – also making it clear that the smart city digital twins are different than industrial digital twins due to the need to model and include the acts and wishes of the citizens and not just simulate cities like machines.

All these previous aspects combined with the results of the interoperability testing extract as initial lesson learnt the importance of standard data models, but the complexity to afford with the compliance of them due to the high amount of current standards. Efforts should be made for defining common terminologies and concepts, creating common criteria since design. Literature indicates that probability of success is partially due to design stage [14]. Furthermore, a growing number of large-scale smart-city projects bids are started with the conscious decision of providing bidding documents containing only a coarse



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"functional program" and expecting quick iterative results as opposed to a thorough reflexion based on returns of experience in the form of detailed functional requirements. mySMARTLife partners overcame this aspect during the first two years of project, establishing periodic technical meetings, as well as parallel sessions during the periodic meetings, between the ICT experts to define and determine the common requirements in terms of standard data models, urban platform architecture [7] and ICT developments.

Even though efforts have been made in this line, it should be highlighted that, in order to be able to switch between Hamburg and Nantes "types", a modification in Nantes repository had to be made at semantic level. This confirms the aforementioned in the availability of multiple standard data models, conceptualisations of the urban platforms and interpretation. For instance, whilst Hamburg lists the thing types in Thing.properties.keywords[0], Nantes provides it as Thing.properties.type. This is where an extra step had to be made to make interoperability possible.

Regarding the Things type, Nantes is compatible with both ways with the cost of data replication. However, having solved the "micro-syntaxis" level of interoperability, it can be seen that the values used are different, we have used different "dialects". As mentioned in the previous chapters, different thesaurus was used to value metadata. For example, the type for all charging points is "EVSE" in Nantes urban platform and "E-Ladestation" in Hamburg urban platform. Such level of interoperability involves linguistic decisions and cannot be treated without cultural concern, especially when the platform owner is a public administration. A direction of work could be to define a common thesaurus of language-agnostic codes in the same idea that was applied to defining the KPIs. Only the associated labels would then be translated according to the local context of each urban platform. However, such thesaurus must be defined and thought about prior to starting implementation works. The situation is that this objective seems hypothetical given the growing number of urban platform-based city projects started with only a coarse "functional program" as a conscious choice rather than written detailed functional requirements coming from thorough studies.

All in all, achieving full interoperability is a very complex task that requires many many efforts, firstly, due to the amount of standard data models, secondly, owing to "interpretability" of metadata. Only cities with high availability of resources could assure 100% of interoperability. Nevertheless, within the perspective of mySMARTLife, considering the indicator ISO 37151:2015 explained before, the project is reaching level 4 - the project increases interoperability sufficiently, whenever the requirements are met (i.e. using the above explained data representation and "things" dictionaries). Services are observed to be "interchangeable" between platforms, but, in some specific cases, adaptations are required.



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# 9. Conclusions

Interoperability is a relevant aspect in any ICT system. Within urban platform developments is even more important as multiple domains converge in the same infrastructure. In this sense, heterogeneous data is ingested and should be made available for further developments. mySMARTLife project is aware of the importance of interoperability and therefore, one individual task was devoted to define the concept, plan and finally, test it. For that end, efforts have been made in establishing one common open specifications framework under which the urban platform could be extended following similar approaches, although adapted to the specific architectures, within each of the three cities of Nantes, Hamburg and Helsinki.

Establishing the interoperability requirement since the design stage is usually synonym of success. mySMARTLife project has demonstrated such an experience, where the efforts during the initial stages of the urban platforms definition have resulted in common data models across the urban data platforms, with similar criteria for data representation and strategies for data exposing and sharing.

Once the common strategy was set up and deployed, the results needed to be tested, which has been the core objective of this document. According to this, it has been demonstrated how mySMARTLife paves the way to guide other cities in terms of interoperable services, fostering the entrepreneurship, i.e. making data available for third parties in order to develop new services, new added value to the city and future tenders from the municipalities to include other city verticals (e.g. waste management) under the same urban infrastructure.

mySMARTLife results show an excellent level of interoperability according to ISO 37151:2015 indicator. Of course, here, it should be considered the availability of data to run a service. That is the reason why this conclusion is extracted from 3 out of the 4 proposed use cases. The fourth one demonstrates that the lack of data is a constraint in the interoperability, at least, to deploy plug&play services. In this sense, functionality needs to be reduced or limited to adapt existing services to the available data that is exposed through open data and open APIs.



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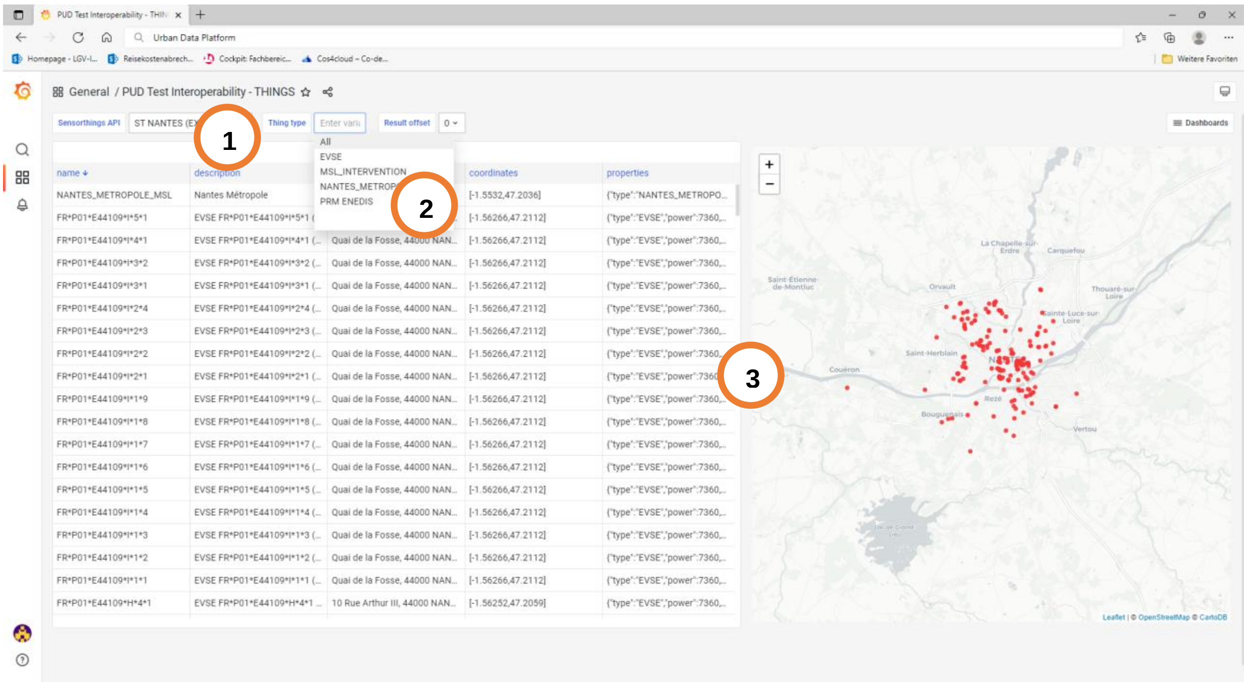
# Annex I: Things dashboard interoperability

## Interoperability tested through the “things” dashboard

Things interoperability in Nantes:




(1) Datasource selection. Here, "ST NANTES” for the SensorThings endpoint of Nantes.

(2) Thing type selection available according to the selected datasource.

(3) The results. Here, we can see charging points list available in Nantes Urban Platform.



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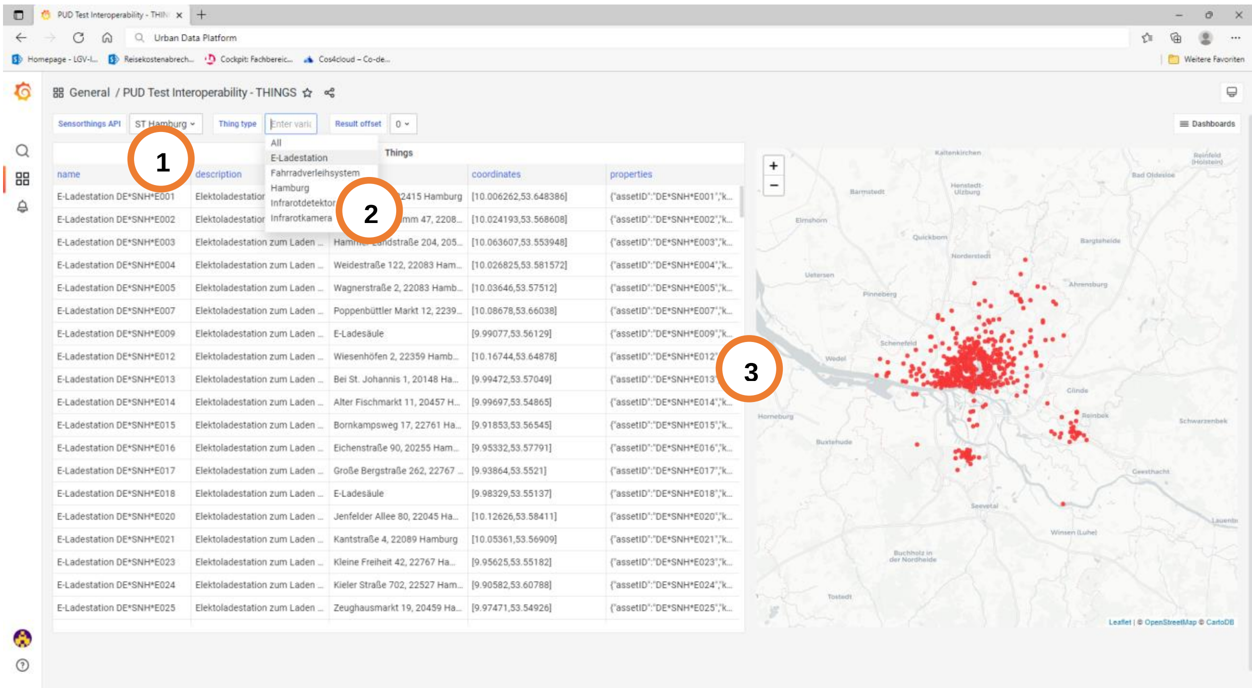
Things interoperability in Hamburg:




(1) Datasource selection. Here, "ST HAMBURG" for the SensorThings endpoint of Hamburg.

(2) Thing type selection available according to the selected datasource.

(3) The results. Here, we can see charging points list available in Hamburg Urban Platform.



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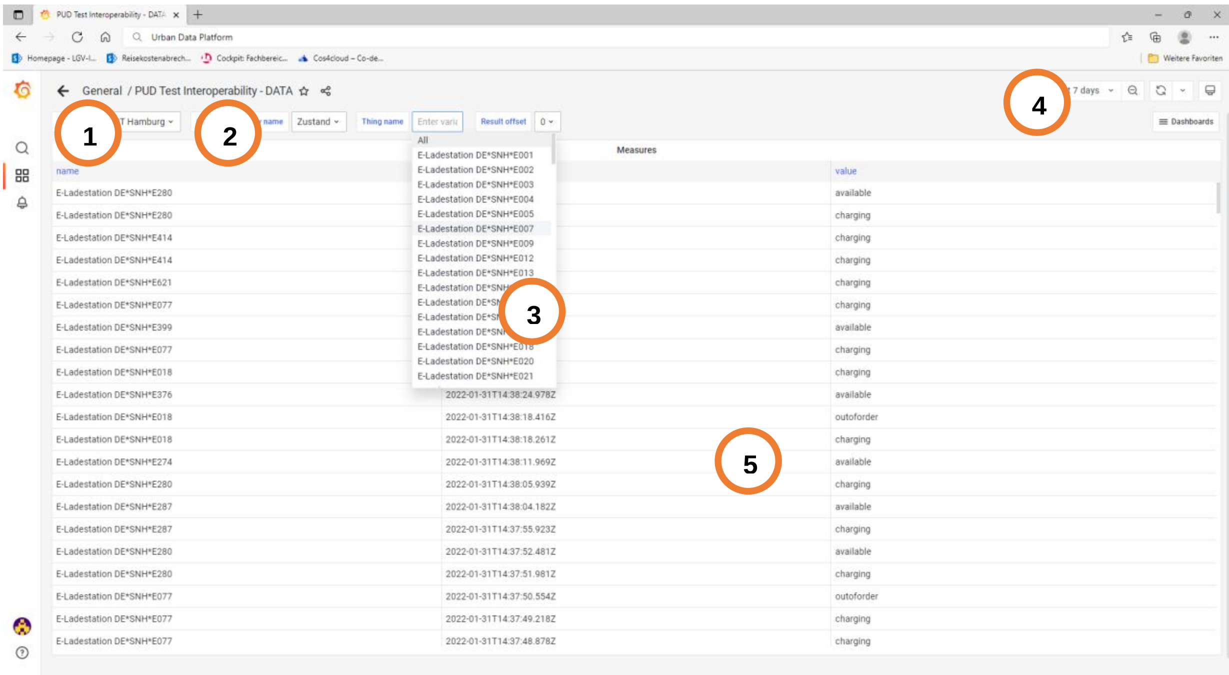
### Interoperability tested through the "observations" dashboard

Interoperability test Observations on the example of ev-charging stations in Hamburg (zoom on tabular view):




(1) Datasource selection. Here, "ST HAMBURG".

(2) Type of observed property, what kind of data the measures are about. Possible values according to the selected datasource. Here: "Zustand" as for the charging point status.

(3) Things list, what physical object we can filter on. Possible values according to the previous filters and the selected datasource. Here: the "E-Ladestation DE*SNH*E007" charging point.

(4) Time frame selection, when. Here: the last 7 days.

(5) The results. Here, we can see the charging points status, whether it is available or if it is charging.



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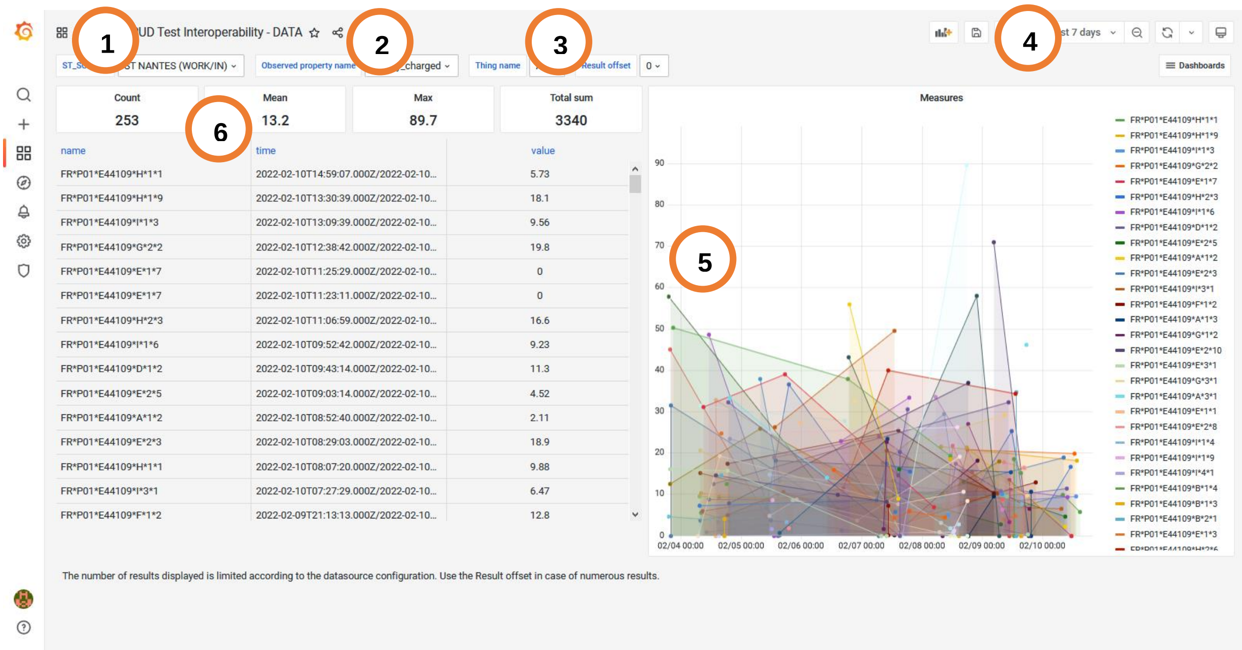
Interoperability test Observations of ev-charging stations in Nantes (tabular and graph views):




(1) Datasource selection. Here, "ST NANTES".

(2) Type of observed property, what kind of data the measures are about. Possible values according to the selected datasource. Here "energy_charged" as for the amount of energy delivered per charging session per charging point.

(3) Things list, what physical object we can filter on. Possible values according to the previous filters and the selected datasource. Here: all charging points are selected.

(4) Time frame selection, when. Here: the last 7 days.

(5) The results. Here, we can see the amount of energy delivered increasing during each charging session.

(6) Calculations. Here, simple statistical calculations: count, max, average, total sum.



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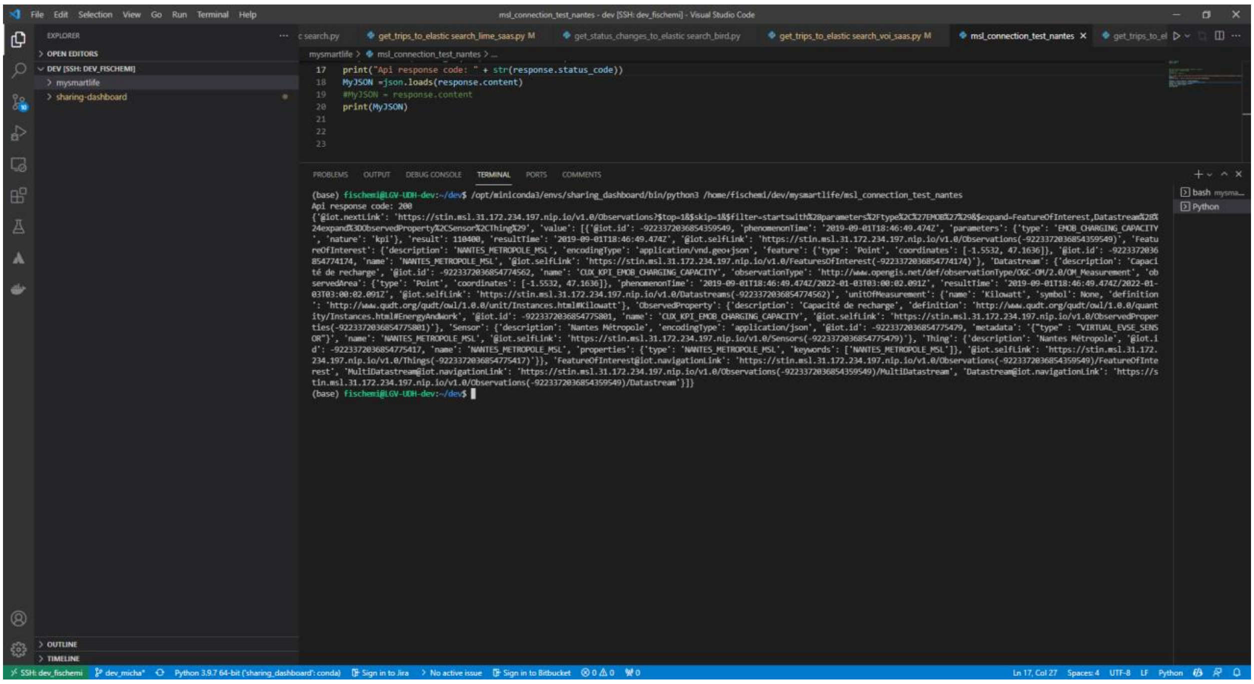
# Annex II: Interoperability at code-level

To go deeper into the technical details of the interoperability plan, another set of tests called "code-based" tests have been designed. These tests consist of trying to retrieve data by using low-level tools which can provide low-level information such as HTTP response code or possibly error codes.

Two code-based tools were used: Python code and Postman HTTP requests analyser. The goal is to obtain data through these means as IT companies would if they had to develop new machine-to-machine services consuming the data provided by the urban data platforms.

## Interoperability tested through code-based APIs calls

API Interoperability test Nantes using Python from Hamburg urban platform:





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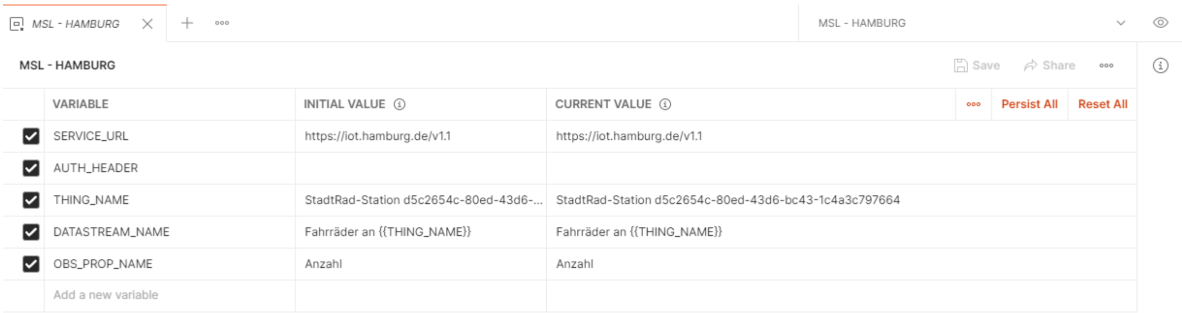
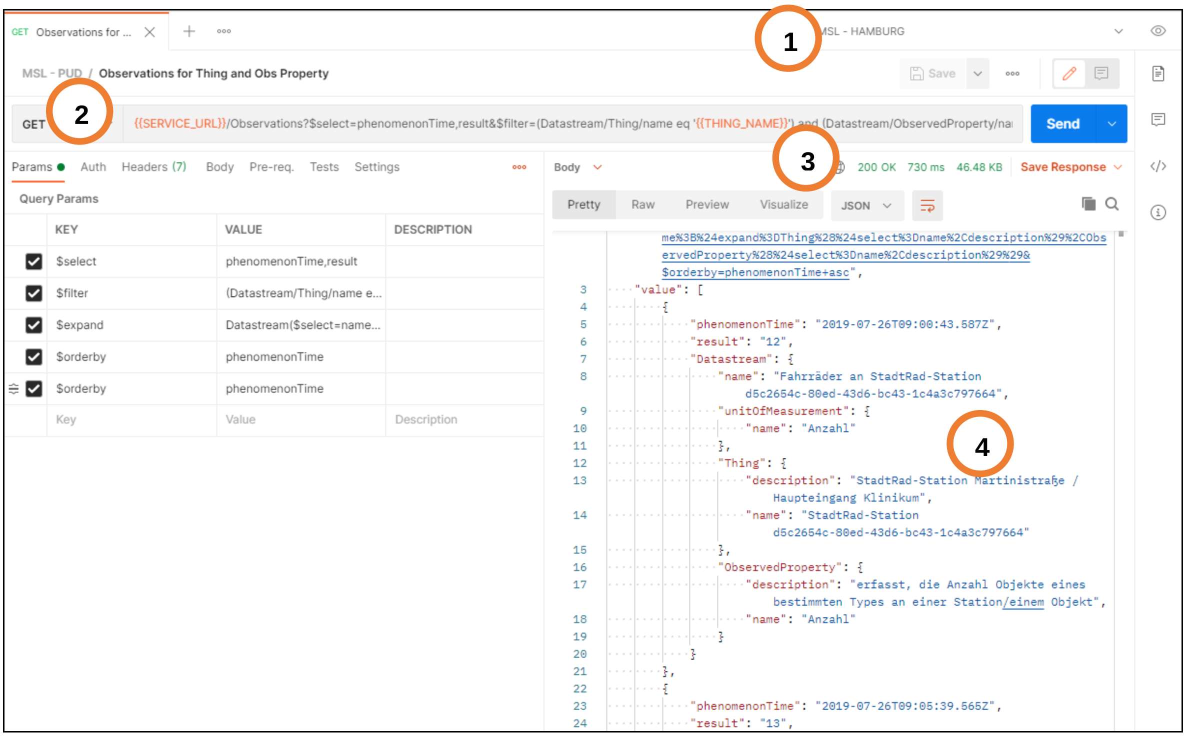
Interoperability test Hamburg using Postman from Nantes urban platform. The following variables were set in the context of the SensorThings "dialect" applicable to Hamburg urban platform:




The above variables are the equivalent of the datasource used by the "Interoperability dashboards". Another set can be designed to apply the Postman tool to the context of other urban platforms. The results are the following:




(1) "Environment" set to Hamburg urban data platform (equivalent to dashboard datasource).

(2) Context agnostic SensorThings API data retrieval service. Here the observations measured for a given "thing, a given "observed property" and a given "data stream" in case several are defined (it can happen when data streams of various periodicity – daily, monthly, etc. – are produced.

(3) Result of the API call. "200" means OK.

(4) The data retrieved and passed to the analyser service.