INTERNET OF FOOD & FARM

D3.11 PROGRESS REPORT ON DEVELOPMENT, INTEGRATION AND DEPLOYMENT OF REUSABLE COMPONENTS FOR WP2

WP 3

March 31st, 2021

Latest Progress of the implemented Reusable Components provided to Use Cases in WP2 and for an extended external stakeholder audience.

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PROJECT SUMMARY

The internet of things (IoT) has a revolutionary potential. A smart web of sensors, actuators, cameras, robots, drones and other connected devices allows for an unprecedented level of control and automated decision-making. The project Internet of Food & Farm 2020 (IoF2020) explores the potential of IoT-technologies for the European food and farming industry.

The goal is ambitious: to make precision farming a reality and to take a vital step towards a more sustainable food value chain. With the help of IoT technologies higher yields and better-quality produce are within reach. Pesticide and fertilizer use will drop and overall efficiency is optimized. IoT technologies also enable better traceability of food, leading to increased food safety.

IoF2020 involves 33 use-cases organised around five trials (arable, dairy, fruits, meat and vegetables) develop, test and demonstrate IoT technologies in an operational farm environment all over Europe, with the first results that were realised in the first quarter of 2018.

IoF2020 uses a lean multi-actor approach focusing on user acceptability, stakeholder engagement and the development of sustainable business models. IoF2020 aims to increase the economic viability and market share of developed technologies, while bringing end-users' and farmers' adoption of these technological solutions to the next stage. The aim of IoF2020 is to build a lasting innovation ecosystem that fosters the uptake of IoT technologies. Therefore, key stakeholders along the food value chain are involved in IoF2020, together with technology service providers, software companies and academic research institutions.

Led by the Wageningen University and Research (WUR), the 100+ members consortium includes partners from agriculture and ICT sectors, and uses open-source technology provided by other initiatives (e.g. FIWARE). IoF2020 is part of Horizon2020 Industrial Leadership and is supported by the European Commission with a budget of €30 million.

EXECUTIVE SUMMARY

The content, status and progress of the joint developments specifically managed in Task 3.6 are documented and communicated with this deliverable 3.11. It provides an overview on the key components that were realised to facilitate the reuse of components and replication of results, when aiming at the implementation of IoT based solution. This deliverable is giving a focus on the following results elaborated by WP3:

- IoF2020 IoT Catalogue
- Smart Data Models
- Access Control and Service Monetization component
- Data Marketplace for Standards and Marketplace component
- AgriWeatherGateway and AgriContractorsGateway
- Security, Privacy and Trust by Design Tutorial

Moreover, this deliverable is analysing the IoF2020 use cases from a technological perspective to summarise key achievements and characteristics, to facilitate an overview for identifying synergies as well as potentials for collaboration, reuse and replication of results by third parties in additions to deliverables D3.12 (implemented IoT catalogue – www.iot-catalogue.com) and D1.2 (implemented catalogue of use cases - https://www.iof2020.eu/use-case-catalogue/).

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ABBREVIATIONS

ACG	AgroContractorsGateway
AEF	Agricultural Industry Electronics Foundation
AgGateway	Non-profit organization for industry's transition to digital agriculture
API	Application Programming Interface
AWG	AgroWeatherGateway
COTS	Commercial off the Shelf
D	Deliverable
e.g.	exempli gratia (engl. for example)
EPC IS	Electronic Product Code Information System
ETSI	European Telecommunications Standards Institute
EU	European Union
FIWARE	Future Internet Software Initiative
FMIS	Farm Management Information System
GE	Generic Enabler
GS1	Global Standards One
i.e.	id est (engl.: that is to say)
IoF 2020	Internet of Food and Farm 2020
IoT	Internet of Things
ISO	International Organization for Standardization
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
LD	Linked Data
LSP	Large Scale Pilot
MIM	Minimum Interoperability Mechanism
MVP	Minimum Viable Product
NGSI	Next Generation Service Interfaces
OASC	Open & Agile Smart Cities
OPC UA	Open Platform Communications Unified Architecture
POI	Point of Interest
RFID	Radio Frequency Identification
SME	Small and Medium Enterprise
SPT	Security, Privacy and Trust
UC	Use Case
UN/CEFACT	United Nations Centre for Trade Facilitation and Electronic Business
WP	Work package
w.r.t.	with respect to

1 Introduction

The IoF2020 project was successfully realising the design, development, integration and testing of 33 sub-projects implementing IoT based solutions – so called use cases – in the agri-food sectors of arable, dairy, fruits, vegetables and meat (i.e., an upper grouping of the use cases, called “trials” in IoF2020). The main focus of IoF2020 was the test and validation of IoT based solutions for practical application in real world environments. Therefore, each use case included different innovative elements that had to prove its applicability in terms of costs, benefits, reliability, robustness and user acceptance.

Therefore, each use case was following its individual mission, being self-contained in terms of problem addressed, team involved and solution to be developed. The collaboration of individual use cases was not a prerequisite, but also a positive outcome of collaborative work of use cases in their trial areas as well as on an overall project level. Joint areas of interest were e.g. the work on joint data models, reuse of IoT devices as well as facilitating interoperability between agri-food stakeholders. However, the outcome of individual use cases was not necessarily intended as generic components that will facilitate a large uptake by the developers’ community but generating a body of knowledge and lessons learnt that will help both system developers and end-users to make decisions about the applicability of IoT based solutions with respect to their requirements and status in applying IoT as well as ICT in general.

Based on those results, key stakeholders in the use cases were able to refine their strategic agenda in terms of using and offering IoT based solutions. Startup type members in the use cases were even able to attract additional investors or expand their business activities beyond their original sphere of activity, due to attention that such a large-scale project like IoF2020 offers to its members.

Accompanying to the IoF2020 use cases, work package 3 (WP3) focused on IoT as technological enabler and its integration into real world infrastructures. WP3 was aiming at the perspective on how to integrate innovative solutions coming from different parties, since it is envisaged that no single company will be able provide the best solution for all agri-food challenges. Therefore, WP3 was based on the assumption that the integration of information generated by different solutions will be the key enabler to build a holistic picture of what is going on at the farm. Consequently, Farm Management Information Systems, could be able to provide users an integrated view, encompassing information from different verticals and mashing-up the best of breed user interfaces. In the end, Context Information associated to a farm will be enriched with the contributions coming from different vertical solutions (System of Systems), all of them able to share data among each other and enabling a further optimization of processes, saving time, money and resources[1]. Therefore, WP3 was aiming at the development of components that aim at facilitating the reuse and replicability of IoT based solutions.

The underlying objective of WP3 was to define so called “Minimum Interoperability Mechanisms” that will finally help system developers to offer their IoT based solutions at lower costs as well as end-users to ease the integration of their systems as well as avoiding a vendor lock-in. The work built upon available standards, aiming at complementing the work with a more agile type of standardisation that can evolve at market speed, while WP3 had the objective of not reinventing the wheel, rather being flexible than end in perfection that would costs way more time and efforts.

In terms of a reference architecture and interoperability points[2], this was the reason that WP3 mainly focused on the information management and mediation layers combining the north bound application layer with the south bound layers that are finally connecting the physical device to the virtual world. This also reflected the IoF2020 challenge of accommodating very broad requirements of the different trial sectors, that were individually involved in decades of standardisation work (e.g. ISOBus, Adapt, EPC IS, UN/CEFACT, AgGateway, ETSI RFID protocols). Very typical examples that were addressed by several use cases were the integration of weather stations, combining diverse IoT sensors or also the combination of federated data spaces specifically popular in the operation of agricultural machinery. Also tracking and tracing scenarios asked for data related integration of solutions, specifically when aiming at the provision or exchange of data along the food chain.

1 See also IoF2020 Deliverable D3.8, presenting an analysis of use cases in relation to the perspective of a system of systems approach and specifically context information used.

2 See also IoF2020 Deliverable D3.3, presenting the envisaged approach how IoT and related technologies can be applied to the domain of agri-food, with a view creating interoperable and portable solutions.

This deliverable is presenting the progress made on the development, integration, and deployment of re-usable components. This deliverable provides an overview on the key components that were realised to facilitate the reuse of components and replication of results, when aiming at the implementation of IoT based solution. In chapter 2, the progress with respect to the following results is presented:

- IoF2020 IoT Catalogue
- Smart Data Models
- Access Control and Service Monetization component
- Data Marketplace for Standards and Marketplace component
- AgriWeatherGateway and AgriContractorsGateway
- Security, Privacy and Trust by Design Tutorial

Moreover, in the subsequent chapters, this deliverable is analysing the IoF2020 use cases from a technological perspective to summarise their characteristics and key achievements, to facilitate an overview for identifying synergies as well as potentials for collaboration, reuse and replication of results by third parties in additions to deliverables D3.12 (implemented IoT catalogue – www.iot-catalogue.com) and D1.2 (implemented catalogue of use cases - https://www.iof2020.eu/use-case-catalogue/).

2 Latest Status of Reusable IoF2020 Components beyond the Project

2.1 Towards Minimum Interoperability Mechanisms

In the first year of the IoF2020 project, WP3 analysed all the 19 use cases that were starting right from the beginning in early 2017. Deliverable D3.2 is presenting these use cases from different modelling perspectives, specifically detailing different views (i.e. 6 views: domain model, deployment, IoT functional, business process hierarchy, interoperability endpoints, information model view) as well as analysing gaps, identifying reusable assets and carrying out an analysis of security, privacy and trust.

The heterogeneity of use cases in terms of variety of IoT based solutions and the individual agri-food environments addressed, made it rather difficult to summarise results of the use case solutions and to identify most successful strategies to tackle the different challenges when aiming at the deployment of IoT in the agri-food sector. Therefore, WP3 compiled the different viewpoints along a reference architecture as presented in deliverable D3.3, identifying and summarising the main relevant standards that have to be considered by the technological solutions proposed to implement the different use cases, so that interoperability and replicability are achieved. The objective was to enable the building of an Internet of Things ecosystem around the IoF2020 project and ultimately around Smart Farming in Europe. In other words, to make use case developers aware of related opportunities and barriers, to facilitate and trigger collaboration and synergies and as input for collaboration with external stakeholders. Six plus two interoperability points were identified, while also highlighting the additional need for privacy guidelines that are considered as an important asset to be taken into account by European Agricultural Associations as well as related standard development organisations like AEF, AgGateway, or GS1.

Moreover, the large-scale projects (LSPs) IoF2020 and Synchronicity were agreeing that specifically requirements on interoperability of systems, reuse of components and replicability of solutions are a key asset that will help both the IoT developers' community as well as related end-users to push the adoption of IoT based solutions. Synchronicity was following a paradigm of so-called Minimum Interoperability Mechanisms (MIMs). These go beyond the concept of Interoperability points as they are not just defining requirements on interfaces but push the adoption of defined functional modules in a reference architecture model that all developers shall comply with.

In collaboration with the Synchronicity LSP, the Open & Agile Smart Cities (OASC) are promoting the paradigm of MIMs with their mission to unite cities and communities around the world to build a global market for solutions, services, and data based on the needs of cities and communities. As highlighted by the OASC, to achieve this mission, OASC champions the MIMs, a set of practical capabilities based on open technical specifications that allow cities and communities to replicate and scale solutions globally. The MIMs are developed by the OASC Technology Council and governed by the Council of Cities and the Board of Directors. Finally aiming at the potential that MIMs provide the technical foundation for procurement and deployment of urban data platforms and end-to-end solutions in cities & communities worldwide[3].

The team in IoF2020 WP3 is sharing this vision of realising concrete MIMs and considers it also relevant and compatible for the agri-food business domain. Of course, comparing the agri-food domain with smart cities there are key differences in terms of stakeholders involved and the organisation of procurement processes, as cities are usually representing a key procurement body that is taking care for a large amount of ICT infrastructure in the cities themselves. Similar stakeholders are difficult to identify in the agri-food sector as procurement processes are organised rather bottom-up than top-down. However, one could possibly identify key players like agricultural farmer cooperatives, large food processors, traders or retailers at similar positions that could identify potential MIMs that are relevant for solution development along the food chain.

Following this line of thinking and aiming at facilitating the development of IoT based solutions, WP3 was working on the elaboration of a minimal set of MIMs that could represent the baseline for future collaboration of stakeholders along the food chain. Therefore, WP3 realised the following results that shall facilitate the replication of solutions realised in the IoF2020 use cases:

- **The IoT-catalogue**, aiming at further extending its content and opening the catalogue to additional initiatives. UNPARALLEL as owner of the IoT catalogue is also working on further features to enable catalogue users to add their content directly, facilitating cross-referencing of results and

[3] See also https://oascities.org/minimal-interoperability-mechanisms/

lessons learnt. However, during the runtime of IoF2020, also use cases of other large scale projects were already added (e.g. Monica), while other LSPs were using the catalogue as a kind of template to publish their results in a similar format, while only focusing on one business domain (i.e. OASC and smart cities). UNPARALLEL elaborated different business models for being able to further maintain the IoT catalogue also after the end of IoF2020.

- **The Smart Data Model initiative** of the FIWARE Foundation is aiming at standardisation of data models at market speed. It shall facilitate the collaboration of related stakeholders as well as offer an open collaboration space, based on resources published via GitHub. Besides agri-food, this initiative is also involving other business domains (e.g. smart cities, environment, manufacturing, energy, robotics), aiming at the realisation of synergies also beyond individual domains and sectors. However, at the same time, the initiative is based on the usage of existing standards, avoiding to reinvent the wheel. The FIWARE Foundation will further promote this initiative after the end of the IoF2020 project.
- **CoatRack service monetization open source software**, serving for the access control, authentication, authorization, service publishing, usage monitoring and finally monetization of service usage. The open source software was proposed as new FIWARE component and reviewed by the FIWARE technical steering committee (TSC). In February 2021, the FIWARE TSC decided to include CoatRack as FIWARE incubated enabler. At the same time it was worked on the integration with the FIWARE Business API Ecosystem to offer a facilitation of commercial delivery and usage service APIs. CoatRack is owned by ATB & CORIZON that will further work on its maintenance, evolution and offering of related commercial service offerings.
- **The data marketplace for standards** was implemented by ficodes and focuses on the provision of relevant standards developed by AgGateway, GS1, and FIWARE, with a focus on the development of agri-food solutions offering features along the food chain. This will be further maintained and supported, also offering a showcase for the underlying marketplace component to be used for the exploitation of other data sources.
- The development of the **Agri Contractors and Agri Weather Gateways** offers new components for collaboration by farmers exchanging local data as well as facilitating data reuse by Farm Management Information System providers and agricultural equipment operators. The open source software is finalised in March 2021 and will be available via GitHub soon. Agricolus as provider of the gateways and owner of an FMIS started collaboration with different stakeholders and aims at further promotion of the open source also beyond IoF2020.
- The **security, privacy and trust by design** tutorial that is compiling diverse guidelines and best practices for overall system design. It is a light-weight approach that shall help developers to be reminded of taking into account SPT by design at an early stage in the development life-cycle as well as to guide a more novice stakeholder in a way that facilitate a general understanding of the principle to initiate an awareness and commitment to assign required efforts and costs to related activities already at an early moment in time.

These results are representing a baseline for future exploitation of project results beyond the end of the IoF2020 project. Therefore, links to results and the related teams are also forwarded to the SmartAgriHubs community, for its inclusion in the SmartAgriHubs library of available resources/results for digital innovation in the agri-food sector as well as pushing individual initiatives that are combining open source and commercial strategies accordingly. The following sections 2.2 to 2.7 are detailing those results.

2.2 IoF2020 IoT Catalogue

In this chapter will be described what is the IoT-Catalogue, what was made in IoF2020, statistics about the IoF2020 available in IoT-Catalogue, and views on what will happen to the IoT-Catalogue after project end.

2.2.1 IoT-Catalogue Introduction

The IoT-Catalogue is a web-based catalogue for Internet-of-Things (IoT) solutions, available at www.iot-catalogue.com with continuous updates. The IoT-Catalogue brings IoT users and technology providers together, from the domain needs to IoT products (and back) via validated solutions with components, assembly guides, documentation, and more.

In the following figure we can see an overview showing the available features. The information in the IoT-Catalogue was inserted in a way which is searchable with a lot of relations between each item.

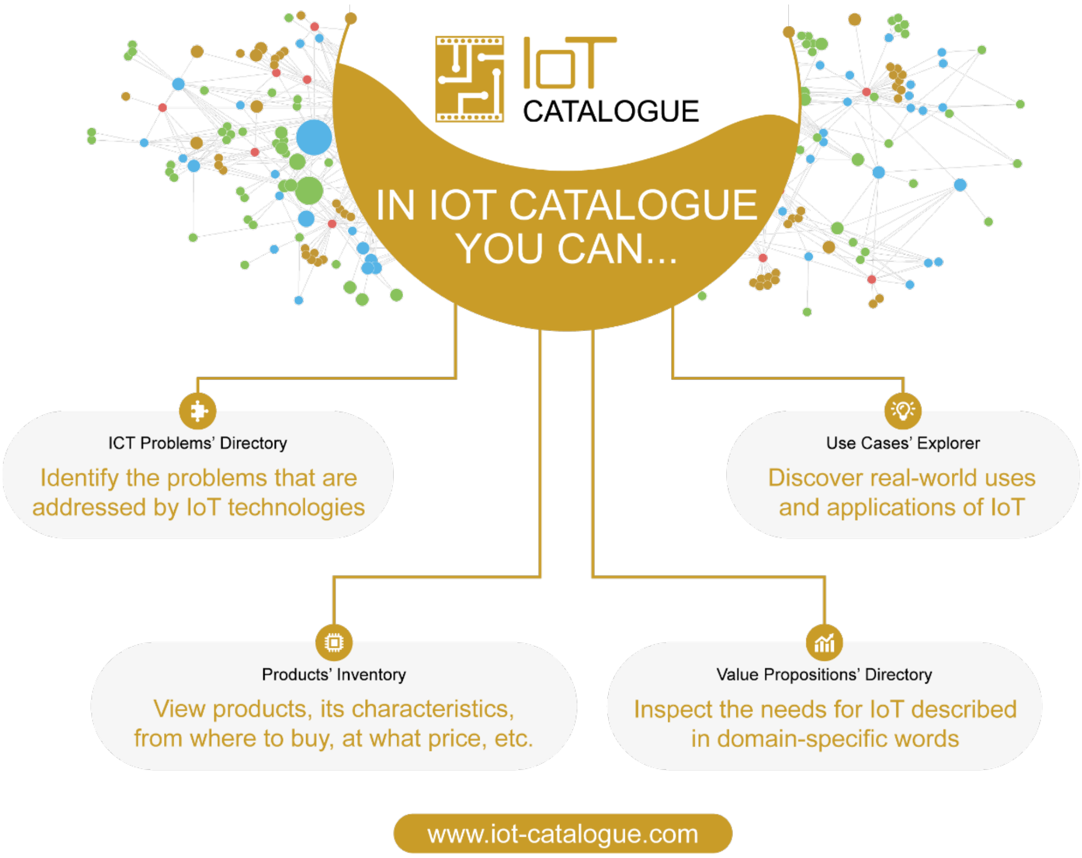

Figure 1: IoT-Catalogue Functionalities

The IoT-Catalogue was already online before the beginning of the IoF2020, but a lot of new requests appears during the project which led to new features. These new adds provided flexibility to support new features or allow different kinds of information that can be used to satisfy the needs of the project and at the same time making the IoT-Catalogue to extend, reflecting evolving requirements.

2.2.2 Developments in the IoT-Catalogue

This section will describe the three big main concepts, which were explored leading us to new features in the IoT-Catalogue.

2.2.2.1 Use Cases

Aggregating everything as a use case, was a very important step. Not only aggregating, but also characterising it with Value Proposition, ICT problems, Functions, Target, and Domains. A lot of this work and terms were initially elaborated in the Synergy Analysis performed by WP3, which also resulted in deliverable D3.9. Using that document, it was realised that it was much simpler having that terms characterising the use case, because it is easier to understand the use case dimension by simple terms/characteristics explaining the functionalities needed by the use cases.

For example, it is important to distinguish between control and planning where control is an immediate actuation/intervention on an operational level and planning processes where interventions are planned, in advance, based on predicted circumstances, constraints and resources.

Having everything well characterised, in top of that we created relation between everything in the use case. Doing that, all the information in the IoT-Catalogue is searchable and indexable. This also allow us to see the reusability between use cases. This could be in terms of reusable components, reusable ICT problems and so on.

Currently use cases have a lot of sections as we can see below. We would like to mention some of them:

- Stats about the use case and about individual validation
- Information about the places where the deployment was done
- Key performance indicators
- Team involved in the validation
- Characterization in terms of Values propositions, ICT Problems, Functions, Target and Domains
- Set of products used
- Media gallery, containing photos and videos

The following figures will show the use case page in the IoT-Catalogue, presenting the mentioned features.

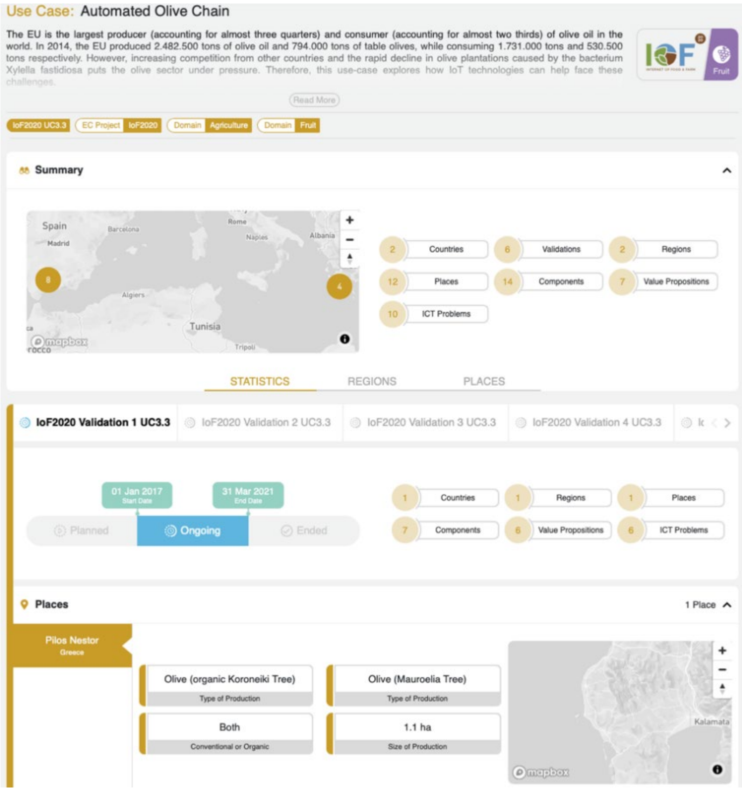

Figure 2: Use Case with stats and places

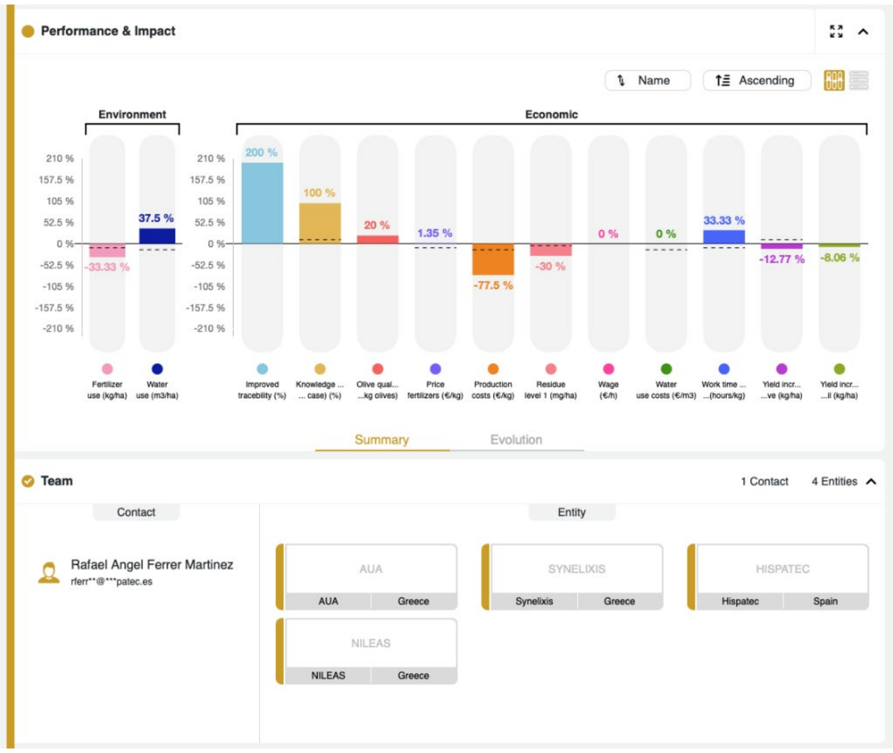

Figure 3: Use Case with KPIs and Teams

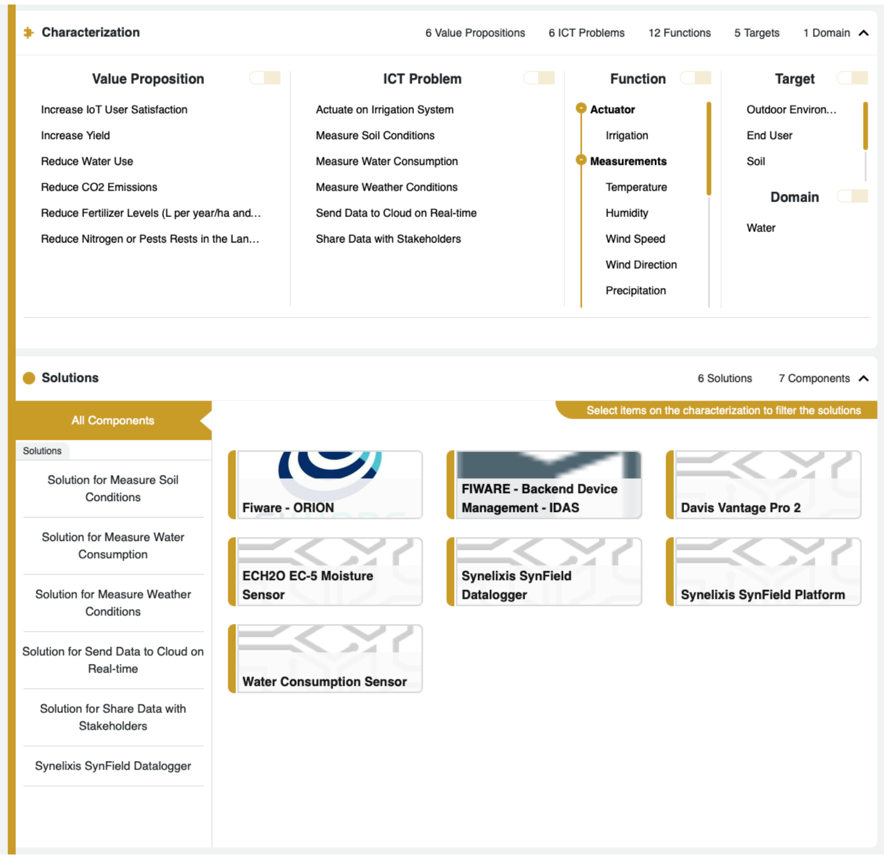

Figure 4: Use Case with characterisation and solutions

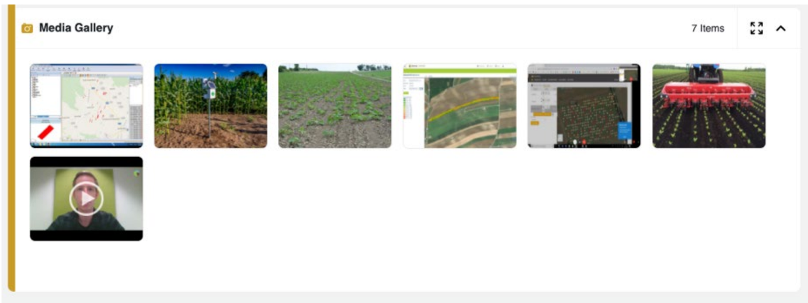

Figure 5: Use Case with Media Gallery

2.2.2.2 KPIs Visualiser

KPIs are a great way to present the impact that the use cases were realising in the scope of IoF2020. To simplify the user's life who want to check that info, a graphical tool was developed, which will give the opportunity to view and understand the evolution of KPIs. The KPIs information itself was elaborated by WP4 in cooperation with the use cases in WP2.

There are 4 sections available in our tool: Summary, Evolution, Comments and Notes. We will explain each individually.

In Figure 6 below we can see the Summary bar aspect. Two views are available: graph bar view and card view. The first one contains multiple graphic bars representing each KPI and a popup for each containing several information like KPI name, Description, KPI value from the last year available, target expected and a comment about that value. The second one contains a list of cards containing all the KPIs with a selector at the top allowing users to choose the year they want to observe and compare.

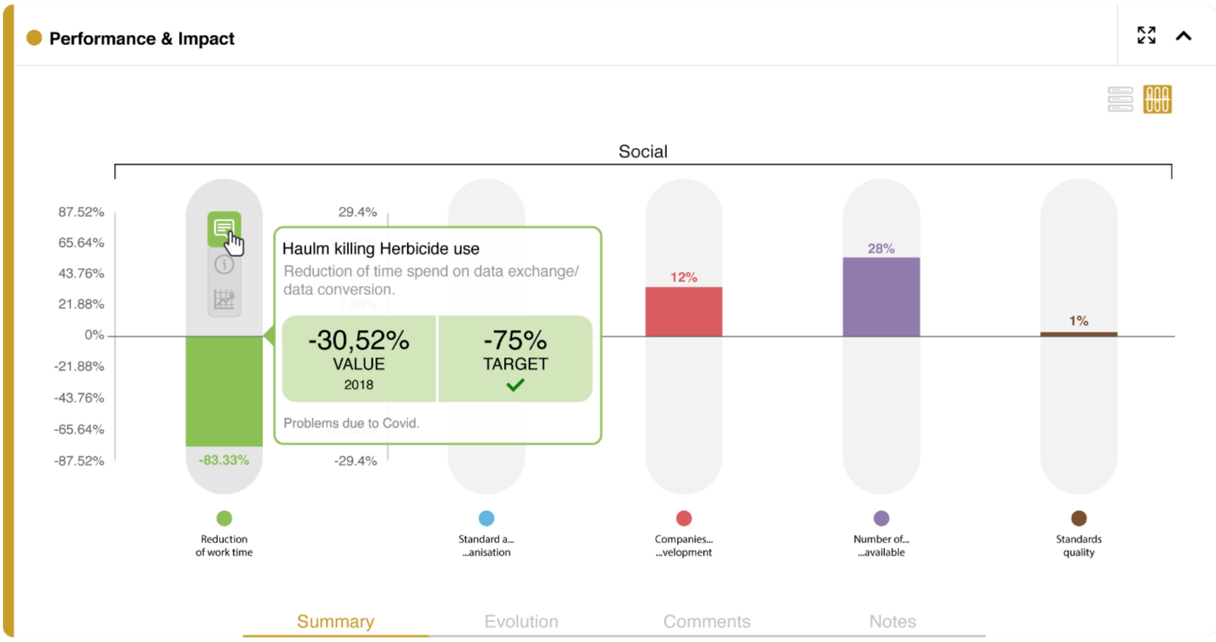

Figure 6: KPIs Summary bar graph view

As you can see in the last figure, in the selected graph we have custom icons with custom actions. For example, we can go directly to the evolution tab, with the KPI already chosen.

In this next set of figures, we are presenting our KPIs card view where user can choose the year they want to observe and compare the different years. Checking the different images, we can see how the highlight zone change taking in account the year chosen.

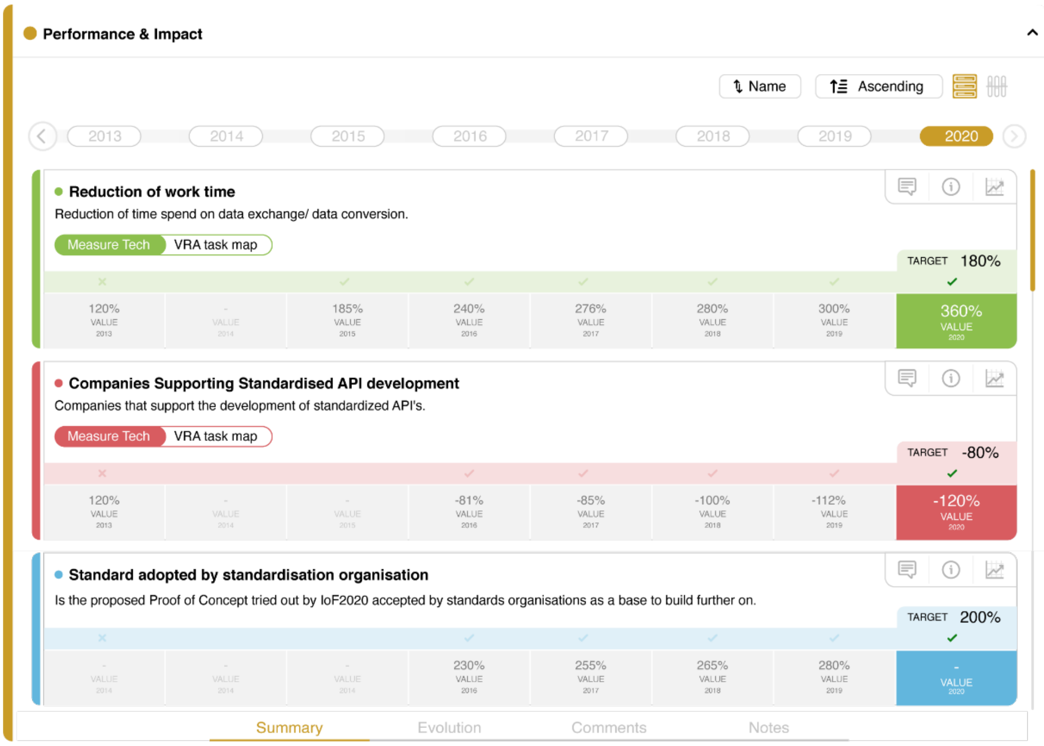

Figure 7: KPIs Summary bar card view 2020

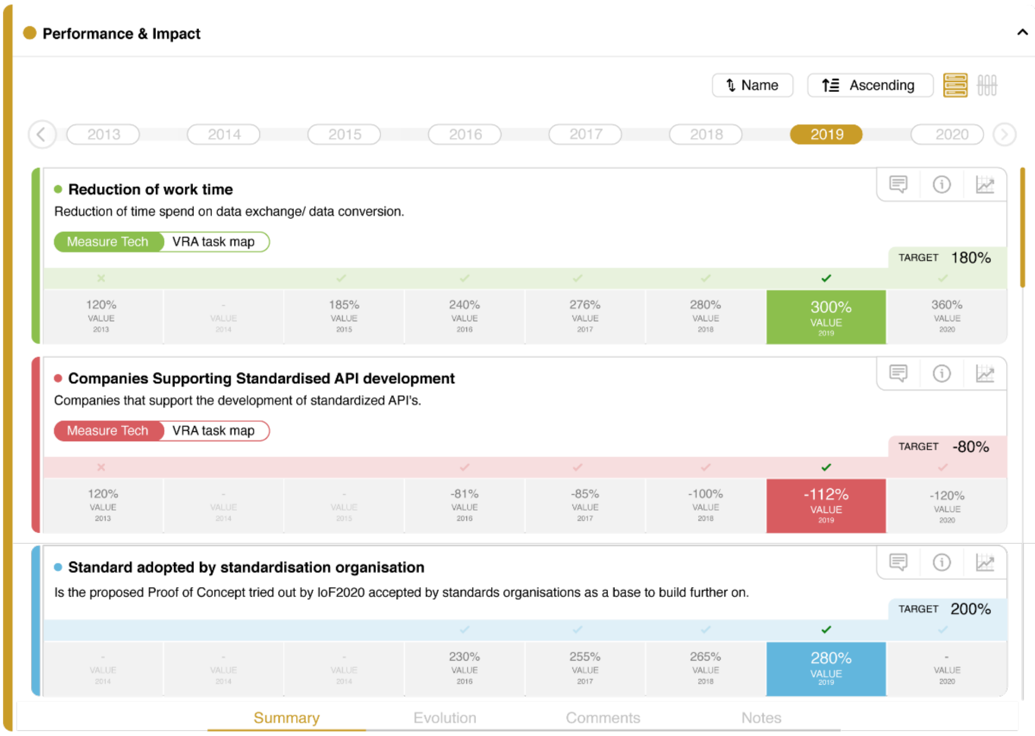

Figure 8: KPIs Summary bar card view 2019

As it is possible to see in the following Figure 9, we have also an Evolution bar where we can see how the KPI evolute through the years. This is an easy way to understand when some indicator changes their behaviour. Passing through the measures per year with the mouse, it will appear a similar popup as it exists in the Summary tab, but now user have the option to see information about all year, and the last one.

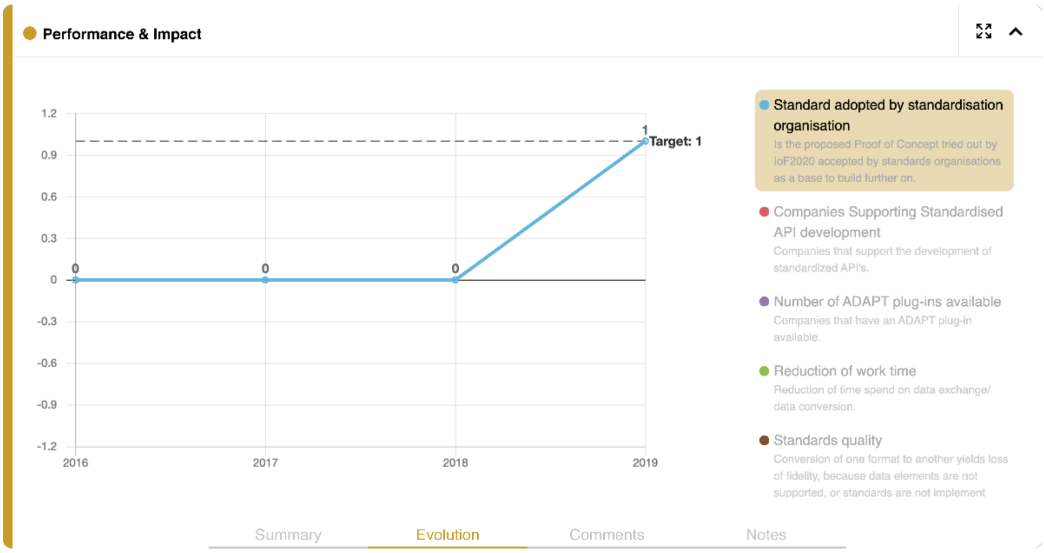

Figure 9: KPI evolution bar in the IoT catalogue.

We have another tab, called comments. In this tab we have two types of comments. It could be a comment about a specific measure or about the KPI in general.

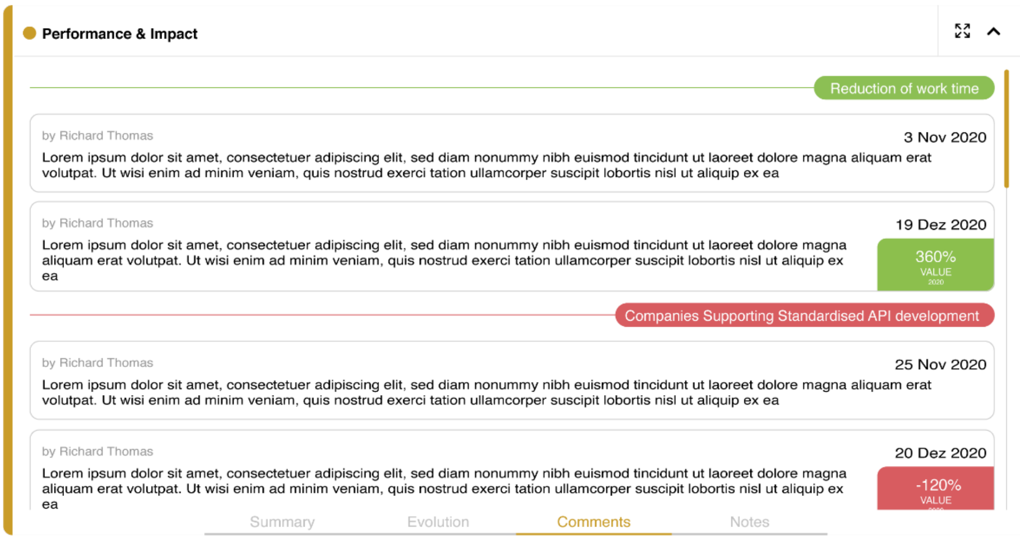

Figure 10: Display of comments with respect to use case performance and impact in the IoT-catalogue.

Another tab is available called notes. This is the place where generic notes about all the KPIs can be added. This zone can be used to insert, for example, disclaimers and explain how the values are calculated.

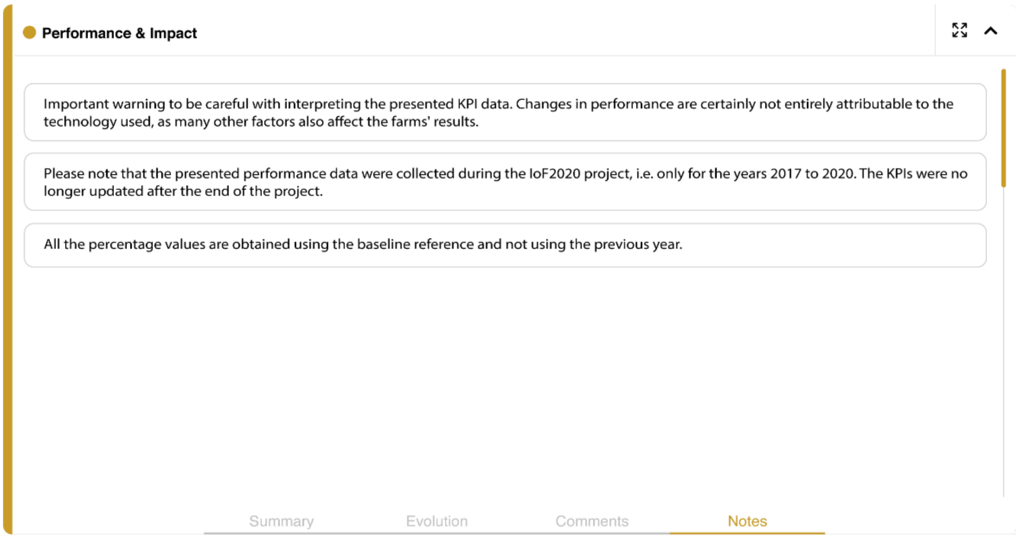

Figure 11: Adding notes to the performance and impact information in the IoT-catalogue.

We would like to highlight a feature which can be used in the IoT-Catalogue. It is based in an overlay function, which will appear above everything giving the highlight needed.

As we can see in Figure 12 below this will appear when we click on the "fullscreen icon" available in the top right corner of the Performance and Impact bar. At the left we have different items, which we already described before, Graphic view, Card view and evolution View. Then in the right side, user will be able to rearrange as they want according to the desired layout. This can be used, for example, to display two different KPIs showing their evolution and compare it. A good example for this, would be to compare Increase yield and reduce water, to see if the yield was good even with the reduction of water. Of course, the Yield depends on many factors, but it can help to take some conclusions.

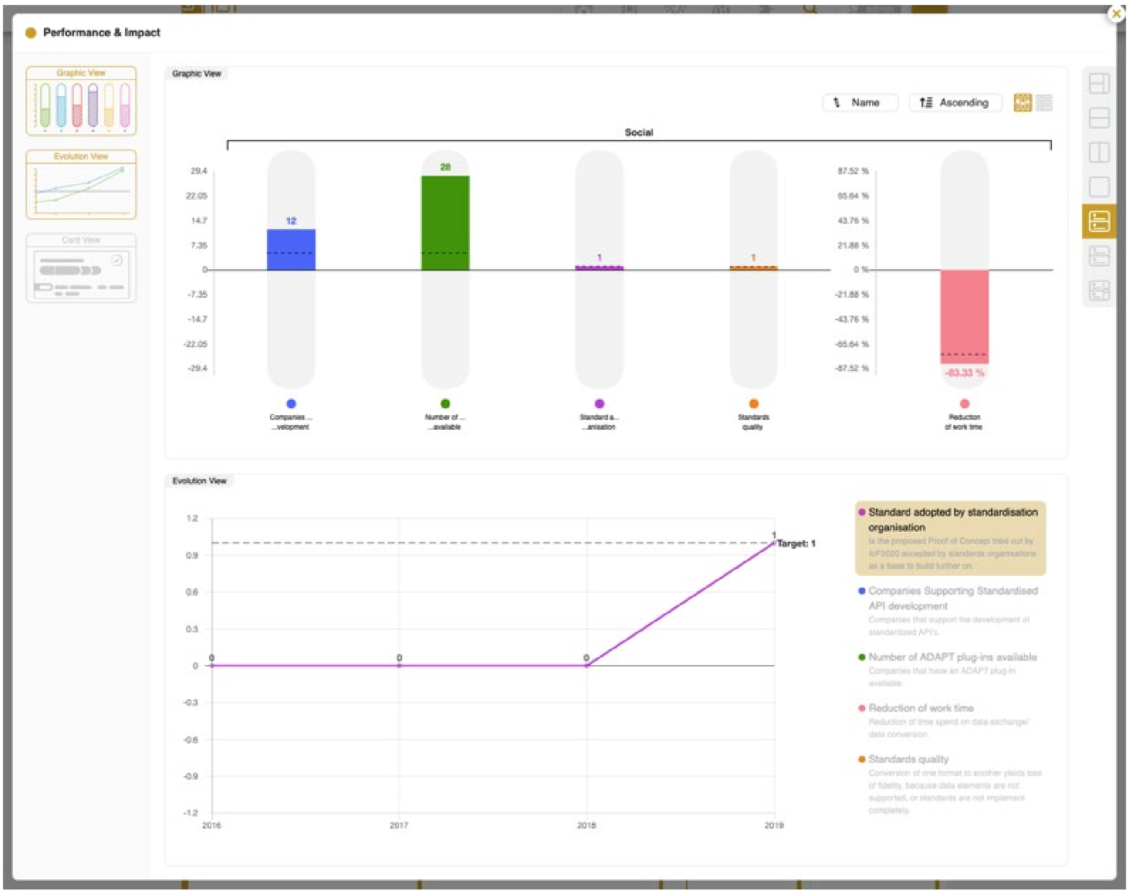

Figure 12: Overlay function in the IoT catalogue.

2.2.2.3 Bubble Diagram

The Bubble Diagram is an interactive tool within the IoT-Catalogue. This new feature helps to represent the connections within the project and shows how complex the connections can be. It also shows the reusability of the value propositions, ICT problems and components.

To access this tool, at the top of the IoF2020 Project page there is an "Interactive Project Navigator" card. By clicking on "Try it here" button (Figure 13) you will enter in the Full Screen view mode (Figure 14).

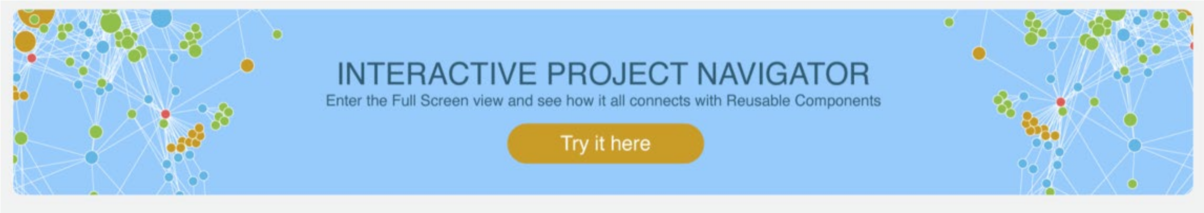

Figure 13: IoF2020 Interactive Project Navigator card

When entering in the "INTERACTIVE PROJECT NAVIGATOR" all categories are selected, allowing an IoF2020 overview. The lines reflect the connections, the project is linked to use cases, following the use cases to validations and the places to the validations. The validations are characterized through value propositions and ICT problems. To finalise the ICT problems are related with components. The dimension of the bubbles reflects their reusability.

On the left side are the Categories to be explored, which includes projects, use cases, validations, places, entities, value propositions, ICT problems and components.

That categories can be hidden as user want to have that relation or not. The diagram can become simpler being hidden or not.

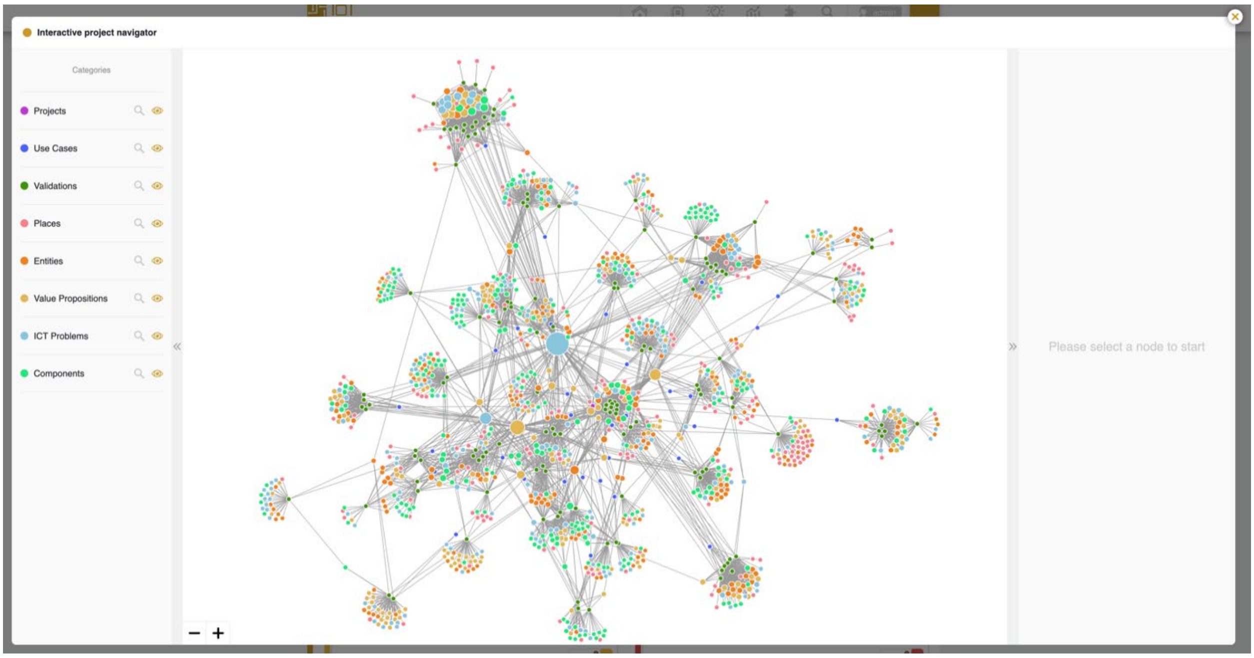

Figure 14: IoF2020 Interactive Project Navigation overview.

In Figure 15 the Categories selected are the Projects, Use Cases, Validations and Components. So, it means Places, Entities, Value propositions and ICT problems will not appear in the diagram. In the following example it was selected the IoF2020 Project, which led to appearing on the right side a brief description of the project, the list of use cases and components that are part of it and the respective statistics. It is also possible to see the reusability of the components, visible by the connections between different validations.

The information available at the right could change according to the category as it will be possible to check during this sub chapter.

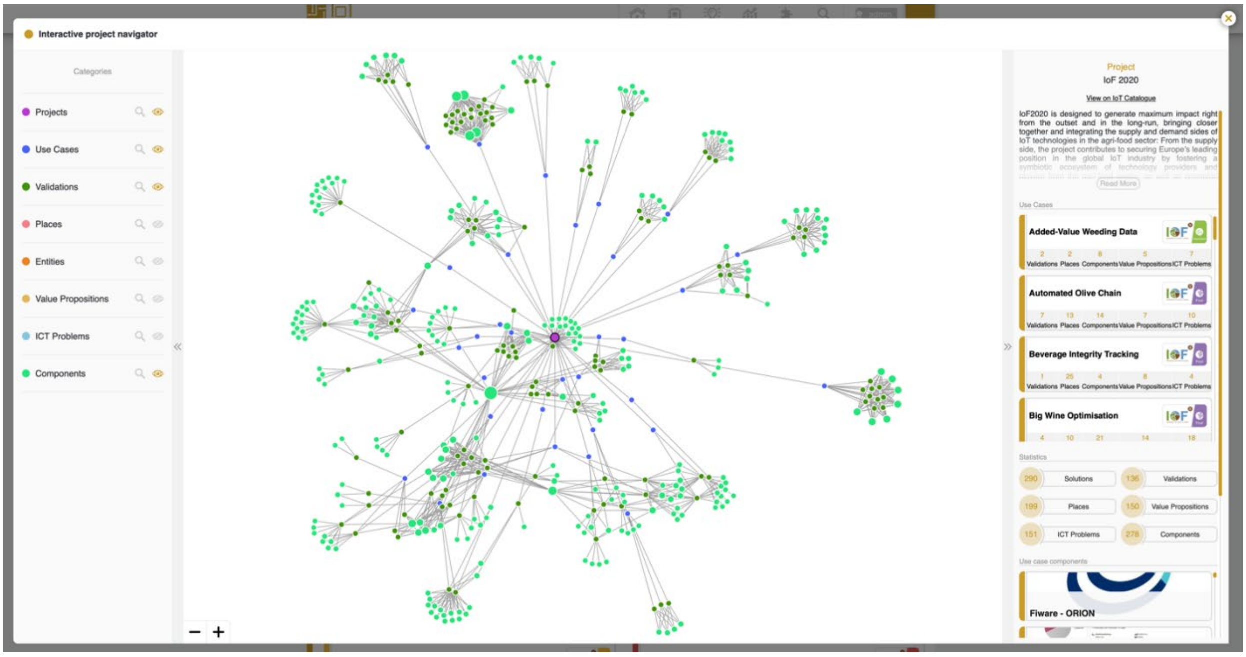

Figure 15: IoF2020 and components.

Figure 16 represents the reusability of the component PORPHYRIO Smart Farm Assistant. The information about the component (right side) includes a brief description of the component, the use cases where it is used and the ICT problems that it solves. The ICT Problem and Value proposition are hidden that's why the connection is being made to validation, because it's the category where Value proposition and ICT problems are included. If the component is also a component of a product, this information will appear along with the rest in the right side.

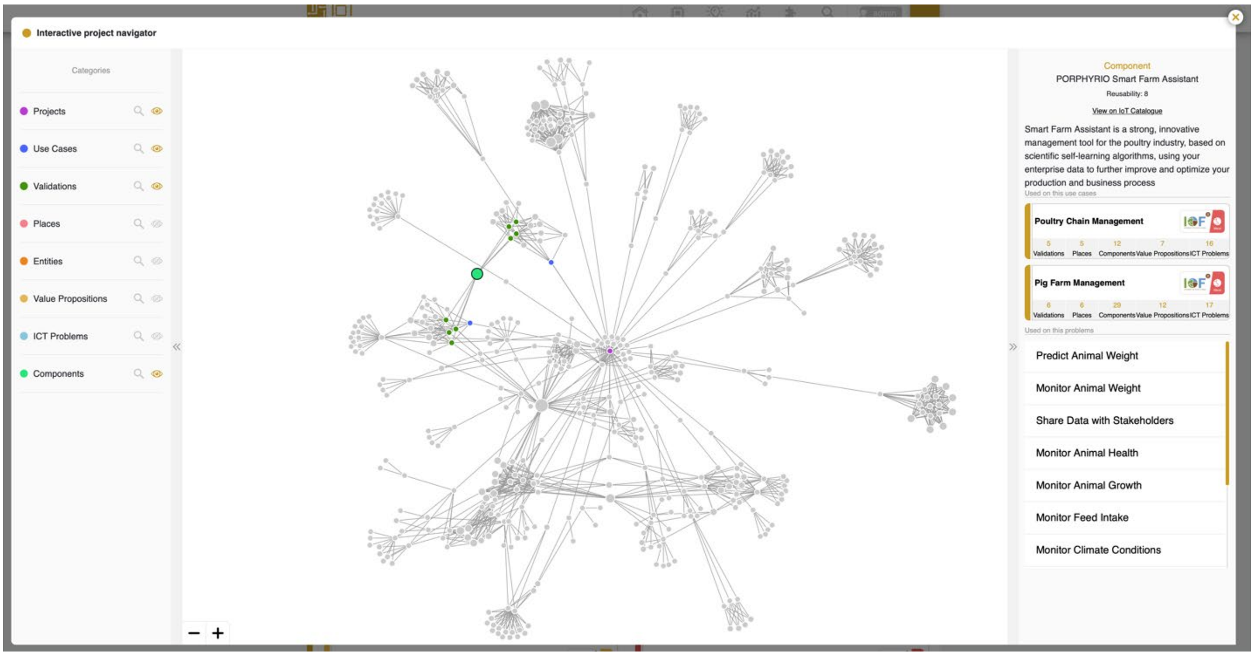

Figure 16: IoF2020 component PORPHYRIO Smart Farm Assistant.

2.2.3 IoF2020 Results @ IoT-Catalogue

In this section we will present the IoF2020 project page containing multiple information about the results of the project and the statistics results achieved:

- **IoF2020 Project Page:**
  It is the entry point for the IoF2020 Use Cases, showing an overview with some statistics about all use cases and reusable components.
- **Use Cases Statistics:**
  It shows the detailed statistics about the information available in the IoT-Catalogue.

2.2.3.1 IoF2020 Project page

In the IoT-Catalogue, all projects have their own Project page. On this page, all the information associated with the project is gathered and organized by sections.

The Project page about IoF2020[4] has an interactive project navigation (1) a short summary about the IoF2020 project in the bottom, the available trials (2), the use cases (3), statistics (4), a list with the most reused components (5), and IoF mode (6).

4 https://www.iot-catalogue.com/projects/5d95b18df02fdc9e36eaf447

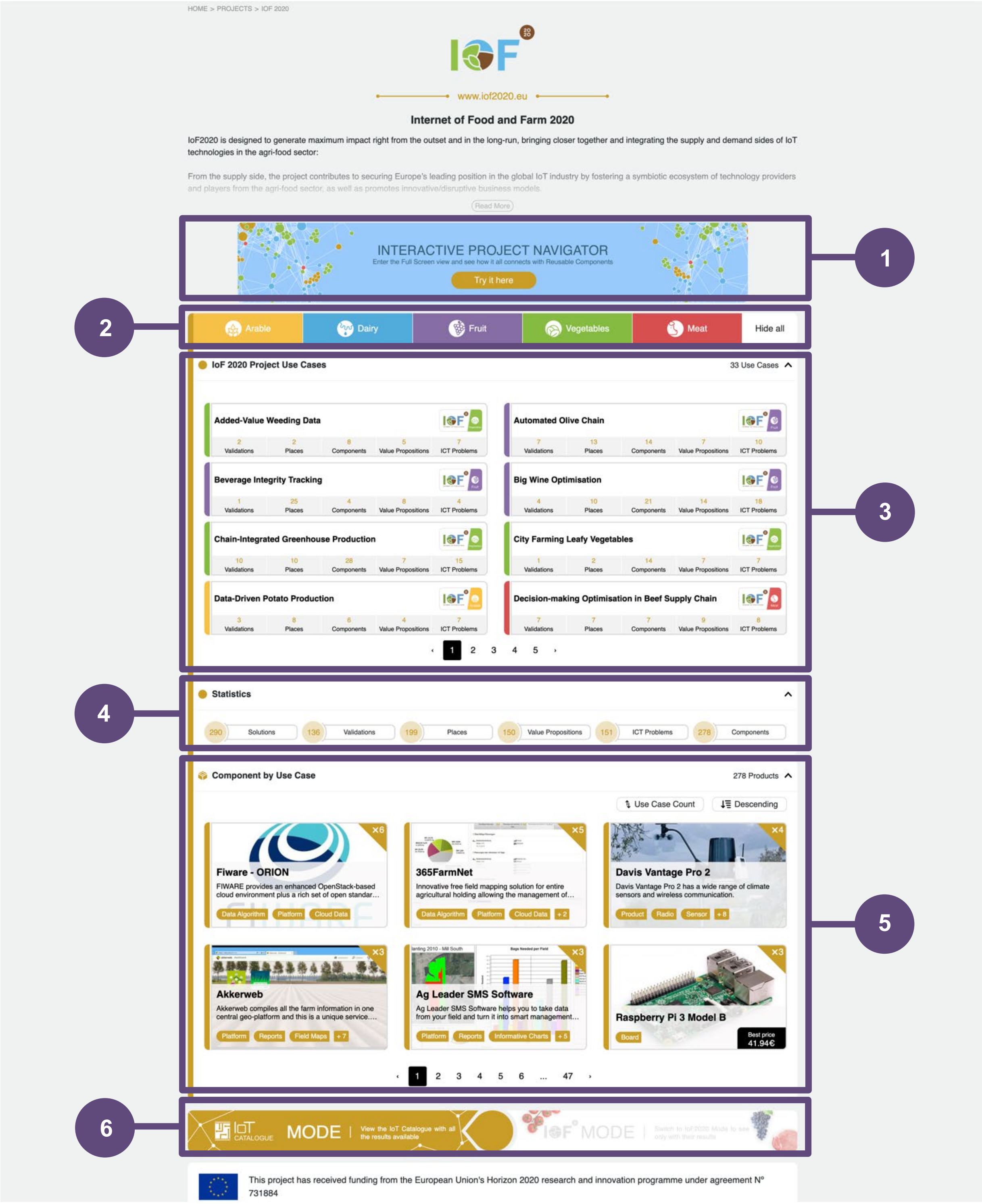

Figure 17: IoF2020 Landing page.

Each section on the project page shows the following:

1. The interactive project navigation allows to visualize the relations between use cases, validations, places, value propositions, ICT problems and components inside the project through a network. It also allows exploring the reusability of value propositions, ICT problems, and components, through the dimension of the bubbles
2. IoF2020 trial selector. It has five options: Arable, Dairy, Fruit, Vegetables and Meat. It also has a shortcut to view or hide all. Depending on the selection, the following options change to reflect the current selection

3. All the use cases according to the trials selected. It is possible to go directly to the use case clicking in the card
4. Statistics about solutions, validations, places, value propositions, ICT problems and products according to the chosen trials
5. A list with how many times the component was reused in use case inside the project
6. When IoF2020 mode is select, all information available in the IoT-Catalogue will be filtered taking in account the project, appearing only information related to the project.

2.2.3.2 Use Case Statistics

Statistics are the easiest way to show the type and number of information available in the IoT-Catalogue. Statistics allow users to get a quick overview about what is being worked, all the IoF2020 use cases. A total of 33 use cases, 19 Original and 14 Open Call use cases.

Table 1 shows how many validations, places, value propositions, ICT problems and products exist in all IoF2020 use cases[5].

Table 1: IoF2020 Statistics

	Validations	Places	Value Propositions	ICT Problems	Products
IoF2020 Use Cases	136	199	150	151	278

In Table 2, the type of information is the same, shown in the previous table, but the use cases are divided in the different trials, to get a different view. The results achieved in each trial.

Table 2: Statistics about each trial

Trials	Solutions	Validations	Places	Value Propositions	ICT Problems	Products
Arable	61	37	43	39	28	82
Dairy	41	19	27	22	31	41
Fruit	55	22	59	32	34	61
Vegetables	57	34	42	21	23	62
Meat	76	24	28	44	40	51

[5] Since the IoT-Catalogue is a web-based tool in constant evolution, the live numbers can be different.

Table 3 shows the statistics for the use case with the respective Trial. The results include the number of countries, validations, regions, places, products, value propositions and ICT problems.

Table 3: List of the actual use cases available in IoT-Catalogue

Trial	Name	Countries	Validations	Regions	Places	Products	Value Propositions	ICT Problems
Arable	1.1-Within-field Management Zoning	2	2	3	3	21	8	11
	1.2-Precision Crop Management	1	1	1	3	13	13	8
	1.3-Soya Protein Management	2	4	5	6	10	11	8
	1.4-Farm Machine Interoperability	4	5	7	7	25	19	18
	1.5-Potato Data Processing Exchange	3	4	4	4	11	7	5
	1.6-Data-Driven Potato Production	3	3	3	8	6	4	7
	1.7-Traceability For Food And Feed Logistics	2	5	2	5	6	9	6
	1.8-Solar-Powered Field Sensors	3	3	1	3	8	11	8
	1.9-Within-Field Management Zoning Baltics	2	10	9	10	7	8	3
Dairy	2.1-Grazing Cow Monitor	1	3	4	5	4	7	5
	2.2-Happy Cow	4	1	4	4	4	6	5
	2.3-Herdsman+	2	3	3	3	15	3	5
	2.4-Remote Milk Quality	1	1	1	1	3	5	5
	2.5-Early Lameness Detection through Machine Learning	3	5	3	5	7	9	8
	2.6-Precision Mineral Supplementation	4	3	6	6	5	2	17
	2.7-Multi-sensor Cow Monitoring	3	3	1	3	3	9	4
Fruit	3.1-Fresh Table Grapes Chain	2	6	5	7	18	7	13
	3.2-Big Wine Optimisation	4	4	7	10	21	14	18
	3.3-Automated Olive Chain	2	7	3	13	14	7	10
	3.4-Intelligent Fruit Logistics	7	>7000	30	>7000	5	3	11
	3.5-Smart Orchard Spray Application	3	3	3	3	5	9	5
	3.6-Beverage Integrity Tracking	10	1	22	25	4	8	4
Vegetables	4.1-City Farming Leafy Vegetables	1	1	2	2	14	7	7
	4.2-Chain-Integrated Greenhouse Production	2	10	4	10	28	7	15
	4.3-Added-Value Weeding Data	2	2	2	2	8	5	7
	4.4-Enhanced Quality Certification System	1	2	6	9	6	7	8

Trial	Name	Countries	Validations	Regions	Places	Products	Value Propositions	ICT Problems
	4.5-Digital Ecosystem Utilization (CYSLOP)	3	19	15	19	6	9	10
Meat	5.1-Pig Farm Management	2	6	6	6	29	12	17
	5.2-Poultry Chain Management	1	5	4	5	12	7	16
	5.3-Meat Transparency and Traceability	1	2	3	3	1	17	8
	5.4-Decision-making Optimisation in Beef Supply Chain	6	7	7	7	7	9	8
	5.5-Feed Supply Chain Management	3	3	5	6	2	8	5
	5.6-Interoperable Pig Health Tracking	1	1	1	1	2	15	6

As it was mentioned before a new feature was added during the IoF2020 project, the support for showing KPIs in IoT-Catalogue was developed and improved continuously, as described in 2.2.2.2.. In Table 4 is shown the total of KPIs and readings. Readings correspond to the number times that KPI is measured.

Table 4: IoF2020 KPIs

	KPIs	Readings
IoF2020 Use Cases	256	2510

2.2.3.3 Reusability

A single component can be used to solve problems among several use cases. For example, the weather data obtained from a meteorological station (Davis Vantage Pro) can be useful for a use case dedicated to arable and a use case dedicated to fruit, knowing that a component is being reused is useful to find other entities working or developing projects with needs similar to yours, allowing the cooperation between several entities with similar interests, this information which is often hard to obtain is modelled and provided by IoT Catalogue.

In IoF2020, there are 33 use cases characterized by five different trials; each use case contains several components used to solve the problem proposed, and in some cases a component is used among different use cases and trials of IoF2020. Figure 18 shows the number of reusable components according to the number of use cases. For example, we can see we have 27 components which are used in 2 use cases at the same time (but could be two different use case for each component).

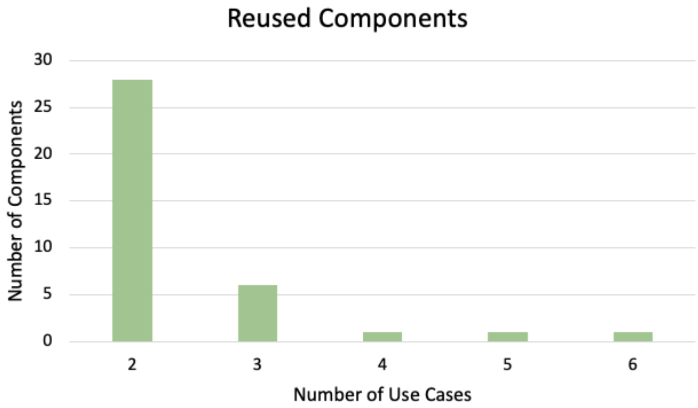

Figure 18: Number of Components reused on use cases.

A component can be reused among different use cases from the same trial or from different trials. For example, a ground sensor (ECH2O 5TE Ground Sensor) is used on Automated Olive Chain and on Fresh Table Grapes Chain, which are two use cases from the same trial (Fruit). This indicates that this component has a specific purpose. However, a platform used for big data analysis (FIWARE - BigData Analysis - Cosmos) is used on Chain Integrated Greenhouse production and Precision Crop Management, two use cases from different trials (Vegetables and Arable). In this case, this component has a more generic purpose. The following Table 5 gives information about which components belong to different use cases from the same and different trials.

Table 5: Reused components in the same and in different trials.

Number of Use Cases	Same Trial	Different Trials
2	21	7
3	0	6
4	0	1
5	0	1
6	0	1

2.2.4 IoT-Catalogue beyond IoF2020

Since the IoF2020 project start that the idea of the IoT-Catalogue was to support reusability, not only during the project timeframe (e.g., in the open calls) but especially after the project end to promote further the adoption and reuse of IoF2020 innovations. On outstanding example is the use of the IoT-Catalogue as an enabling technology for Digital Innovation Hubs (DIHs), especially in the agri-food domain.

The IoT-Catalogue is a key enabling technology for the business of Digital Innovation Hubs (DIHs) – it enables DIHs to explore and share digital innovations (including impact) in their operating fields; it enables DIHs to aid their innovators in picking & choosing digital technologies; it is a platform where DIHs can follow trends on digital technologies in their (and other) application areas; etc.

In this context, the IoT-Catalogue is to take a key role in the H2020 SmartAgriHubs project focused on Digital Innovation Hubs for the agri-food sector. The IoT-Catalogue is part of the Flagship Innovation Experiment #22 (FIE#22) – the "Iberian Irrigation Portal" – for the creation of a Competences' Catalogue for Irrigated Agriculture Digitisation to enable the identification of experts and technologies for Irrigated Agriculture Digitisation in the Iberian region – the 'IoT Catalogue' extended to the Smart Irrigated Agriculture domain.

And then, out of FIE#22, the IoT-Catalogue will be able to further support digital innovation in other countries and regions of Europe. Dr. George Beers, project coordination of both IoF2020 and SmartAgriHubs projects – has said in the IoF2020 final event that "*we are pushing the IoT-Catalogue to SmartAgriHubs, and the* *idea is to make the tool available for Digital Innovation Hubs that are operating in the regions, so that the work so far – as it is included in the IoT-Catalogue is what we do at the European level – we make it accessible in the regions. We have nice examples of irrigation solutions in Portugal, but how to make it accessible in Bulgaria? Well, here we have the tool that we can ask the people to look in the IoT-Catalogue and see what they can learn from that, when they are doing a proposal for irrigation innovation in Bulgaria. That's the idea that we want to promote, to push the use of the IoT-Catalogue by the Digital Innovation Hubs that are in the field, that are local level, and the Digital Innovation Hubs will use, it to facilitate, to help, the Innovation experiments in the field.*"

Furthermore, Dr. George Beers said that "*one of the frustration that the IoT-Catalogue tackles is that we see at the moment when we're traveling around throughout Europe, is that there are a lot of projects – Digital Innovation projects – that are all doing the same: the developers are all measuring the moisture of the soil, the temperature of the soil, the wind velocity, the movements of the cattle, i.e. they're all doing the same; and every developer thinks (s)he is the unique one and has made an invention that is absolutely new, and then we see that there are already existing examples elsewhere in Europe, and we hope to get an attitude in digital innovation where people first have a look on what's there, use it and build upon it, make it better, make it applicable for more types of applications, more advanced types of applications, and then give it back to the IoT-Catalogue, so it will be the continuous improvement of the Catalogue – that's what we want to stimulate and to promote in the SmartAgriHubs project.*"

Still in the context of Digital Innovation Hubs, the IoT-Catalogue will be acting as a supporting technology for DIHs part of the Smart Connectivity Digital Innovation Hub Network (SCoDIHNet, https://aioti.eu/scodihnet/). The SCoDIHNet initiative is a network of DIH, with the objective to support DIHs on providing support to the industry in several verticals to develop digital services which need smart connectivity technologies. The SCoDIHNet initiative is co-supported by the Alliance for the Internet of Things Innovation (AIOTI, www.aioti.eu) and the 5GIA (www.5g-ia.eu) on supporting Digital Innovation Hubs that are providing digital innovation services on 5G, IoT, Cybersecurity and Artificial Intelligence.

A key focus of the SCoDIHNet initiative is the replicability of results from EU Large Scale Pilot Projects. The aim is to establish mechanisms for Digital Innovation Hubs to take advantage of the EU Large Scale Projects results to replicate use cases and solutions at the local level. To this, it is required first to collect the results from the EU Large Scale Pilot Projects – validation cases, enablers, solutions, technologies, stakeholders, access modalities, platforms, contacts, etc. Then, it is required to make these available in an easy way for SCoDIHNet DIHs to identify and study them (e.g., check if they are compatible with the requirements of their local customers) and be able to contact the related persons to see how to replicate and/or reuse them. The IoT-Catalogue is targeted to hold this information and support this process, particularly outreaching the results of the IoF2020 Large Scale Pilot project for SCoDIHNet DIHs in agri-food.

2.2.5 IoT-Catalogue Business Models

A set of digital business models have been identified to monetise the IoT-Catalogue: (1) e-Marketplace for digital technologies; (2) Assets' Digital portfolio tool; (3) Data monetisation; and (4) Online Advertisement.

1. **e-Marketplace for digital technologies**:
   Electronic or online marketplaces (e-marketplaces) are online market platforms that connect sellers with buyers. The IoT-Catalogue aims to be the one-stop shop for digital innovations by connecting technology providers to end-users (and vice-versa) of digital technologies. The intention is to enable technology providers to showcase and advertise their products via the IoT-Catalogue – the added-value is that technologies can also be presented in the context of application (i.e., in validation use-cases). For one side, technology providers would be asked to pay a fee for using the platform and/or else Unparallel would get paid per referral, i.e., when a customer goes to the technology provider store/website and buys the technology from the seller. From another side, end-users (or their representatives) would be able to launch challenges (as new use-cases, unmet value propositions or ICT problems) that technology providers might be able to respond to – UNPARALLEL would charge a fee to users willing to use advanced IoT-Catalogue features such as Challenges.
2. **Assets' digital portfolio tool**:
   This business model builds on the assumption that IoT-Catalogue users will have their digital assets – case studies, technologies, projects, etc. - represented in the platform. It is then only natural that users require to have a seamless integration of their digital assets within their own websites to list up-to-date and coherent information on their assets. Here, the IoT-Catalogue will act as the tool to hold and manage the digital portfolio of digital assets related to users and provide the means of an easy and

effective integration of the IoT-Catalogue into third-party systems. UNPARALLEL would get paid for providing such a service to the IoT-Catalogue users by charging a fee to use the system in the above-mentioned way.

3. **Data monetization**:
   Data monetization explores the opportunity of providing rich digital market data and insights to market research and advisory firms. Firms like Gartner and other need detailed data from the digital technologies market of several application domains to assert maturity and adoption of technologies and applications, market trends, etc. Anonymized statistical data out of the IoT-Catalogue can be a source of valuable information for the busines of market research and advisory firms. UNPARALLEL would charge a fee for providing such data to interested parties by providing specific viewpoints to the data in the IoT-Catalogue on a subscription basis on charging per report.
4. **Online Advertisement**:
   Targeted online advertisement is a monetization model where advertisers bid to display brief advertisements, services, products, etc. to web users. Unparallel will explore the inclusion of online adds – using online advertising platform such as Google Ads and others – inside the IoT-Catalogue. For instance, when displaying cards for technologies or use-cases to include cards with advertisements of third parties. The business model here will be to explore web traffic volumes in the IoT-Catalogue to generate income particularly on displaying advertising messages and/or referring visitors to the advertisers' websites.

2.3 Smart Data Models

This part of the activities includes the 'translation' from the use cases into data models that can be used in the agri-food sector for the use cases and beyond, and eventually, after the end of the project's end. These activities have included the generalization of the collected data models for making usable beyond the use case. Examples of these activities are:

- Extension from a limited number of elements in a payload (i.e., three silos) to a generic number of them.
- Generalization of some elements to more generic terms (i.e., what applies for pig can mostly apply to the element Animal) and therefore could be used in different situations.
- Adaptation of existing data models for the use (sometimes it requires the identification of terms, i.e. A compartment is equivalent to zone as a part of a farm building). Depending on the use case one term or the other is used, although the data model could be the same.

2.3.1 Lessons learnt about Data Model Standardisation

The following lessons were learnt when working on the data models, especially reflecting on the impact they could have on medium to long-term standardisation:

1. Knowledge on the subject, eventually in the IT technology, does not mean to have expertise on standardisation activities. Support by the project was a must in order to finish the definition of the data models.
2. Data Models standardisation is appreciated as long it reduces time for implementation and it does not impose limits to the management of the data required for the business. However, individual use cases neither have the resources (time) nor the knowledge to accomplish this task. It led to the development of wizards to help on data model creation. (See services to users and contributors)
3. Flexibility and simplicity is a must for adoption. Once a data model was standardised it does not mean that the potential users really understand how to use it and therefore examples are a must. A new service for this purpose was developed. (See services to users and contributors)

2.3.2 Accomplished Data Models in the Agri-Food Business Domain

The list of data models directly updated or created during IoF2020 activities include this list. The links point to the official repository in the smart data models initiative:

- AgriApp.
  This entity contains a harmonised description of a generic app made for the Agrifood domain.
- AgriCrop.
  This entity contains a harmonised description of a generic crop.
- AgriFarm.
  This entity contains a harmonised description of a generic farm made up of buildings and parcels.
- AgriGreenhouse.
  This entity contains a harmonised description of the conditions recorded within a generic greenhouse, a type of AgriParcel.
- AgriParcel.
  This entity contains a harmonised description of a generic parcel of land.
- AgriParcelOperation.
  This entity contains a harmonised description of a generic operation performed on a parcel of land.
- AgriParcelRecord.
  This entity contains a harmonised description of the conditions recorded on a parcel of land.
- AgriPest.
  This entity contains a harmonised description of an agricultural pest.
- AgriProductType.
  This entity contains a harmonised description of a generic agricultural product type. This entity is primarily associated with the agricultural vertical and related IoT applications. The AgriProductType includes a hierarchical structure that allows product types to be grouped in a flexible way.

- AgriSoil.
  This entity contains a harmonised description of a generic soil.
- Animal.
  An observation of animal conditions at a certain place and time. This data model has been developed for the IoF2020 UC ShareBeef by UCO and SensoWave.
- Compartment.
  Artificial area in a building or department that is measured by certain sensors. A compartment is not necessarily a physical separator. It can be a department or a grouping of several pens within a department that are being measured by the same sensor.
- Pen.
  Fenced area in a building or department or outside housing a group of animals. Animals in a pen can move and interact freely. Pens are often not completely separated from each other (half walls, iron bars, fences,…), making it possible that animals from neighbouring pens can see/touch

Other identified data models are also being identified and their gathered elements passed to the Smart Data Models initiative to be adopted as official data models after the project ends.

- Building.
  This data model is already available, and it is used as the unique identifier of a building where the Compartments are located in.
- Carcass.
  Animal body after being primarily slaughtered and processed.
- Crate.
  Individual housing area of breeding sows that may be used in some stages of the reproduction cycle.
- Consumption.
  This data model would compile those properties related to the feeding consumption of the animals either water or food.
- HealthTreatment.
  A health treatment of the animal or group of animals at the farm, dose and used product are registered
- SlaughterAnimal.
  Data model for traceability purposes including additional information about the animal (beyond its relation with the animal, slaughter house, etc).
- SlaughterHouse.
  The place a animal is slaughtered and processed into meat

2.3.3 Other related data models

There are other data models related to the use cases.

- **Devices:**
  - MotionDeviceSystem. MotionDeviceSystemType provides a representation of a motion device system as an entry point to the OPC UA device set. This instance organises the information model of a complete robotics system using instances of the described ObjectTypes. A motion device system may consist of multiple motion devices, controllers and safety systems.
  - Device. An apparatus (hardware + software + firmware) intended to accomplish a particular task (sensing the environment, actuating, etc.).
  - DeviceModel. This entity captures the static properties of a Device.

- **Weather:**
  - WeatherAlert. A weather alert generated by a user or device in a given location
  - WeatherForecast. A harmonised description of a Weather Forecast
  - WeatherObserved. An observation of weather conditions at a certain place and time.

- **Environment:**
  - [AirQualityObserved](). An observation of air quality conditions at a certain place and time. [NoiseLevelObserved](). An observation of those acoustic parameters that estimate noise pressure levels at a certain place and time.
  - [WaterObserved](). Water observation data model is intended to represent the parameters of flow, level and volume of water observed, as well as the swell information, over a fixed or variable area. This observation also includes the masses of floating objects in this area. The data collected is provided by Sensors, Cameras, Water stations positioned at specific or sensitive locations for rivers, streams, torrent, lakes, seas, etc.

2.3.4 Services Developed for Users and Contributors

As a consequence of the interaction with the different use cases some tools have been developed to help to standardise the data models used across different use cases for those people without specific training in standardisation.

2.3.4.1 Service for searching suitable data models, attributes (properties), or definitions

The service for searching suitable data models, attributes (properties), or definitions allows the search by any element of a data model, including:

- Property name
- Description: Written definition of the attribute
- Data Model: Data model where this property is present (it can be repeated)
- Type: Basic type (string, number, array, boolean, object
- Format: for strings it is possible to be a date time, uri, etc
- Repository Name: subject (group of data models) the data model belongs to
- NGSI type: It can be property, Relationship or geo property.
- Model: Reference model for the property (i.e. width is modelled in schema.org/width)
- Units: Preferred units for those elements providing measurements.

The following Figure 19 presents the search form as user interface of the service.

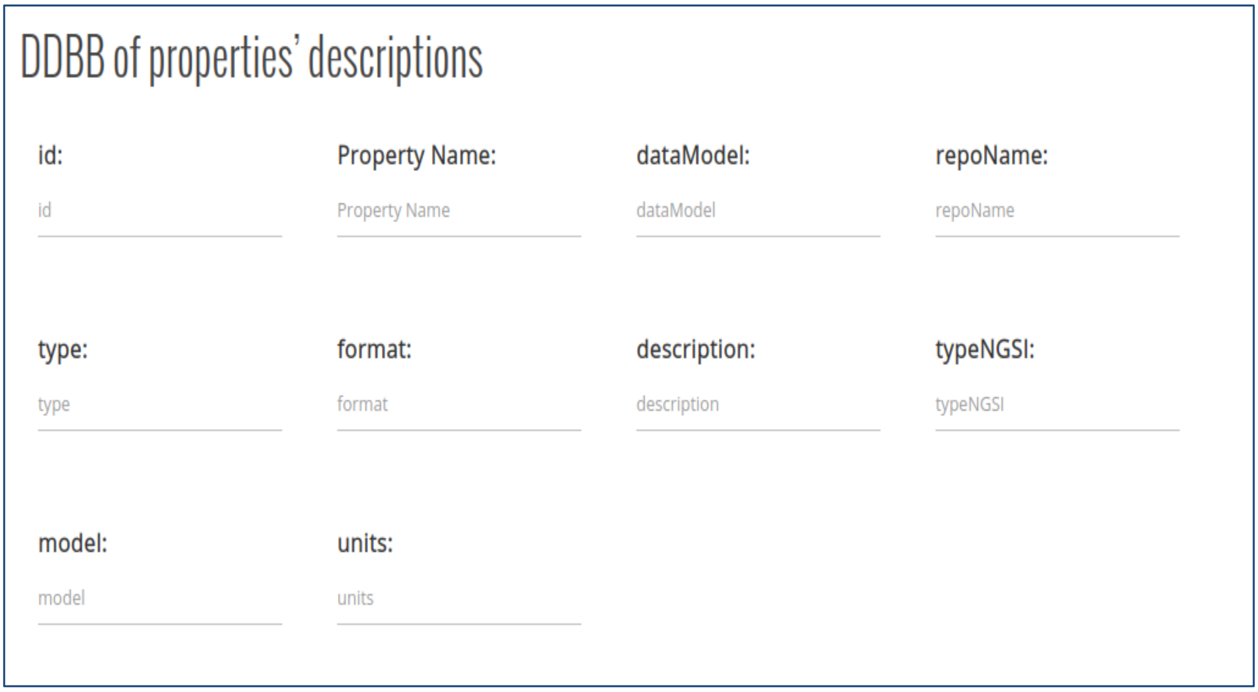

Figure 19: Search form. > 12.000 properties searchable.

2.3.4.2 Creation of a data model out a google spreadsheet

The creation of a data model out a google spreadsheet allows the creation of a basic data model without much knowledge of json schema or standardisation. The spreadsheet is presented in Figure 20.

	A	B	C	D	E
1					
2	Subject	dataModel.WasteManagement	This is the Subject where this data model should be included. Find in the link here the list of acti		
3	DataModel	WmgmtBin	Name of the entity of the data model. One word starting with capital letter		
4	Title	hola	Title of the json schema describing the entity		
5	Global description	Data model for solid waste management bins	Text description of the entity (to be included into the json schema describing the data model)		
6		This spreadsheet is freely modified on blue zones. If you want to keep your data you have to make a copy			
7	**PROPERTIES**				
8	property name	ngsi type	type	Other restrictions (not	Description
9	prop1	Property	string		Color of the bin. Could be used for indicating the type of The color coding should follow the conventions applicabl geographical area the bins are located.
10	prop3	Property	date-time		
11	prop4	Geoproperty			
12	prop6	Property	number	{"minimum":0}	Iñkñl
13	property5	Property	boolean		Test
14	property6	Relationship	array		
15	property7	Property	object		
16	property8	Property	date-time		
17	property9	Property	uri		
18		Property			
19	property11	Property			
20	property12	Property			

Figure 20: Google Spreadsheet based solution to create an NGSI compatible data model.

By making a copy of the spreadsheet and filling just the name of the property, its type of data, its type of NGSI element and the description of the property it can be submitted through a form and the result is a drafted data model, documented as seen in this example.

It captures only the simplest versions of a data model, but for a fresh start is lowering some barriers.

The code for this conversion is being made publicly available.

2.3.4.3 Creation of payloads compliant with data models

The last service is related with the use of existing data models and the generation of payloads to be tested in the IT systems of the use cases. So once a data model is chosen there is an option in this link, which is available in the main menu of the site smartdatamodels.org.

There is a form where once included the link to the raw version of a data model, it generates random payloads compliant with NGSI standard (LD version). Like in this example.

2.4 Access Control and Service Monetization Component

2.4.1 Motivation

Providers of IoT-based solutions can potentially extend their business models towards third parties by offering their individual services also to a larger stakeholder audience. Aiming to further monetize services, they could provide own services, while also taking the advantage of consuming services that are offered by third parties. To facilitate offering/using software services, the IoF2020 partner organisations ATB and CORIZON were joining forces to develop "CoatRack" as potential MIM, an open software component that provides a trusted framework for access control and service monetization.

As presented in the following schematic Figure 21, CoatRack facilitates the service provision and access control as well as service monetization. The typical users of CoatRack are software developers who are offering and/or using software services as basis to offer additional applications for specific end-users.

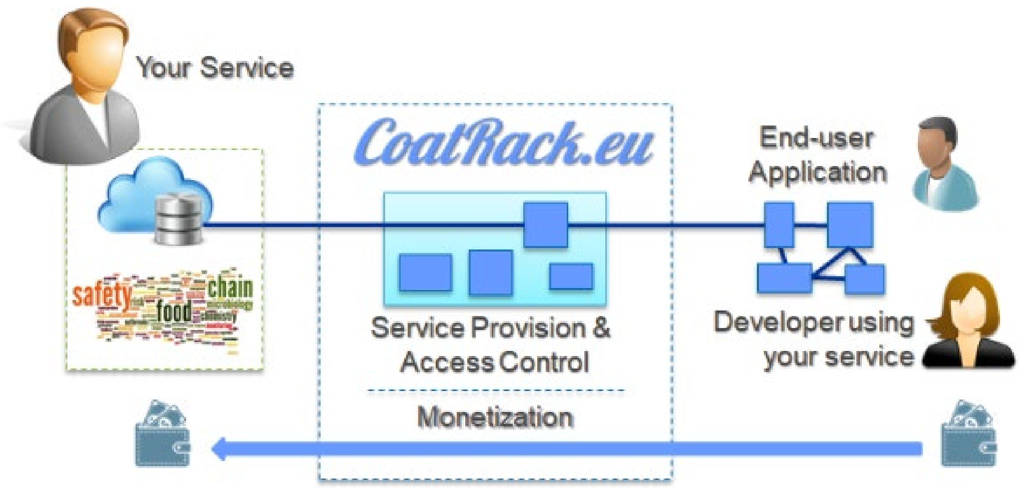

Figure 21: Interaction of service providers and service users, facilitated by CoatRack.

There are different application scenarios that can be supported by CoatRack, for example:

- **Monetize services**
  with the possibility to offer and consume software services in N-to-M relationships of service providers and consumers.
- **Visualising statistics**
  about the access to services, to enable an understanding of users' interest.
- **Share ICT (infrastructure/ overhead) costs**
  inside an organisation, which can be applied for internal as well as external services.

The basis for the monetization of available services as well as access control is the provision of individual access keys to customers and/or partner organisations. According to the selected terms for payment, CoatRack will track service consumption and facilitate the monetization. CoatRack helps to define the payment model, to reflect the selected business model for monetizing a single software service or a solution package. Therefore, the current implementation enables flat-rate and pay-per-access models.

2.4.2 Technical Overview

From the point of view of a developer, who would like to offer backend services to other parties, some general work is usually required in addition to developing the service API itself, e.g.:

- Implementing mechanisms for authentication/authorization.
- Providing access credentials to the users.
- Monitoring calls to the API.
- Generating statistics.

CoatRack facilitates these general tasks, so that developers can focus on their core competencies – developing software services and user interfaces – and reduce efforts for the management of the backend-to-backend communication.

Looking from a technical perspective, CoatRack can be considered as a framework to manage backend-to-backend communication via REST APIs, comprising:

- Distributed, lightweight API gateways.
- A centralized web application to generate and manage those gateways.

The following Figure 22 shows the typical CoatRack architecture. The central CoatRack web application is depicted on the right and one CoatRack service gateway is depicted on the left. The calls from the client to the service API are routed and logged by the custom CoatRack gateway, which can be installed in the service provider's local network. The communication payload itself is exchanged directly between the provider and consumer of the service and not routed via CoatRack. This avoids communication bottlenecks as well as assures that CoatRack will not track service content information that is of a confidential nature. Configuration and statistics are accessible via the CoatRack web application.

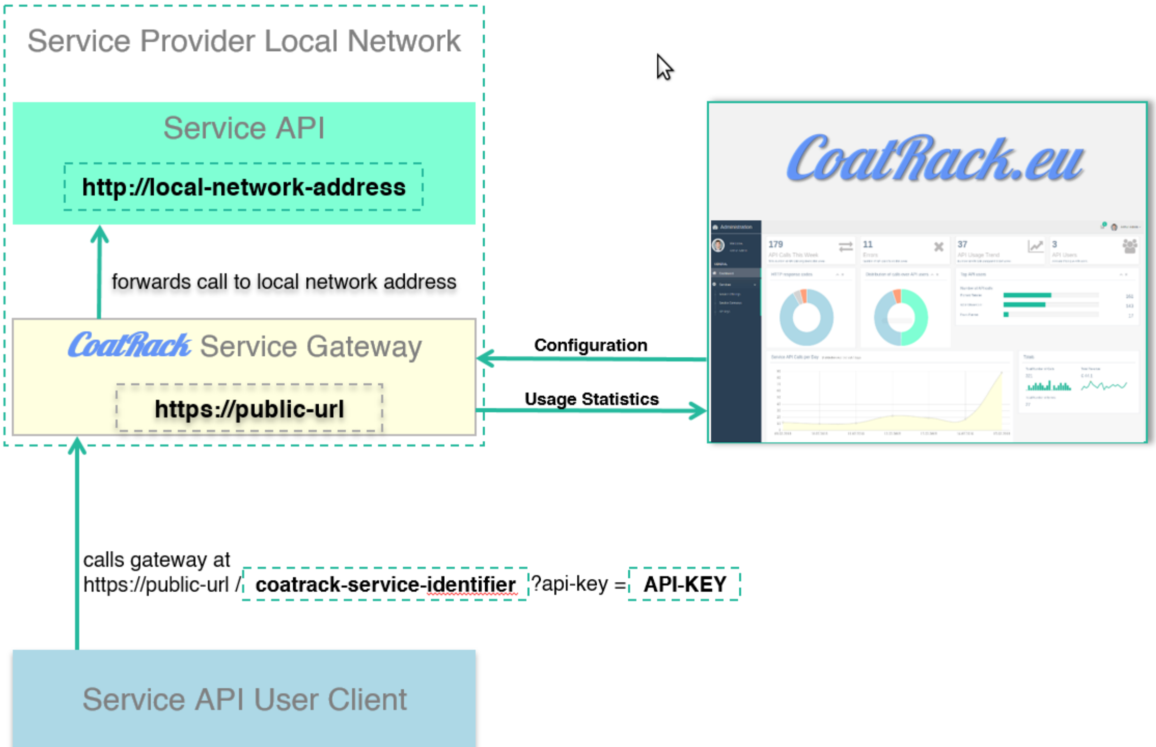

Figure 22: General architecture overview of CoatRack for Service Monetization.

To set-up a new service offering, the service provider should first register all required details of the service via the central CoatRack web application. As soon as this is done, the service provider can download a CoatRack gateway that is configured/customized individually for this specific service. The gateway can be installed in the local server that is also hosting the service API that shall be exposed to third parties via the CoatRack gateway. Changes in the service configuration can be done in the central CoatRack web application, which can also update the configuration of the CoatRack gateway that was already installed in the service provider's local environment.

Having a more detailed look at the CoatRack web application, it comprises several components that have to be installed and configured when setting up a new instance of CoatRack. This is indicated in the detailed architecture diagram in Figure 23.

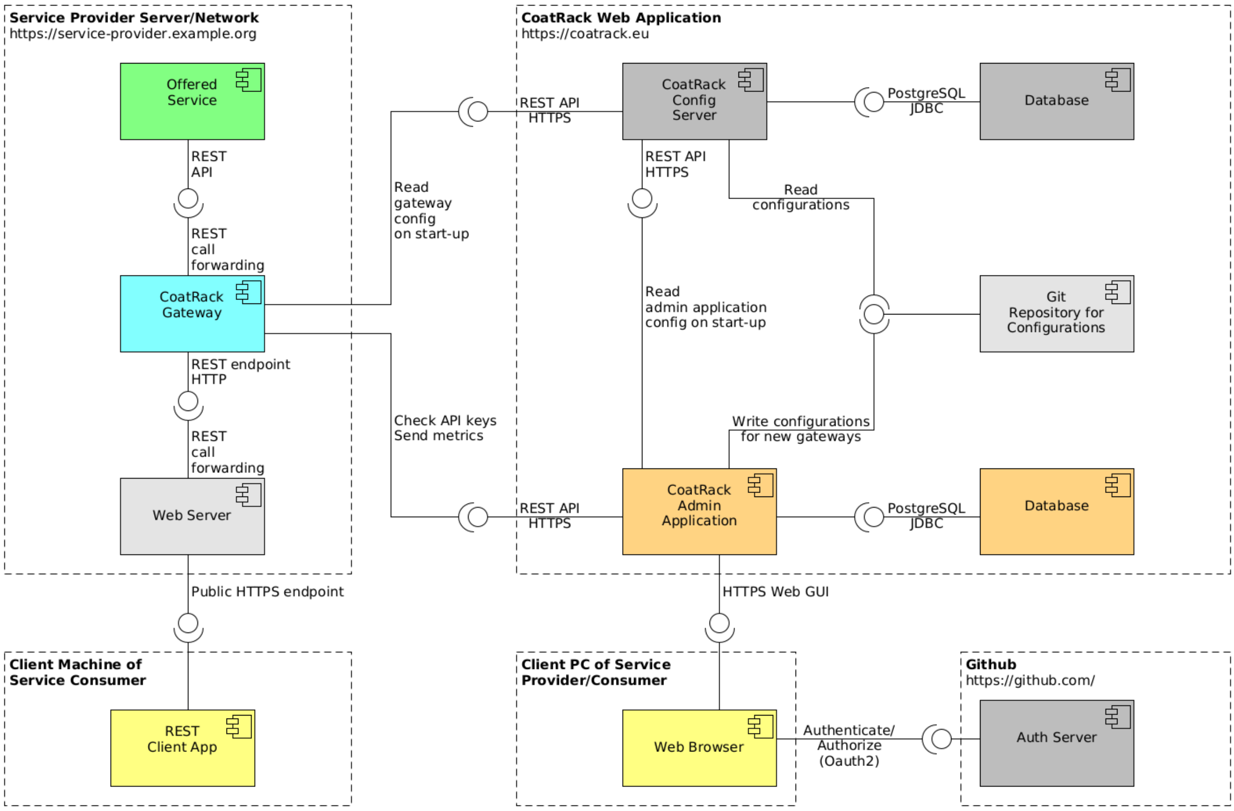

Figure 23: CoatRack deployment architecture

The central core component of CoatRack is the admin application, indicated in the centre of Figure 23, which can be accessed by service providers and service consumers using a web browser (authentication/authorization is done via OAuth 2 / OpenID Connect). General data about the services and gateways as well as the metrics about service usage are stored in the database of the admin application, while the individual customized configurations per gateway are stored in a Git repository. The CoatRack config server allows the gateways to read their configuration at start-up time, but also enables the "live update" of a gateway configuration at runtime.

The CoatRack gateway itself, indicated on the left of Figure 23, should usually be installed "behind" a web server (e.g. Apache or NGINX) that provides an encrypted public HTTPS endpoint.

2.4.3 Getting started with CoatRack

To quickly get familiar with the basics of CoatRack, it is advisable for software developers to simply try it out. The easiest option is to use the public instance of CoatRack, which is available at https://coatrack.eu (see Figure 24).

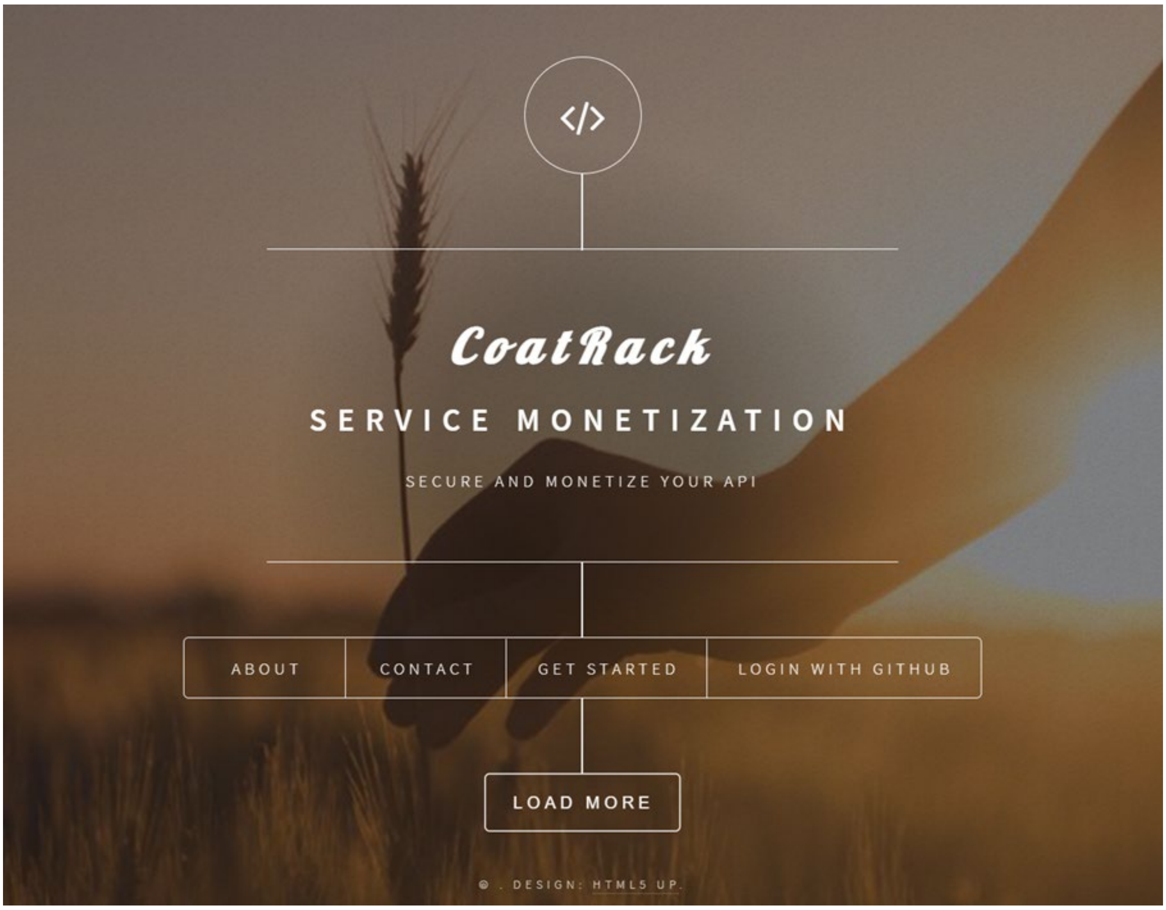

Figure 24: Landing page of CoatRack (https://coatrack.eu).

After logging in with an existing Github account and filling in the registration form, the CoatRack admin application will open. There are two "getting started tutorials" to learn the basics of CoatRack, accessible from inside the application after logging in:

- Offering service APIs via CoatRack
- Using service APIs offered via CoatRack

These tutorials guide the users through a few simple steps, creating a basic setup to offer/use software services (see an example in Figure 25).

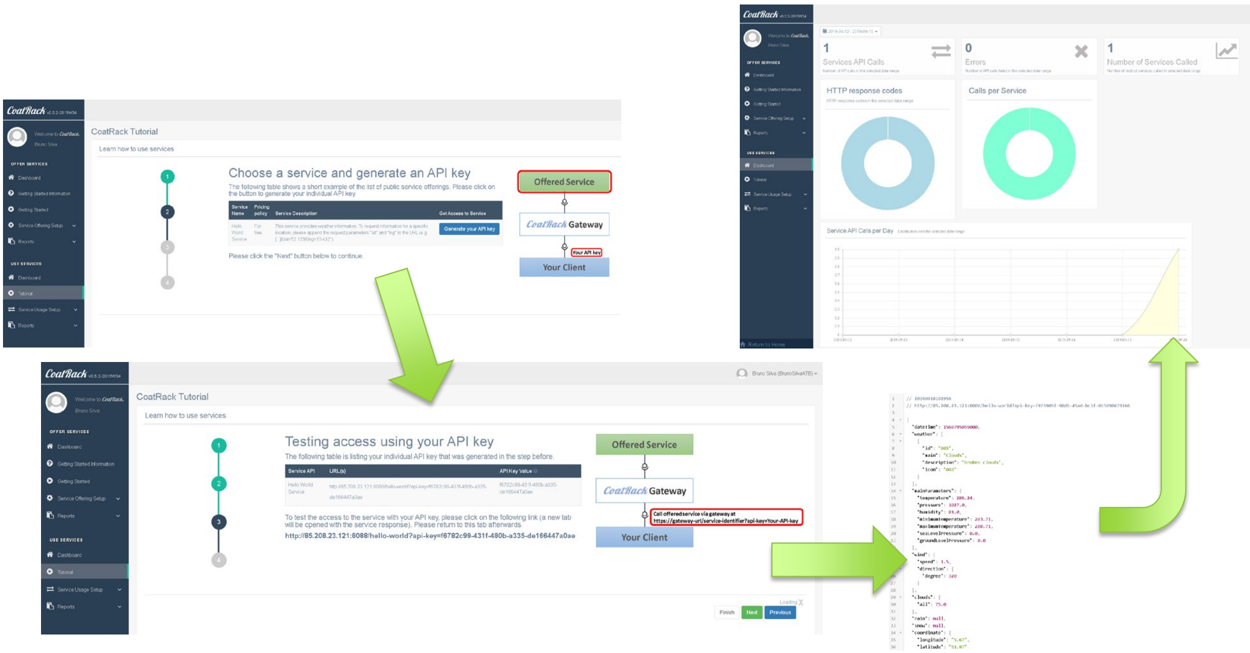

Figure 25: Tutorial on https://coatrack.eu – Learn how to use services.

To have a more detailed look at the source code or to run their own CoatRack instance, developers should have a look at the open source repository, available at https://github.com/coatrack/coatrack. CoatRack is provided under the Apache 2.0 open source license, so that developers can simply download the source code, build and run CoatRack on their own.

All components in the CoatRack architecture are also available as Docker container images. Those containers can be deployed in a local Docker runtime with the use of Docker compose. As alternative, the container images can also be used on Kubernetes with the use of the Kubernetes deployment descriptors (configurations, services, deployments, etc.). The Kubernetes deployment descriptors can easily be ported to any Kubernetes-based cloud platform (Google cloud, Azure, Amazon, etc.). Theoretically, it is also possible to run the generated gateway on a different platform than the admin container, but generally it is advised to keep all the components on the same platform.

2.4.4 CoatRack beyond IoF2020

As explained above, CoatRack facilitates monetization & access control for software service delivery, supporting some general tasks, so that developers can reduce efforts and focus on their core competencies and development tasks. CoatRack is available as open source software – under Apache 2.0 license – and its development will continue after the end of the IoF2020 project.

Just recently, the FIWARE open source initiative accepted CoatRack as „incubated“ software component into their catalogue, accessible at https://www.fiware.org/developers/catalogue/. CoatRack can still be used as a standalone software, but it can also be combined with other FIWARE components to support more complex requirements. As an example, a CoatRack plugin was developed for the FIWARE Business API Ecosystem/Marketplace (see also section 2.5), which allows to use CoatRack for access control to a FIWARE Context Broker, while the service can be offered via the FIWARE marketplace.

Besides the open-source offering, CoatRack will also stay available "as-a-service" via the public instance at https://www.coatrack.eu. Commercial usage of CoatRack can be arranged on fair, reasonable, and non-discriminatory (FRAND) terms. With the exception of consultancy, pricing is based on a per-use basis. This freemium offering is also available outside the scope and after the end of IoF2020.

Besides using CoatRack as a service via the public instance, CORIZON and ATB will also offer commercial support for individual CoatRack installations on request. Individual offerings are provided for customised solutions and supporting infrastructures with multiple services and more complex partner structures.

2.5 Data Marketplace for Standards and Configurable Dashboards Components

The use cases of the IoF2020 project deal with a large amount of data that needs to be managed, maintained, exchanged, published and, in some cases, monetised. This huge set of data comes mainly from IoT sensors, but also from GPS, drones or robots operating in the farm, as well as from many external sources such as services to monitor processes within the supply chain, services providing weather data, and other public or private data sources.

In the context of WP3, FICODES has provided a comprehensive framework for supporting such data management, including the means for visualisation, publishing, and monetising data while enforcing access control and managing data usage terms and conditions. Latest version of this framework is depicted in the following Figure 26.

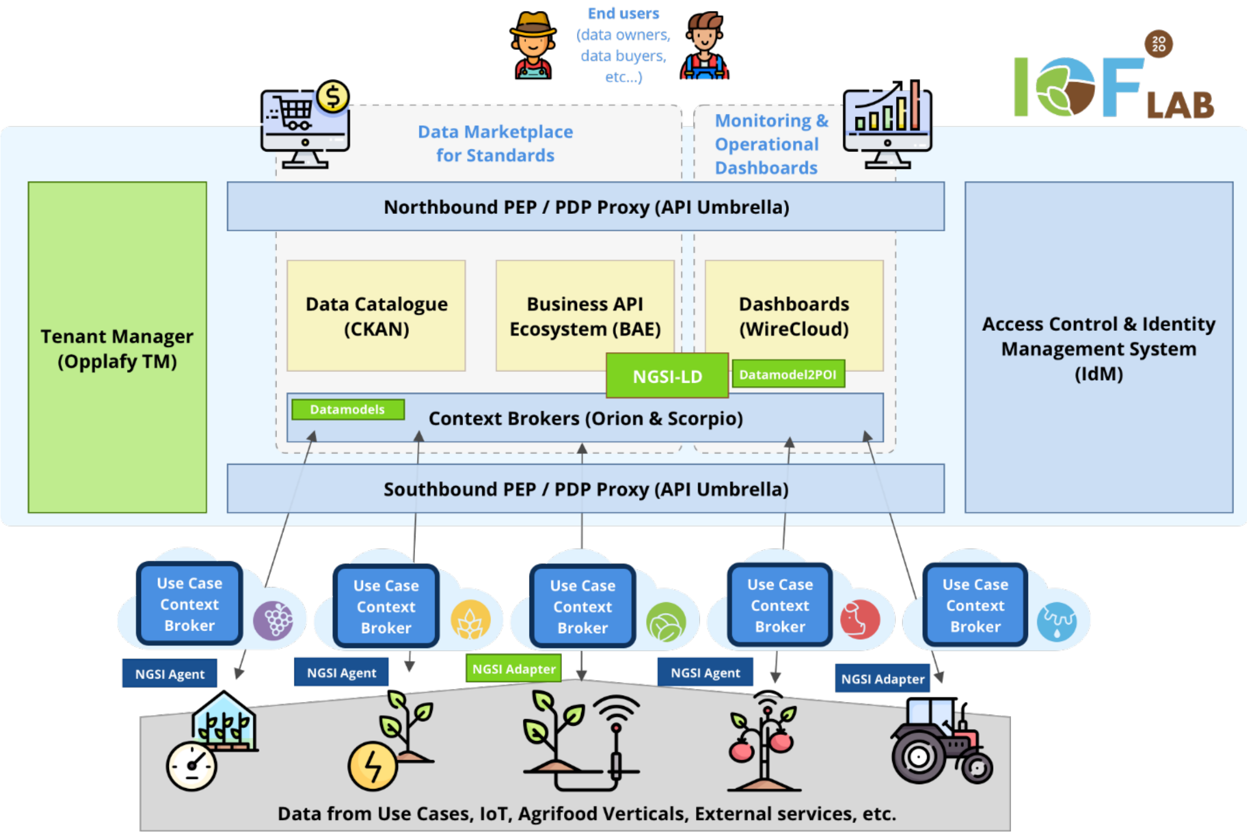

Figure 26: Architecture of the FIWARE-based IoF2020 Lab.

A first version of this framework was deployed in January 2020 and has since then been available within the IoF2020 Lab. It is made of a number of components integrated within a FIWARE-based architecture. During this last Reporting Period, these deployed IoF2020 Lab components have been updated and improved, and they can be now summarised as follows:

- **Context Broker**. This component has been updated to provide full support for the NGSI-LD standard, keeping backwards compatibility with NGSIv2. It now exposes its APIs in the following URLs:
  - NGSI-LD: http://context.iof2020lab.eu/ngsi-ld/v1/
  - NGSIv2: http://context.iof2020lab.eu/v2
- Both the **Business API Ecosystem** and **Wirecloud**, core elements of the Data Marketplace and the Configurable Dashboards reusable components, have been thoroughly improved to support NGSI-LD. The Data Marketplace has evolved to give shape to a Library of Codelist and Reference Data (Data Marketplace for Standards). These improvements are described more in detail in next sections.

The rest of the components (Tenant Manager, IdM, API Umbrella and CKAN) have only had little changes, such as deployment of the latest stable version. The reader can find a full description of all these components in the deliverable D3.6: “Enhancement and Configurations of Open Platforms and Reusable Components” as well as the description of the IoF2020 Lab in D3.8: “Hosting Environment and IoF2020 Lab”.

2.5.1 Data Marketplace for Standards

The Data Marketplace is one of the assets deployed in the IoF2020 Lab. It is available at https://market.iof2020lab.eu/. It can be seen as a complete framework for data management, including the means for visualising, publishing, and monetising data while enforcing access control and managing data usage terms and conditions. It is made up of the Data Catalogue and Business API Ecosystem FIWARE components, and it now fully supports both the **NGSIv2 and NGSI-LD** protocols exposed by the FIWARE Context Broker.

The core component of the Data Marketplace is the **Business API Ecosystem (BAE)**. It is a complete market solution that allows the monetisation of any kind of (digital) asset, and can be extended by means of plugins to offer advanced functionality and monetisation on certain types of assets. Each plugin represents a particular asset type or type of product to be offered, and includes all the specific validation and activation codes. In the context of IoF2020 and the IoF2020 Lab, the BAE was deployed with a special focus on the monetisation of context data in the form of NGSI, but definitely it can be extended to support any other types of assets.

The BAE supports a complete product and offering management and asset monetisation, leveraging the *TM Forum Open Business APIs*. In this regard, it provides the means for product and offering creation and acquisition management, including terms and conditions, SLAs, custom characteristics or data relationships. The BAE can force customers acquiring access to the data to accept the terms and conditions, even in those scenarios where the data is provided for free but specific clauses need to be satisfied in its usage (e.g. not commercial use, etc.). It supports user charging for accessing data, enabling the creation of rich price models for the monetized products, including single and recurrent payments as well as pay-per-use. These price models can be combined and enriched with price alterations (i.e. discounts, etc…), enabling the creation of more complex and advanced models.

The BAE also provides users with searching, discovering and classification features, enabling them to create in runtime a whole set of categories that can be used by data providers to classify their offers and enable users to filter and discover them. Categories in the BAE can be nested, allowing to provide different levels of granularity to the offering classification.

In addition, the BAE provides revenue sharing features enabling providers to establish how the revenue generated by a particular offering is distributed among the different stakeholders involved.

Last but not least, it is important to remark that the functionality of the Data Marketplace is offered as a combination of the Business API Ecosystem, and the FIWARE Security Framework, which provides user, role, permission and access policy management, as well as data-access monitorization.

Data Marketplace Progress

In this last Reporting Period, there are several improvements carried out on the Data Marketplace. Firstly, it has now **support for the Context Information Management API (NGSI-LD) Specification**, so users can now share and monetise data through the latest version of the NGSI protocol when needed. This way, the Marketplace is aligned with the latest version of the FIWARE Context Brokers, and can be used by many stakeholders, no matter which version of NGSI they use.

The Data Marketplace has also been **integrated with CoatRack**, the Service Monetisation reusable component. This effort has been done jointly by FICODES and ATB. Thanks to this integration, it is now possible to use CoatRack as the component in charge of the service access control and the generation of Accounting Data, while the Marketplace is used to offer CoatRack services to third parties, take care of acquisition of access rights and manage customer charges. The next Figure 27 shows how both components fit together.

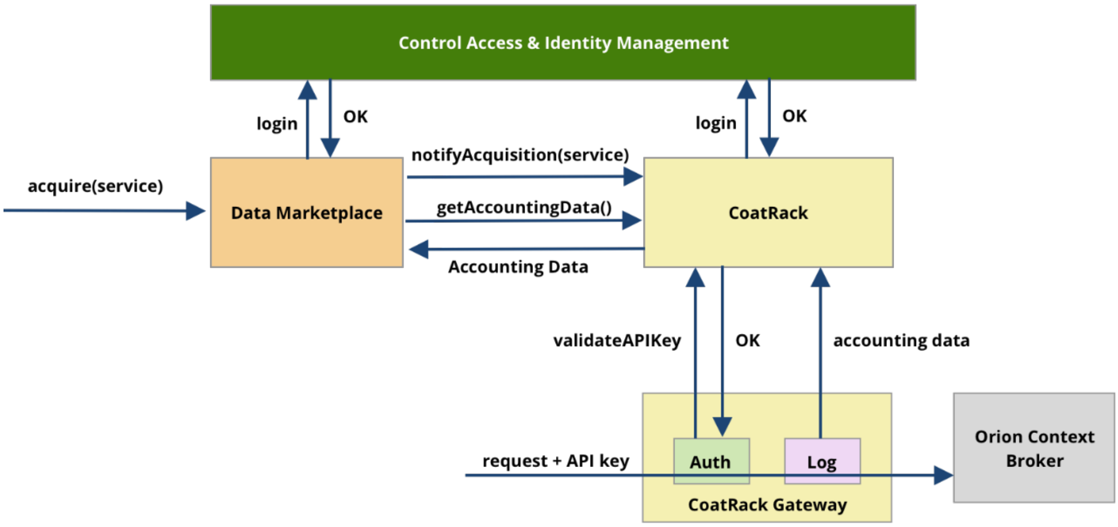

Figure 27: Data Market integration with Coatrack.

However, the most remarkable improvement has been carried out by FICODES and Wageningen University & Research (WUR), performing the analysis and later-development of a number of functional requirements requested by AgGateway in order to turn the Data Marketplace into a **Library of Codelists and Reference Data**. Several updates of the original FIWARE Marketplace have been implemented by FICODES, incorporating new features and updating the deployed versions with new assets and configurations. The following points describe the main features implemented in the system.

New style of the user interface.

The style of the Data Marketplace has been completely redesigned to make it more user friendly and appealing. The following Figure 28 shows the front page with the new style.

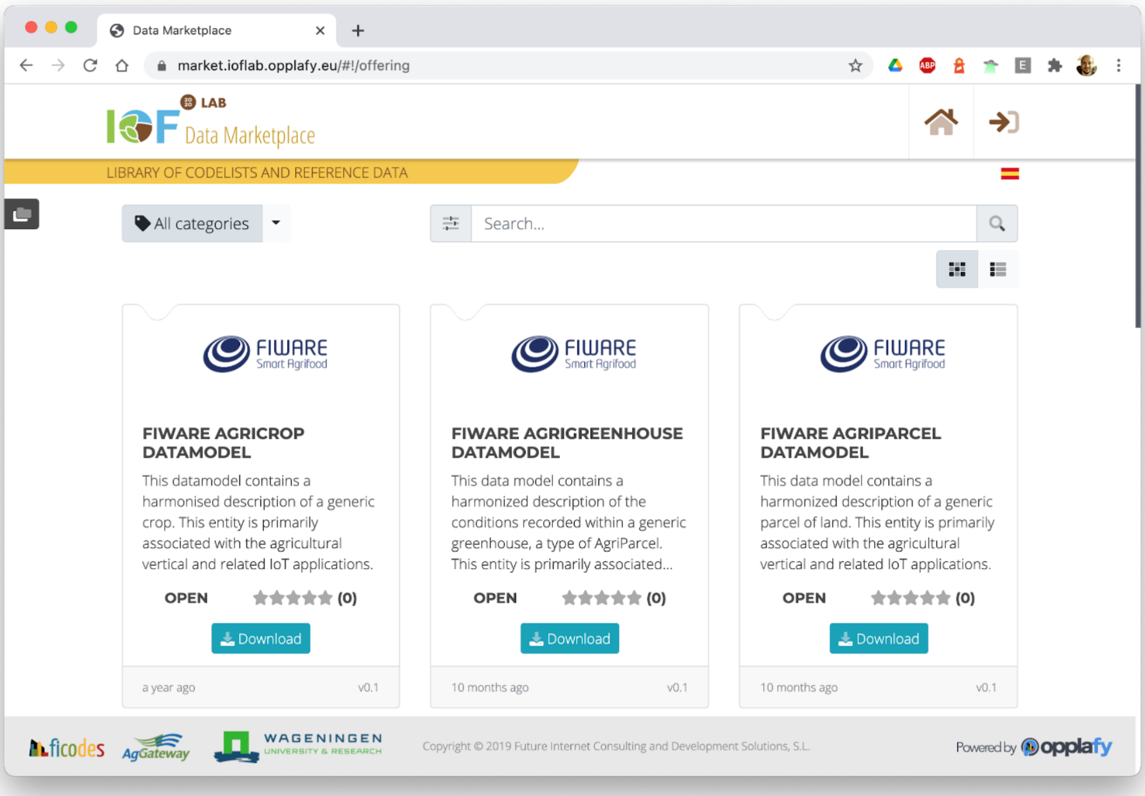

Figure 28: The frontpage of the Data Marketplace and its new style.

Product and offering content.

The main change made in the original version of the FIWARE Marketplace is related with the product and offering models. In the original version the pricing model attached to an offering allows to create paid or free offerings that can be acquired by the data consumers of the system. Such a model requires data consumers to add the offering to the cart, accept the terms and conditions (if provided) and pay (if monetised). With this model the marketplace supports both paid Reference Data, or free ones for being able to monitor which users consume which data.

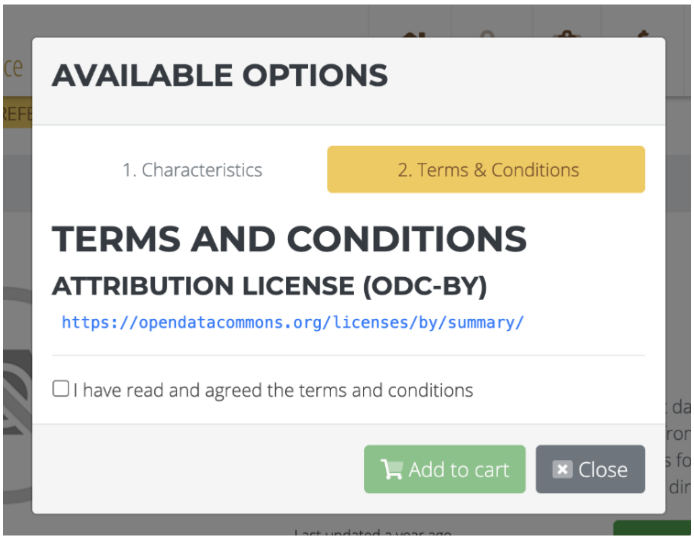

Figure 29: Terms & Conditions must be accepted if provided.

However, this original behaviour was not suitable for registering Reference Data that is usually publicly offered on the web, or that it is wanted to be open for all users. In order to cover such a feature, a new model called *"open"* was introduced in the system. This *"open"* model allows the assets attached to offerings of this kind to be directly downloaded or accessed (if an URL is provided) without the need of acquiring or even logging in into the system.

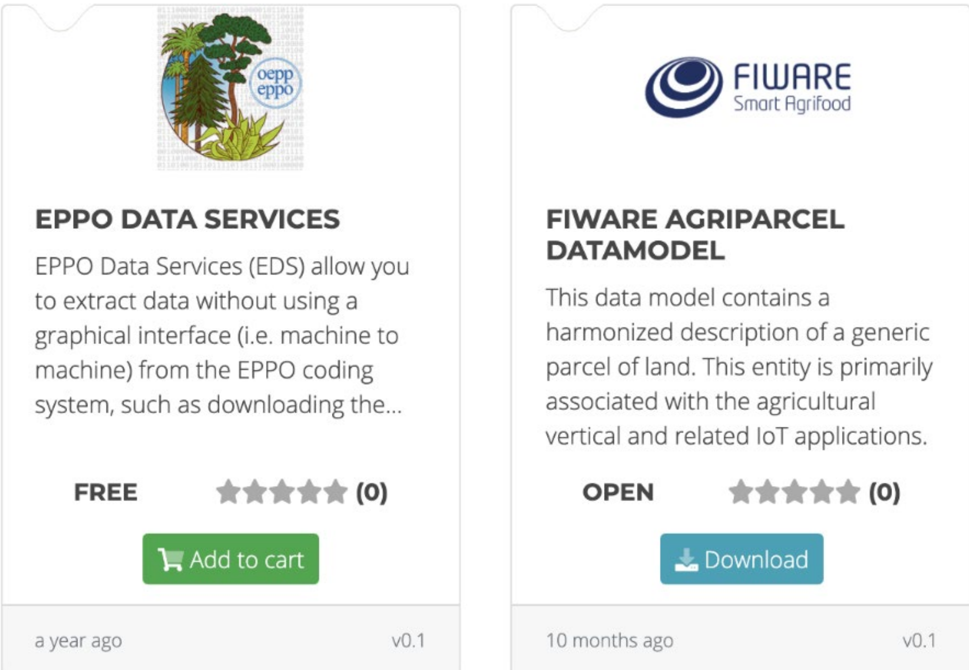

Figure 30: Pricing model vs Open model.

In addition, a new *Digital Asset Type* called Reference Data has been developed. It is intended to support the publication of the different code lists and standards. Such asset type allows either to provide a URL pointing to an asset or upload it if it is a file.

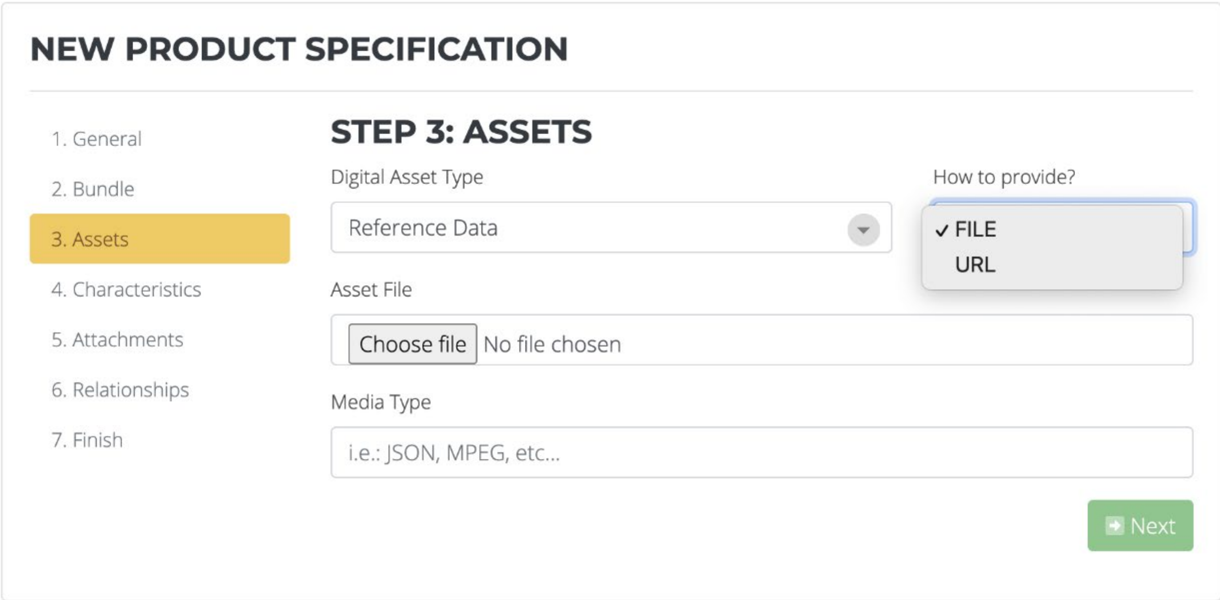

Figure 31: The Reference Data digital asset type.

Moreover, some aspects of the interface have been modified to fit the context of Reference Data. In particular, the field "Brand" used to describe product owners has been replaced by "Source" in both the product creation form and the offering description view.

On the other hand, for the particular case of offerings including Reference Data assets, the product fields of the offering description (Product Name and Product Version) have been updated to Codelist Name and Codelist Version.

Finally the instance has been deployed as a "non-profit" one, meaning that the default revenue model (part of the revenues that goes to the publisher) has been set to 0%; therefore all the revenues generated by paid products is earned by the data provider itself.

Categories.

The deployed instance has been configured with a couple of categories used to filter and classify the different offerings. The provided categories allow to classify offerings by type of component and by sector. The following categories has been created:

- Component
  - Standard
  - Code list
  - Data model
  - Identifier
  - Software module
- Agriculture
  - Arable
  - Beef
  - Dairy
  - Fruit
  - Pig
  - Poultry
  - Vegetables
  - Supply Chain Management

The categories are created and maintained by the system administrator, who can create or update the existing. The different categories can be nested, allowing to provide more detailed classifications if needed. They can be selected by the user when an offering is created, and can be used to filter the search results in the home page of the Marketplace.

Figure 32 below shows the example of the offerings filtered on *agriculture* -> *arable* category.

Figure 32: Filtering by category: Arable.

The next Figure 33 shows the results when filtering under the *Component* -> *Identifier* category.

Figure 33: Filtering by category: Component Identifier.

Catalogues.

The Data Marketplace also supports the notion of catalogue. A catalogue represents a set of offerings made available by the same provider. It is possible to filter based on the desired catalogue. This is achieved by using the hidden sidebar.

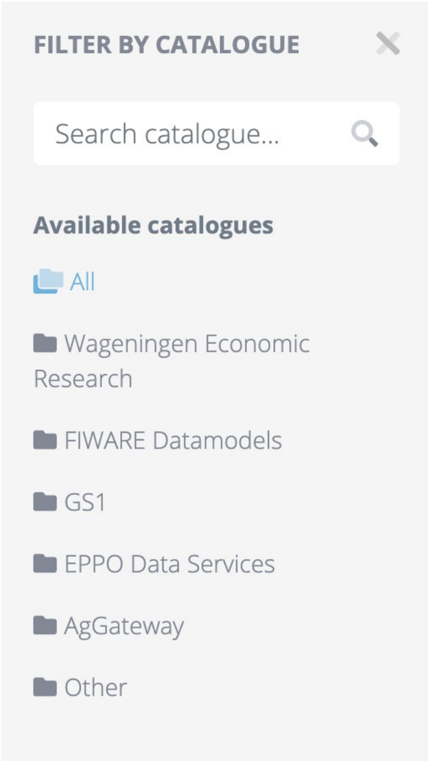

Figure 34: Sidebar with filtering options by catalogue.

2.5.2 Operational Dashboards and data visualisation: Configurable Dashboards

FICODES provides WireCloud as a reusable component for those use cases in need for straightforward adaptive and incremental visualization features, such as configurable monitoring and operational dashboards. It is available at http://dashboards.iof2020lab.eu/.

WireCloud is the reference implementation of the FIWARE Application Mashup GE. It is a web mashup platform aimed at creating web applications in an easy way by means of two kinds of web components (widgets and operators). It also offers an API to different services (e.g., REST APIs), besides several out-of-the-box features such as the wiring tool, in which widgets can be "wired" to share/flow data among them, a layout management to place the widgets just by dragging them, or a user's management system leveraging different authentication protocols such as OpenID, OAuth2.0, etc.

WireCloud provides agri-food stakeholders with a framework for building web-based monitoring and operational dashboards, able to provide adaptive and incremental data visualizations to fit their needs. For a full description of Wirecloud, please refer to deliverable D3.6: "Enhancement and Configurations of Open Platforms and Reusable Components".

Configurable Dashboards Progress

In this Reporting Period, several tasks have been carried out to keep WireCloud healthy and up to date, as well as to enhance user experience and ease branding. The first improvement, likewise the Marketplace, has been the **adoption of the NGSI-LD standard**. Lot of work has been done to update the **"ngsijs" library** to thoroughly support the new standard. To make use of this library, users have the brand new NGSI-LD-Source operator at their disposal. This operator allows them to retrieve context data from NGSI-LD Context Brokers, such as Scorpio. Hence, users can now take advantage of their new features such as:

– Alignment with JSON-LD and enablement of semantic web
– Management of temporal entities, including support for aggregating data, and visualise them by using chart, table and other related widgets.
– Multivalued properties
– MQTT support for notifications
– Support for retrieving entities directly in GeoJson format and showing them on a map
– And many more...

Regarding **style and usability**, a new IoF2020 Lab theme has also been developed to match the style of the project. This improvement simplifies the way themes can be created, so use cases could create their own theme/branding more easily. The IoF2020 Lab theme can be seen in the following Figure 35.

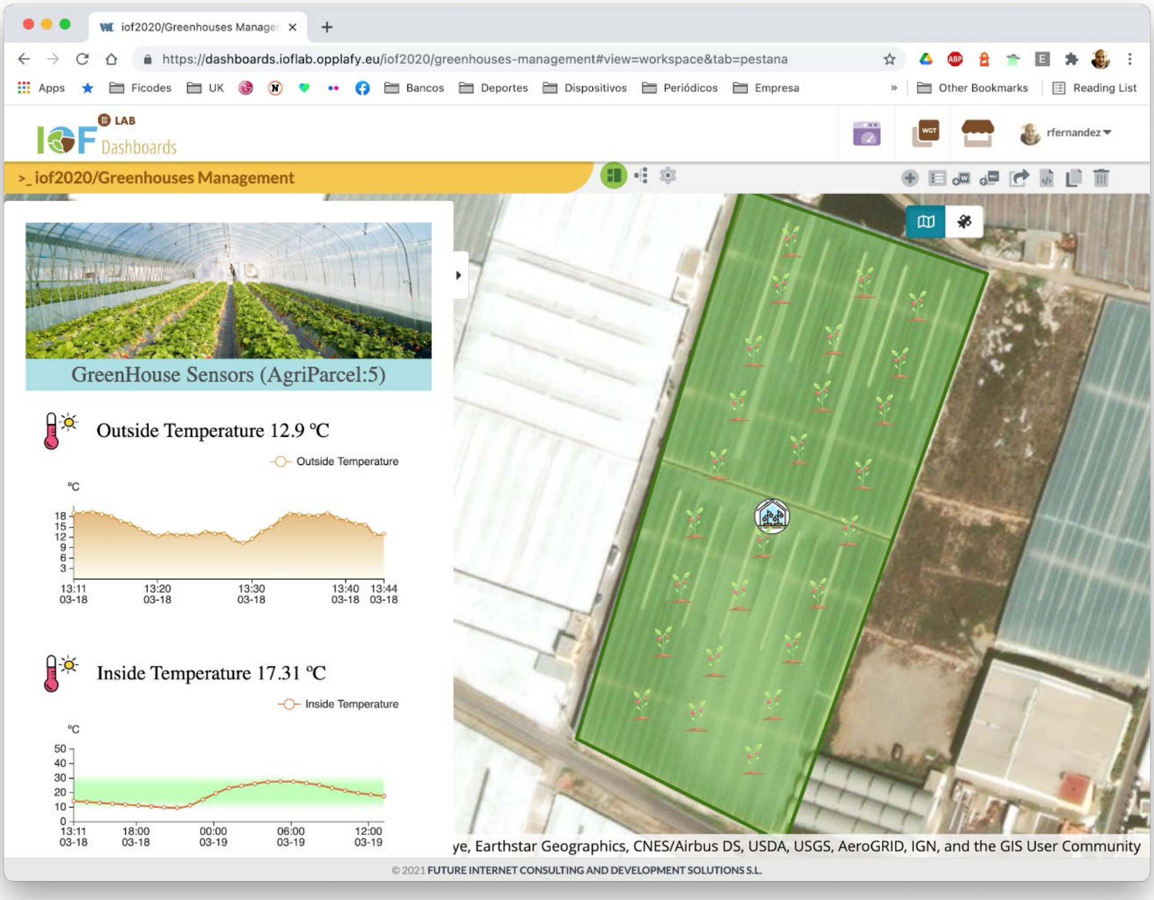

Figure 35: Example of *WireCloud* dashboard: Greenhouses management.

Finally, FICODES has developed both an operator (`ngsi-entity2poi-nunjucks`) and a widget (`ngsi-entity-details-nunjucks`), apart from the NGSI-LD source operator, to deal with the proper visualisation of the FIWARE (Agrifood) Smart Data Models generated in the IoF2020 context. By using these assets, users can easily deal with georeferenced harmonised data, and get styled POIs (Points of Interest) on maps with fully detailed tooltips, filled with the correct data. They, likewise, can select one of those POIs and get a detailed view of the data off-the-shelf. This feature can be seen in the previous figure, in which a GreenHouse data is been shown in a side panel. Next Figure 36 shows how these assets can be configured (using the Wiring feature) to get data from the Context Broker.

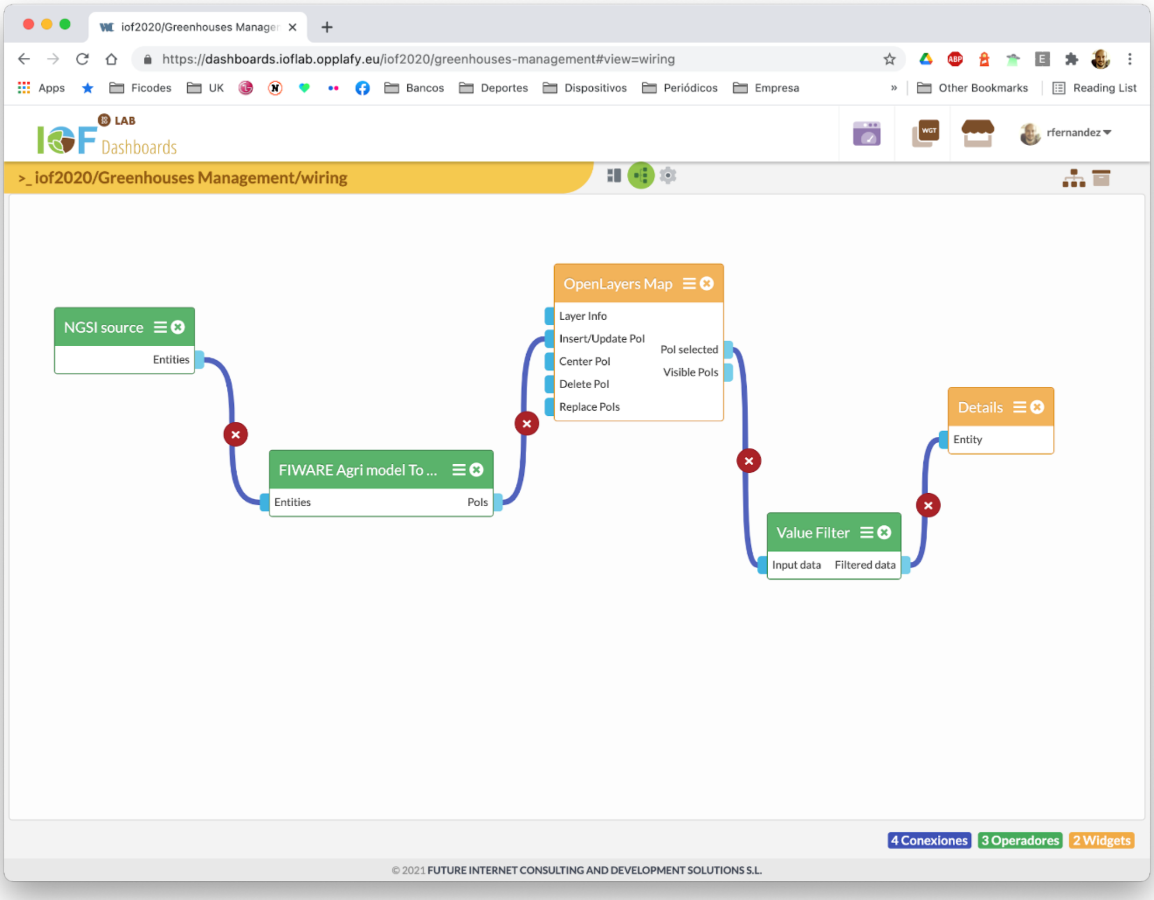

Figure 36: Example of how to configure the developed assets exploiting FIWARE Smart Data Models.

These assets make use of templates according to the description provided by the aforementioned FIWARE Smart Data Models. They are available in GitHub repository (https://github.com/Ficodes/smart-datamodel-views), and have been shared through the catalogue tool, which manages the lifecycle of WireCloud inner components (widgets, operators and mashups), supporting its publication, maintenance, search and discovery. This catalogue supports federation, enabling organizations to have their own private instances or using global ones. It is important to remark that those templates can be easily adapted to visualise any kind of data stored on the Context Broker.

2.6 AgroWeatherGateway and AgroContractorsGateway

During the course of the IoF2020 project, two completely open-source software modules have been developed. These modules are part of a family of software products called AgroGateways. The first module called AgroWeatherGateway (AWG) allows the visualization of data of weather stations belonging to different providers. The second module called AgroContractorsGateway (ACG) allows the visualization of data coming from agricultural machinery (for example tractors) operating in the field.

The current state of the art for digital products at the service of agriculture includes a series of proprietary software that can connect with specific hardware often belonging to the hardware manufacturing parent company. This means that there are no sufficiently robust open-source solutions that a user can use to connect hardware from different vendors. This is true for both weather stations and agricultural machinery. Customers using hardware technologies must use different platforms to connect to devices from different suppliers. The purpose of the two AgroGateway modules developed in the project is precisely to bridge this gap and provide users with a single platform for accessing sensors and viewing data. Furthermore, having a single platform also allows access to data to be made available according to the open data paradigm.

For example, just think that Agro Contractors are an important part of the agricultural landscape in Europe, there are:

- > 20k contractors in France
- > 4,5k contractors in Germany
- > 30k contractors in Poland

These data refer to "Eurofound-Employment and industrial relations in the agricultural and rural contractor (ARC) sector" 2012.

Each agricultural contractor has many different customers with different needs and different ways of interacting with the contractor. Usually, contractors tend to be equipped with more sophisticated machineries that allow them to work better and safer. For example, contractors use new generation machineries with embed data logger and sensors that interact with standards like CanBus and ISOBus.

Contractors' data are valuable to farmers but at the moment are seldom delivered to them and almost never introduced in an agritech platform.

The same considerations can be made for weather station data. In addition, however, it must be considered that manufacturers of weather stations are in greater number than those of agricultural machinery and for a customer there is also the difficulty of having a single point of access to data for different providers.

In a first market analysis this kind of product is missing and, moreover, is more than welcomed by the public administration and by platform producers to simplify the access to this kind of data.

All this leads to consider that AWG and ACG has some major interests:

- Providing a standardized interface to several producers that can be used by AG platforms and other AG related products.
- Providing a standalone platform that can be used to visualize data coming from different sensors/machineries.
- Providing a product that can be used event by the government (local and central) and contractors to connect many different sensors/machineries and to provide access to the farmers.
- Providing a product that can operate independently or can be interconnected with other platforms.

Agricolus and the project partners recognised FIWARE as the natural architecture to choose for this kind of development. In particular the AgroGateway family of product can be developed as FIWARE Domain Specific Enabler related to the FIWARE Agri-Food Reference Architecture. This DSE enables a standardised connection to many (hopefully all) the agro-weather and machinery sensors in the market relying on Orion Context Broker technology and NGSI-LD standard. The software

The development of the AgroContractors and AgroWeather Gateways offers new components for collaboration by farmers exchanging local data as well as facilitating data reuse by Farm Management Information System providers and agricultural equipment operators. The open source software is finalized in March 2021 and is available via GitHub at the link https://github.com/Agricolus . Agricolus as provider of the gateways and owner of an FMIS started collaboration with different stakeholders (e.g. Coldiretti, CNH, JohnDeere) and aims at further promotion of the open-source also beyond IoF2020.

The software has been released as public software under the AGPL license and is compatible with different distribution formats thanks to Docker packaging. This allows the use on different cloud platforms (e.g. Microsoft Azure Cloud, GoogleCloud, AWS, etc.).

The main development is dedicated to these areas:

- Context Providers: will interact with different producers' ecosystems and cloud applications. Each producer may allow the access to a cloud repository or directly to the sensors.
- The context provider will manage the communication layers, the authentication of the weather stations/machinery, sensors specific configurations and other hardware related data (such as alarm notifications in case of hardware failure, if provided)
- Authentication ad Roles Management: a simple authentication with an admin role for admin-users and access to specific group of sensors (each sensor will be included in a group of sensors)
- APIs access for external applications: upon specific authorizations third parties will be enabled to access real time data form the DSE with given credentials.
- Web interface useful to view data as table, map and chart and to manage the application functionalities.
  - Web Interface for AWG:
    - Sensors management and configuration:
      - CRUD operations on weather stations
      - Weather stations POI management
      - Specific hardware producer configuration of each weather station
    - Weather stations web map:
      - Weather stations are visualized in a web map
    - Weather stations charts and data:
      - Actual and historic data for each weather station can be accessed and visualized in a graphic format
      - Actual and historic data can be downloaded in a CSV format
  - Web Interface for ACG:
    - Vendors' Machines management:
      - Visualization and import vendors' machines operated by the contractor.
    - Machines movements:
      - Visualization of machine movements inside and outside fields.

The following Figure 37 connects the FIWARE stack for Smart Agrifood Applications with the technological levels developed in the AgroGateway modules.

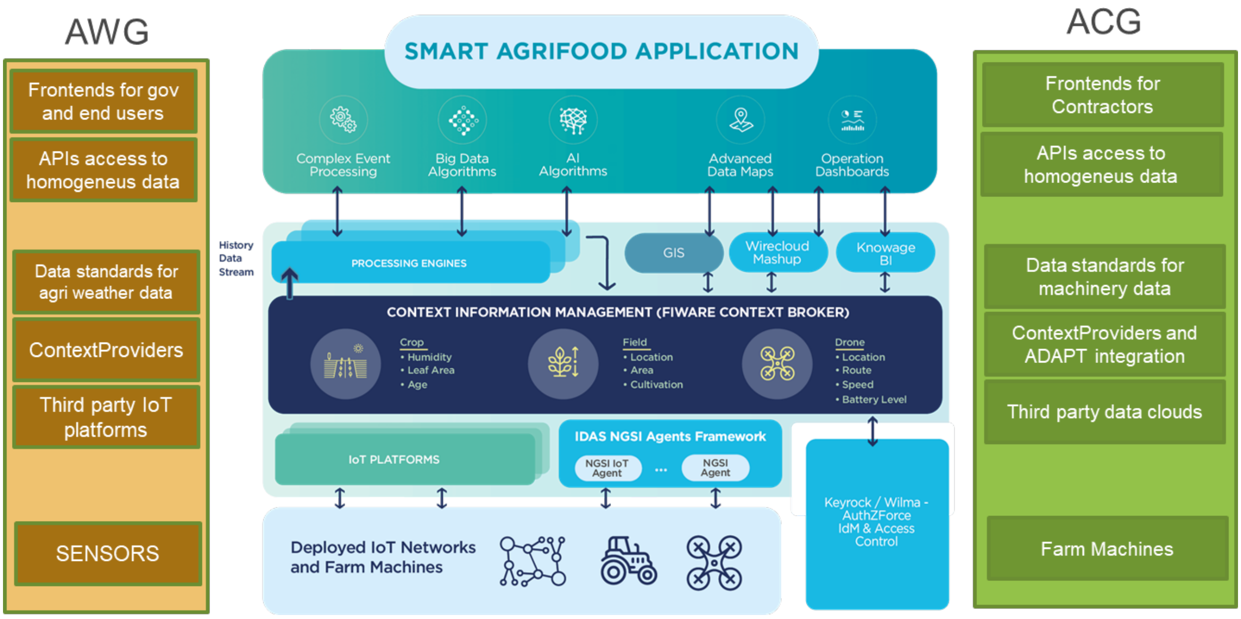

Figure 37: AgroGateway modules in relation to the FIWARE stack for Smart Agri-food Applications.

The two software modules, being part of the same product family and using standard FIWARE components and interfaces, can communicate not only with each other, but also with other Farm Management Information Systems that rely on the same components. The following Figure 38 shows, for example, the interaction of the two modules in a complex scenario in which an FMIS (Agricolus) is used.

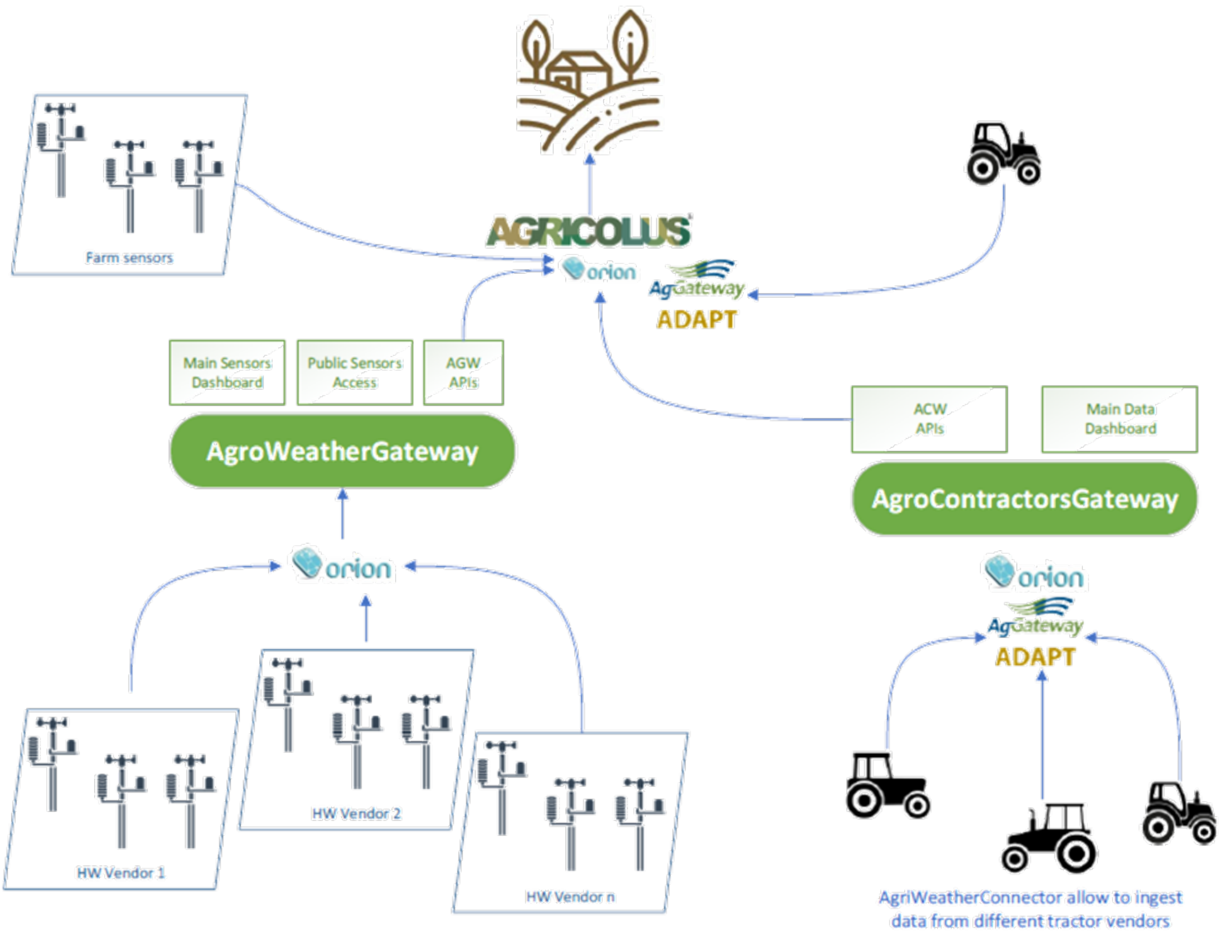

Figure 38: Interaction of the AgroGateways in a complex scenario with an FMIS (Agricolus).

This is a list of features made available by the product:

- Data harmonization done with NGSI-LD Data Models (updating Observed Data Model)
- Context Providers for at least 3 main sensors producers, service definition
- Authentication/Authorization for sensors with group policies
- APIs for data access
- Admin frontend with overall sensors dashboard, superAdmin for hw setup
- End user portal that will have access to data
- VM bundle with the entire solution ready for government implementation

The following is an overview of the architecture of ACG (for AWG the architectural choices are the same):

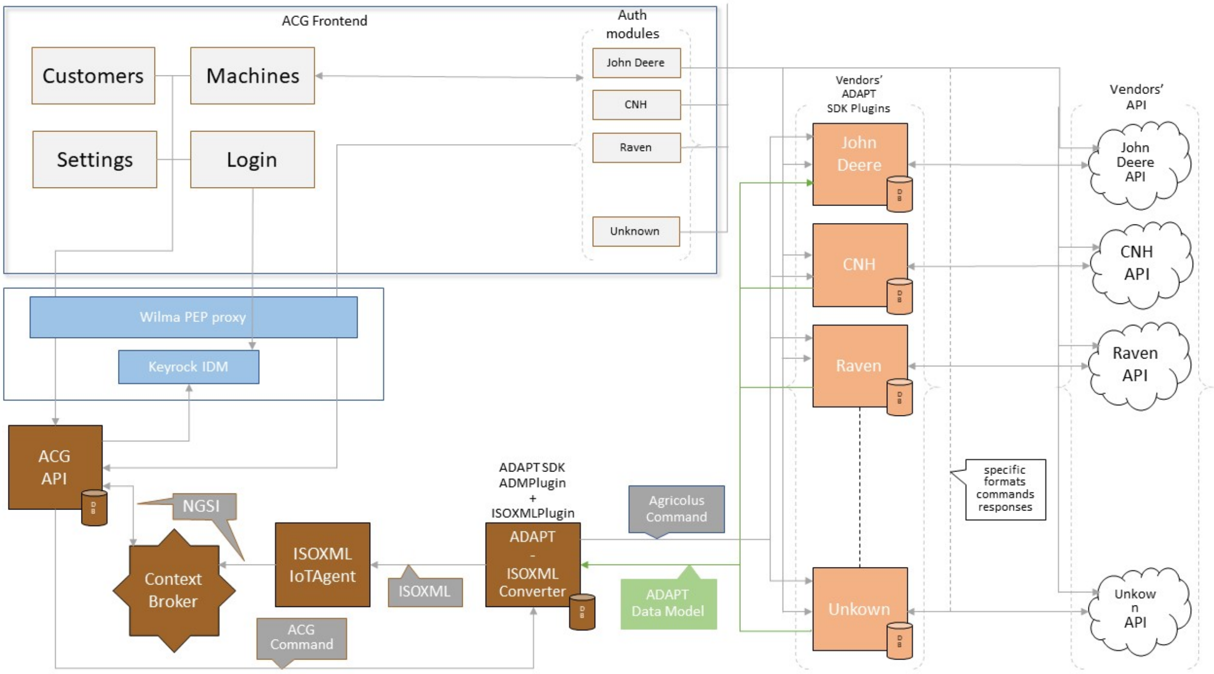

Figure 39: Architecture of the AgroContractorsGateway.

In the overview there are:

1. **Auth modules:**
   Will interact with different producers ecosystems and cloud applications. Each producer may allow the access to a cloud repository or directly to the data through theirs proprietary ADAPT representations. The frontend modules need to provide SSO mechanism to vendors' platforms and will interact with the AGR.Vendors api in order to execute the operations (retrieve machines informations and theire positions, retrieve customers and fields boundaries).
2. **Login/APIs Access:**
   Access to ACG.Api and ACG.Vendors will be mediated by Wilma PEP Proxy and the auth flow will be executed through Keyrok

Finally, some screenshots of the applications (AWG and ACG) are shown below.

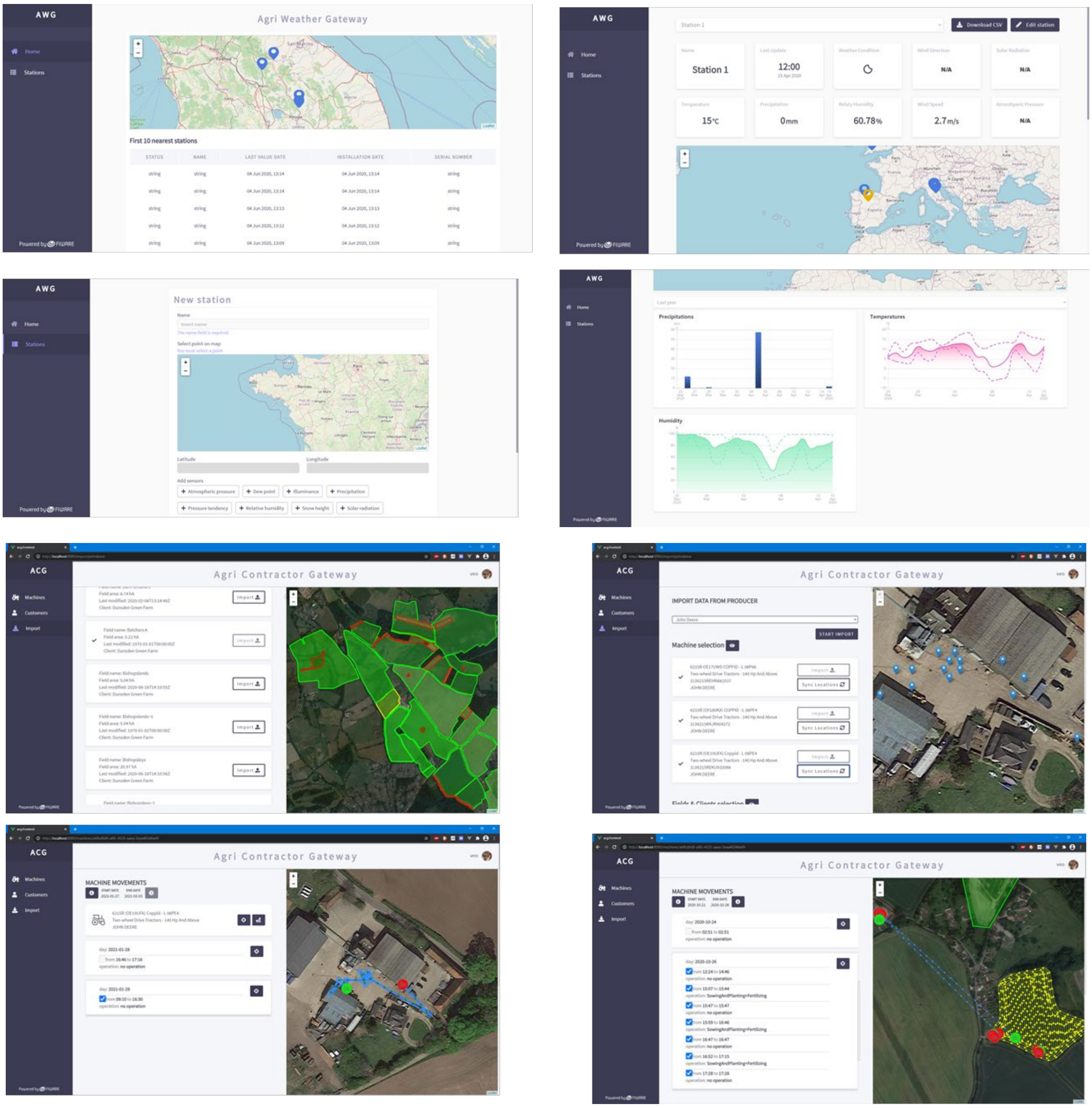

Figure 40: Screenshots of the applications (AgroWeatherGateway and AgroContractorsGateway).

2.7 Security, Privacy and Trust by Design Tutorial

In this reporting period, partner NXP from WP3 guided the WP2 use cases through an assessment with regard to security, privacy and trust (SPT) of the planned IoT solutions at project start and provided individual consultancy (Webinar series) about SPT countermeasures during the project duration.

A second iteration of the security assessment has been completed within Q2 of 2020. This approach enabled to also included the newly joined open call use cases into the security assessment. Further it allowed to update the security analysis for the initial use cases to identify and measure security improvements that have been achieved within the scope of IoF2020. Some of the analysis results are highlighted below.

In the 1st iteration 18 of 19 use cases participated in the security analysis. For the 2nd iteration 21 of 33 use cases participated (this also includes 14 open call use cases too). There were a total of 1134 threats identified. They were classified as critical, high & low types:

	Process						External Entity		Data Store				Data Flow		
Number	501						71		194				368		
Threat*)	S	T	R	I	D	E	S	R	T	R*	I	D	T	I	D
Critic	38	29	33	29	31	21	21	16	13	17	20	13	63	58	52
High	10	11	3	9	15	11	1	1	9	3	11	10	8	15	12
Low	38	44	49	45	37	46	14	18	35	5	26	31	52	50	54

*) where STRIDE stands for:
Spoofing **T**ampering **R**epudiation
Information Disclosure **D**enial of Service **E**levation of Privilege

Threats were split according to areas of impact and to respective trigger based on a data flow representation of the developed IoT solution. NXP helped partners to resolve 529 threats from identified list. Due to limited time & resource situation, focus was placed on critical threats in every use case. NXP along with partners were successfully able to **reduce 60% of critical threats** by the end of the project.

During the fruitful individual consultation calls and feedback iterations with the use cases, repeated typical challenges and problems with regard to SPT have been identified by NXP, together with suitable recommendations for standard security mitigations and resolutions.

In Q3 of 2020 NXP conducted 5 sessions to provide guidance on security threat resolutions and mitigation techniques as well as to provide an open discussion on these topics. In order to leverage synergies between use cases facing similar questions these sessions have been conducted in a trial-wise manner. Recordings and material of the held webinars and further resources are available in the SPT Basecamp area: https://3.basecamp.com/3618432/projects/13678055

In the scope of the sessions the ecosystem chair of the Dairy Trial mentioned their experience of doing security assessment with NXP. The link to blog is as follows: https://www.iof2020.eu/blog/2020/05/iof2020-dairy-trial-experience-with-the-stride-analysis

There was a plan to integrate SPT guidelines developed by NXP in IoT Catalogue as challenges, methodology, lessons learnt are applicable to any IoT use case. NXP provided all the material to Unparallel Team handling IoT Catalogue. However, Unparallel decided not to integrate in their IoT catalogue because these guidelines do not specifically mention challenges/issues faced in individual IoF2020 use cases. Due to privacy concern, it is impossible to mention security vulnerabilities of individual use case IoT solutions.

To enable reusability of these project results, learnings and the SPT material compiled during the project duration the online magazine “Security by design for developing IoT solutions” was created by WP3 in cooperation with S&P from WP5. The magazine will be available on the IoF2020 website and will be online also after project end. It should give guidance on the topic and features an interactive design which picks up the reader at a general and comprehensive level, but yet allows interested readers to dig deeper into the topic and related resources when navigating through different sections and popups. The link to the magazine is as follows: https://iof2020.h5mag.com/iof_security_by_design/cover

NXP WP3 contribution can be summarized as mentioned below

- Educated use case owners about importance of SPT
- Fostered early employment of “SPT by design” principles in system architecture (→First time right → Reduced time to market → Win customer trust)
- Established common strategy / guidelines to assess & achieve desired security maturity
- Promoted standard best practices & certified security countermeasures (→reuse & interoperability)
- Provided individual security consultation for developing secure IoT solution

Security awareness was raised among IoF2020 use cases together with the fact that security consists of three pillars as illustrated in the following Figure 41. Also security assessments should be seen as an iterative process due to changing environment, solution and threat landscape.

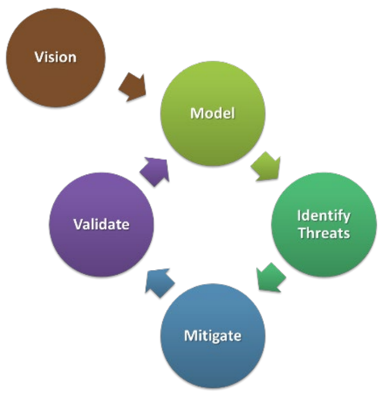

Figure 41: Three pillars for balancing security in relation to iterative realisation of security assessments.

2.8 Reflection on IoF2020 Standardisation Activities

The standardisation in IoF2020 followed different lines of action as the nature of the different sectors addressed is varying, taking into account standard development organisations and progress achieved so far. Therefore, the following shall be highlighted for different action lines:

- Agricultural equipment related data:
  - The teams were working on the ADAPT standard, to exchange data from ISOBUS (ISO 11783) to FMIS. The team in UC1.4 in close collaboration with WP3 was also validating the usage of NGSI-LD for transferring data into an Orion Context Broker Instance, driven by parties active in the AEF (i.e. CNH, 365FarmNet, Kverneland) and the FIWARE Foundation (leader of task 3.2) that is actively contributing to the evolution of ETSI NGSI-LD specs based on detected needs.
  - As an extension to ADAPT and ISOBUS, the team in UC 1.4 and specifically CNH was working on inputs for standardisation in relation to ISO 11783, with respect on an Extended Farm Data Interface (EFDI).
  - In addition to the work on ADAPT, work was also accomplished w.r.t. development of an AgriContractorsGateway that provides open source software for the integration of IoT devices and FMIS.
- Evolution of NGSI-LD API as core integration API
  - The FIWARE Foundation was actively contributing to the evolution of ETSI NGSI-LD specs based on detected needs, taking into account the requirements identified in IoF2020. It is worked on core systems integration API, core platform integration API and core API used by applications as consumers and producers of (context) data.
- The FIWARE Foundation is also working on the evolution of existing IoT Agents in FIWARE to be used combined with NGSI-LD.
  - The work is addressing incorporation of data from IoT sensors directly into digital twin representation of the farm.
  - Work is done in cooperation with OASIS and OMA.
- An effort was started by the FIWARE Foundation and TM Forum to define Common Smart Data Models for Agri-food to be used in combination to NGSI-LD (see also section 2.3).
  - The strategic objective is to make sure that systems within SoS architectures interoperate and can be integrated plug & play with low effort.
  - Collaboration takes also place with ETSI, GSMA, and AgGateway. In late 2019 it was started to work on a memorandum of cooperation between the FIWARE Foundation and AgGateway.
  - The initiative was launched with a space available on GitHub in February 2020, gathering different available data models, based on existing standards, while also filling gaps in collaboration with the IoF 2020 use cases. Adding related outcome of the collaboration in June 2020. The second collection of smart data models integrating AgGateway models was accomplished in Nov 2020.
  - The space in GitHub was also complemented with an own URL (https://smartdatamodels.org)
  - Complementary to this, also an AgroWeatherGateway was implemented that is based on the related standards and is made available as open source software, aiming at facilitating the integration of weather stations, as several IoF2020 use cases were challenged with this.
- Marketplace for standards and code lists (see also section 2.5)
  - Based on a cooperation with AgGateway Europe, a marketplace was implemented to publish key standards and code lists that are relevant for IoT based solutions in agri-food. The related IoF2020 partner ficodes also plans to operate the marketplace beyond IoF2020.
- EPCIS/NGSI-LD gateway for tracking agri-food products.
  - GS1 was working on the integration of event based IoT data communication (i.e. as usual in EPCIS environments) with entity based data communication as usual in NGSI-LD environments.
  - Based on use case related work, those views were mapped. It became clear that it can be combined, however, requiring also a practical solution for integration of commonly used systems.
  - Work in IoF2020 delivered an EPCIS/NGSI-LD gateway enabling tracking of products in SoS architectures, also based on cooperation with the Korean partner organisation KAIST. The resulting software was published as open source software, available as FIWARE Generic Enabler in 2020.
- Members of the GS1 team in IoF2020 were mainly contributing to the launch and operation of a mission-specific work group on EPCIS & CBV 2.0 (i.e., ISO/IEC 19987 & 19988). The work group adds a

range of backward-compatible functional enhancements to EPCIS and the CBV standards, grouped into a number of distinct but interwoven bundles:

- Support for sensor-captured data in EPCIS events (e.g., cold chain temperature excursions)
- Inclusion of party certification information in EPCIS data (e.g., record of trade-relevant supplier certifications)
- Optimised, agile, Comprehensive Business Vocabulary (including machine-readable attributes for event validation)
- Addition of JSON/JSON-LD syntax to EPCIS (for developers preferring more compact data models)
- Addition of REST binding support to EPCIS (to overcome high entry barriers of web-services)
- Diverse minor adjustments to EPCIS & CBV specs (various modifications to improve usability)
- The Mission-Specific Work Group (MSWG) will gather the community and expertise needed to complete the enhancements to EPCIS and the CBV.

Moreover, IoF2020 was joining Activity Group 2 of the large-scale pilot projects (LSPs), specifically addressing standardisation. The work was moving towards the topics of interoperability while also reuse of results and replicability of IoT based solutions. In collaboration with Synchronicity, it was agreed that the concept of the so-called Minimum Interoperability Mechanisms (MIMs) is combining those aspects in terms of data exchange related standards as well as identifying generic key components that will facilitate especially reuse and replicability. Therefore, IoF2020 as well as Synchronicity were promoting related work as presented for IoF 2020 in the deliverables D3.3 and D3.11 and aligned their work in relation to the standard development organisations and realisation of open-source software components.

As the IoF2020 project was running longer than the other LSPs, IoF2020 was organising 4 workshops between March 2020 and March 2021 on the topic semantic interoperability, as well as joining additional workshops organised in cooperation with OPEN DEI and NGIoT:

- Organisation of the IoF2020 workshop on interoperability on March 25th 2020 with presentations of the projects OpenDEI, ATLAS, FairShare, Cybele and also presenting the IoF2020 Pathway towards Interoperability: Exploitation and contribution to standards and open data models.
- Presentation at the NGIoT Workshop: IoT and Edge Computing – Future directions for Europe on September 11th 2020 – presenting Food/Farming key scenarios and emerging needs in Edge IoT.
- FIWARE Agri-Food Day on November 12th 2020, including IoF2020 related presentations:
  - Interoperability of entity-based and event-based IoT platforms
  - FIWARE for agri-food vision and roadmap
  - A more productive and transparent livestock farming with cattle chain
  - AgriGateways as vertical domain open source applications based on FIWARE
- Presentation at the ICT-AGRI-FOOD knowledge exchange forum on "Bringing research results to market“ on November 19th 2020 – presenting the usage of a FIWARE standard context broker and system of system approach that was used in several IoF2020 use cases.
- Organisation of the IoF2020 Workshop “Standardization & Semantic Interoperability” on December 17th 2020 with involvement of different innovation projects (i.e. ATLAS, DEMETER, NIVA, OpenDEI, SmartAgriHubs) and an IoF2020 presentation on Interoperability Challenges and Standardization at market speed.
- Organisation of the IoF2020 Workshop on March 10th 2021 on “What is the meaning of semantics without cooperation?”, involving different innovation projects and SDOs, discussing also semantics in the scope of the IoF2020 experience.
- Presentation of the WP3 results in the scope of the public IoF2020 final event on March 17th 2020.
- Presentation of WP3 perspective at the “NGIoT Thematic Workshop: Rural Smart Communities and Agrifood” on March 30th 2021.

Besides the ongoing involvement of colleagues from LSPs, it was also possible to involve additional projects like e.g. ATLAS, DEMETER, OPEN DEI, FAIRSHARE, CYBELE, NGIoT, SmartAgriHubs but also SDOs like AEF, AgGateway and GS1. The last workshop organised by IoF2020 was co-located with the IoF2020 final event on March 17th 2021. However, the work will be continued, while being headed after the end of IoF2020 by OpenDEI, ATLAS, DEMTER and NGIoT. On top of that, all relevant results are compiled in an overview (i.e., the IoF2020 legacy) and were handed over to the SmartAgriHubs project to be integrated in the SAH portal.

3 The IoF2020 Use Cases – Key Characteristics

The IoF2020 large scale project was realising 33 use cases that can be divided into two groups in relation to their timing:

- **19 use cases** have started at the beginning of the project
- **14 uses cases** were added to the project through an **open call** and started their activities in *January 2019*.

WP3 had an active role in identifying synergies among use cases, recognizing needs that can be fulfilled by generic IoT reusable components as also presented in Deliverable D3.1. Each use case is developing an IoT solution for a specific problem. This means IoF2020 produced a set of **33 IoT based solutions** in the agri-food domain. Although the realised solutions are individual, there is collaboration among the use cases, and relevant synergies have been identified and followed. The **33** IoF2020 use cases are distributed over five different trials:

- The **arable trial** focuses on wheat, soy bean and potato production and processing in different climate zones. It includes activities across the cropping cycle and machine-to-machine communication. Overall, the use of IoT in arable farming can help to reduce pesticide, fertilizer and energy use, while increasing transparency and food safety.
- The **dairy trial** explores the usefulness of collecting rea-time sensor and GPS location data throughout the whole dairy chain, i.e. from grass to glass. It includes monitoring outdoor grazing cows, application of machine learning technologies and cloud-based services.
- The **fruit trial** aims to gather data on pre- and post-harvest losses to increase the yield and quality of fruits, as well as ensure better traceability of fruit products in relation to the protected designation of origin.
- The **vegetables** trial aims to improve the quality and productivity of lettuce and tomatoes in the controlled cultivation and weeding of the vegetables in organic production. The trial includes use cases in different climate conditions, such as fully controlled indoor greenhouses to open-air cultivation.
- The **meat trial** aims to improve the meat production chains value, addressing activities related to management and optimization of meat production, transparency and traceability. The trial includes use cases related to pork, beef and poultry.

The following Figure 42 is presenting an overview of the IoF2020 use cases also indicating the location of partners that are active in the use cases. Moreover, the following Table 6 is listing for each use case a short description, the application areas addressed as well as the IoT related platforms and devices.

Figure 42: Overview of all use cases of the IoF2020 project.

Table 6: The IoF2020 Use Cases, grouped by sectorial trials.

Trial	Nr.	Name/Chain/Ctry	Short Description	Application Areas Addressed	IoT related platforms and devices
			The Internet of Arable Farming		
T1 Arable	1.1	Within-field management zoning Farming, Logistics **NL**, DE, BE	Defining specific field management zones by developing and linking sensing- and actuating devices with external data.	Management zoning of arable fields; Crop protection; Yield prediction	**Akkerweb**; **Trimble Farm Works**; GPS Sensors; **LoRa WAN**; Soil sensors
	1.2	Precision Crop Management Farming **FR**	Smart wheat crop management by sensors data embedded in a low-power, long-range network infrastructure.	Nitrogen and water monitoring; Precision irrigation control; Crop growth optimization	**FIWARE**, Bosch/Hiphen sensors & gateway; **Bosch cloud; Orange cloud**; free Satellite images from SENTINEL2
	1.3	Soya Protein Management Farming **IT** + Danube countries (CH, RS, **AT**, SK, HR, RO, CZ, UA)	Improving protein production by combining sensor data and translate them into effective machine task operations.	Protein monitoring & forecasting; Rational water usage (irrigation); Mechanical weeding	**365FarmNet**; **SigFox & BLE Wireless Radio**; different sensors for soil, plants & weather
	1.4	Farm Machine Interoperability Farming **NL**, DK, DE, BE	Data exchange between field machinery and farm management information systems for supporting cross-over pilot machine communication.	Sustainable soil tillage; Machine to machine communication for application of task maps; Farm equipment data sharing	**365FarmNet**; **Akkerweb**; **Farm Equipment Manufacturer clouds (CNH, Kverneland)**; sensors for soil, crop & weather
	1.5	Potato Data Processing Exchange Farming, Processing **BE**, NL, **PL**	Data exchange between field and potato processing industry to optimise logistical and quality processes.	Yield prediction, Yield calibre management, Traceability from field to shed after harvesting	**Aurea's cloud platform**; **Microsoft Azure Cloud**; drones, weighing sensors, cameras, RFID
	1.6	Data-Driven Potato Production Farming, Processing **CY, PL, UA**	Smart farming-based services for fertilization, irrigation and pest management, using data from telemetric IoT stations.	Rational water usage (irrigation); Precision fertilization; Pest management; Crop growth optimization	**FIWARE**; **Gaiasense**; **Neuropublic cloud**; Sensors for soil, crop & weather; Satellite data from Sentinel

Trial	Nr.	Name/Chain/Ctry	Short Description	Application Areas Addressed	IoT related platforms and devices
			The Internet of Arable Farming		
	1.7	Traceability For Food And Feed Logistics Farm Asset Production, Farming **BE**, NL, **PL**, FR, BG, RO, ES, SI	Secure and authenticate transport of bulk goods in the agri-food chain guaranteeing a fully traceable delivery of animal feed and human food.	Automatic silo detection; Data exchange between silo, trailer and load stations	**Smart silo server**; LoRa silo reader; silo related sensors; RFID
	1.8	Solar-Powered Field Sensors Farming **DE, RO, HU**	Sensor-based farm management for predictive analysis of diseases, and smart community sensor network to help farmers adopt sustainable farm practices and improve overall agricultural efficiency.	Soil conditions monitoring; climate monitoring; Crop growth optimization; Crop disease recognition	**AWS IoT Core**; soil & weather sensors; Satellite data from Sentinel to be introduced in commercialisation phase
	1.9	Within-Field Manage–ment Zoning Baltics Farming **LT, LV**	Determine macro- and micro-nutritional elements at different stages of plant growth using hyperspectral imaging to increase productivity of plants.	Plant micro- and macro nutrient characterisation; Precision fertilization; Early plant stress detection; Crop management; Yield prediction	**AgroSmart FMIS**; hyperspectral imagers; Self-driven UAV; SpectroRadiometer; Publicly available Satellite data from Sentinel
			The Internet of Dairy Farming		
T2 Dairy	2.1	Grazing Cow Monitor Farming **BE**, NL	Monitoring and managing the outdoor grazing of cows by GPS tracking within ultra-narrow band communication networks.	Cow Tracking and Tracing; Pasture Time Monitoring	**Sensolus IOT cloud platform**; **SigFox**; GPS tracker/ collar sensors; Geobeacons
T2 Dairy	2.2	Happy Cow Farming **NL**	Improving dairy farm productivity through 3D cow activity sensing and cloud machine learning technologies.	Real-time 3D monitoring of dairy cow activity; Animal Health Management; Cow Fertility Management	**Ida Cloud Platform**; collar sensors and gateways
T2 Dairy	2.3	Silent Herdsman Farming **UK**	Herd alert management by a high node count distributed sensor network and a cloud-based platform for decision-making.	Monitoring of animal behaviour (motion); Early detection of livestock diseases	**365FarmNet; GEA FarmView; Afimilk mySilentHerdsman platform**; collar sensors and gateways
T2 Dairy	2.4	Remote Milk Quality Processing, Consumption **NL**	Remote quality assurance of accurate instruments and analysis & pro-active control in the dairy chain.	Remote quality monitoring of raw-, half- and end-products; Validation/calibration quality info; Product composition analysis (incl. fresh-grazed grass & cow pregnancy indicators)	**Milk quality measurement platform**; milk RFID sample containers; "factory-based" RFID controlled autonomous milk measurement & transport lines

Trial	Nr.	Name/Chain/Ctry	Short Description	Application Areas Addressed	IoT related platforms and devices
			The Internet of Arable Farming		
	2.5	MELD - Early Lameness Detection through Machine Learning Farming **IE, PT, IL, ZA**	Provide lame detection as a service using leg mounted sensors and collars in cattle.	Early detection of anomalies in pasture-based cattle herds; Monitoring of animal behaviour (motion)	**Cloud Based Machine Learning platform**; **FIWARE**; collar sensors; pedometers
	2.6	Pitstop+ - Precision Mineral Supplementation Farming **LV, LT, DE, DK**	Precision livestock farming mineral supplementation at dairy farms to improve animal welfare, resource usage and reduce environmental impact.	Animal Health Management; Precision feeding (mineral supplementation); Dairy production optimization; Cattle performance monitoring (health, production and reproduction)	**MS Azure**; ear tags; mineral feeder; ear tags; LoRa gateway
	2.7	Smart Precision Multi-sensor Cow Monitoring Farming, Processing **HU**, CZ, PL, SVK	Smart multi-sensor devices equipped with long range low power communication technology for precision dairy and beef cattle monitoring	Animal welfare monitoring; Optimize use of medication; Traceability; Accurate heat detection and calving alert	**Moonsyst Mooncloud platfrom**; Rumen Bolus; LoRa Gateway
			The Internet of Fruits		
T3 Fruit	3.1	Fresh table grapes chain Farming, Packaging **IT, EL**, BE	Real-time monitoring and control of water supply and crop protection of table grapes and predicting shelf life.	Smart Irrigation; Variable Rate Spraying; Smart Post-Harvest Processing & Packaging	**SynField Ecosystem**; **FIWARE; SigFox; Bluleaf DSS**; soil & weather sensors; irrigation actuators, BLOW device
T3 Fruit	3.2	Big wine optimization Farming, Processing **FR, IT**	Optimizing cultivation and processing of wine by sensor-actuator networks and big data analysis within a cloud framework.	Pest Management; Selective Harvesting; Wine Cellar Monitoring	**sensiNACT**; **FIWARE**; **Wenda SW platform**; weather sensors, fixed & mobile cameras; LoRa devices and gateways; water & electricity meters
T3 Fruit	3.3	Automated olive chain Farming, Processing **ES, EL**	Automated field control, product segmentation, processing and commercialisation of olives and olive oil.	Fertigation; Harvesting Logistics; Smart Mill Processing	**FIWARE; SynField cloud-based sensor-logging ecosystem**; soil sensors; water meters; weather sensors;
T3 Fruit	3.4	Intelligent fruit logistics Logistics,Consumption **DE, NL**	Fresh fruit logistics through virtualization of fruit products by intelligent trays within a low-power long-range network infrastructure.	Returnable Transport Items (RTI) for Fruits packaging and transporting; Field to Fork logistics; Super Market Placing and Monitoring	**ViZiX; MS Azure; SigFox**; **EPCAT**; NXP Smart Tray Sensors

Trial	Nr.	Name/Chain/Ctry	Short Description	Application Areas Addressed	IoT related platforms and devices
			The Internet of Arable Farming		
	3.5	Smartomizer - Smart Orchard Spray Application Farming **HU**, **PL**, **PT**	Use air blast atomizing sprayers to significantly reduce amount of plant production product used in three agricultural subsectors (cherry, apple and almond).	Farm resource job optimization; Specialty crops precise spraying; Machine to machine communication	**Specialty Crop Platform**; GNSS & speed sensors; sprayer related sensors; cellular gateway
	3.6	BIT Farming, Processing, Packaging, Logistics, Consumption **IT**, **PT**, **RO**, **CH**, **FR**, **HU**, **ES**,	Monitor the whole wine and beverage distribution channel, from producer to consumer, to prevent damages during shipping and storage.	Beverage integrity tracker; Product state-of-health assessment; Beverage box monitoring	**WENDA platform**; Bluetooth data loggers including sensors to monitor wine transport; blockchain
			The Internet of Vegetables		
T4 Vegetables	4.1	City farming leafy vegetables (City) Farming, Logistics **NL**	Value chain innovation for leafy vegetables in convenience foods by integrated indoor climate control and logistics.	Advanced sensing of crop conditions in indoor farming; Automatic execution of growth recipes; Integrate production with processing & distribution	**Signify GrowView and data backend**; Lighting control system, indoor climate sensors; Camera; Lightning; AirCon
	4.2	Chain-integrated greenhouse production Farming, Logistics, Consumption **ES**, IT	Integrating the value chain and quality innovation by developing a full sensor-actuator-based system in tomato greenhouses.	Traceability and monitoring ambient conditions of fresh tomatoes along value chains; Pesticide residue management; Energy efficiency management	**FIWARE**; **iVeg platform**; diverse greenhouse climate sensors for inside and outside measurements; weather station; soil sensors; irrigation actuators
	4.3	Added value weeding data Farming **NL**, AT	Boosting the value chain by harvesting weeding data of organic vegetables obtained by advanced visioning systems.	Automated weed control; Crop monitoring and harvest prediction based on weeding data; Optimizing weeding efficiency	**365FarmNet; Akkerweb**; weather station; cameras; GNSS sensor
	4.4	Enhanced quality certification system Farming, Logistics, Consumption **IT**, ES	Enhanced trust and simplification of quality certification systems by use of sensors, RFID tags and intelligent chain analysis.	Compliance to PDO, organic and GlobalGap certification; tracking and tracing, verification of product origin and production method	**Cellar inspection app**

Trial	Nr.	Name/Chain/Ctry	Short Description	Application Areas Addressed	IoT related platforms and devices
			The Internet of Arable Farming		
	4.5	CYSLOP - Digital Ecosystem Utilization Farming, Processing, Logistics, Consumption **GR**, **CY**, **SI**	Increase total farm productivity by delivering tailored information to farmers based on data acquired by IoT devices.	Crop optimization; Plant protection; Irrigation scheduling; Product traceability	**FINoT platform**; FINoT smart agri gateway; FINoT MicroClimate station; FINoT irrigation controller
			The Internet of Meat		
T5 Meat	**5.1**	Pig farm management Farming, Processing, Consumption **BE**, **NL**, IT	Optimise pig production management by interoperable on-farm sensors and slaughter house data.	Pig production monitoring and early warning; Boar taint detection; Informing consumers about production conditions	**FANCOM management software; FarmConnect; Nedap webtool; LINKS IoT platform; FIWARE;** feeding sensors; indoor climate sensors; weight sensors; RFID tags;
T5 Meat	**5.2**	Poultry chain management Farming, Logistics, Processing **ES**, BE	Optimize production, transport and processing of poultry meat by automated ambient monitoring & control and data analysis.	Poultry growth monitoring and weight prediction; Monitoring of picking & logistics; Poultry category assessment slaughterhouse	**Poultry Meat Chain Platform; FIWARE;** water & environment sensors, animal & silo scale; smart bracelets; gateways
T5 Meat	**5.3**	Meat Transparency and Traceability Farming, Logistics, Processing, Consumption **NL**, DE	Enhancing transparency and traceability of meat based on a monitored chain event data in an EPCIS-infrastructure.	Transparency food safety and quality information; Cold chain monitoring; Quality decay prediction and pro-active alerts	**EPCAT based traceability and quality solution; FIWARE;** OLIOT gateway;
T5 Meat	**5.4**	ShareBeef - Decision-making Optimisation in Beef Supply Chain Farm Asset Production, Farming, Processing, Logistics, Consumption **BG**, **HR**, **IE**, **IT**, **PT**, **ES**	Shared value system to integrate and share data along the food supply chain to improve resource efficiency and customer satisfaction.	Animal welfare monitoring; Crop monitoring and optimization; Product certification; Traceability; Data sharing	**FIWARE; Digitanimal smart collars; SigFox**; Sentinel 2 open data; BLE tags; Animal RFID tags; automatic scale; weather and soil sensors
T5 Meat	**5.5**	IoFeed - Feed Supply Chain Management Farm Asset Production, Farming **ES**, **UK**, **DE**	Integral feedstock management system based on 3D camera technology used to monitor stock levels in farms' silos.	Animal feed delivery optimization; Monitor silo content; Logistics optimization	**INSYLO Remote Monitoring platform; FIWARE; LWM2M Cloud Platform**; INSYLO Volumetric sensor;

Trial	Nr.	Name/Chain/Ctry	Short Description	Application Areas Addressed	IoT related platforms and devices
			The Internet of Arable Farming		
	5.6	FitPig - Interoperable Pig Health Tracking Farming **SE**, ES, CH	Context-based alarm and decision support using data collected from monitoring physiological signs from pigs.	Monitor pig welfare; Optimize use of medication; Food safety; Piglet mortality management	**Smart Spot Gateway; FIWARE;** Integrated ear tag sensors; LoRa

The overview presented in Table 6 identifies that there are also certain similarities with respect to the purpose of the IoT based solutions, when considering the different trial areas. One can identify the following perspectives:

- **Trial 1 Arable:**
  The main focus is on analysing the soil, crop and weather conditions, while also using farm equipment, drones and satellite data as input. The sector is based on a long-time cooperation and standardisation effort of equipment manufacturers, while specifically interoperability in combination with Farm Management Information Systems plays a significant role. Due to machine usage, there is not necessarily a shortage of energy, but also challenged by the available connectivity in remote fields.
- **Trial 2 Dairy:**
  The focus is mainly on the animal status, its behaviour, and health observation. Most use cases are deploying collar based solutions that are uniquely identifying the animals and directly tracking required information by the sensors. Depending on the type of connectivity, it requires different settings and imposes also related challenges to assure quality of communication.
- **Trial 3 Fruits:**
  A majority of the use cases are also monitoring the environmental and soil conditions: On top of that, they are also monitoring the specific conditions of the fruits as indicator for related control. Moreover, some use cases are also serving the needs along the food chain, facilitating tracking and tracing, taking care for food conditions along the transport chain.
- **Trial 4 Vegetables:**
  Especially the vertical farming and greenhouse related use cases are excellent examples for the usage of diverse sensors, actuators, middleware, control and optimisation systems. The data is aggregated and allows an optimal growth, while the vertical farming is even opening new potentials towards farming, not depending on external constraints.
- **Trial 5 Meat:**
  There are similarities to trial 2 in terms of the motivation of monitoring health and animal conditions. However, the monitoring needs to use other strategies as the amount and value of animals does not necessarily allow the usage of collars, while trying first ear tags to also monitor related data. At the same time, tracking and tracing shall enable to provide added value information to consumers.

The following chapters 4 to 7 are presenting further details of the realised IoT based solutions accordingly.

4 Deployed Components in the IoF2020 Use Cases

The IoF2020 use cases were realising diverse IoT based solutions. To search about details, it is recommended to use the IoT catalogue (https://www.iot-catalogue.com/) that is facilitating the search by linking the different aspects beyond individual use cases as well as providing further information about the places, teams and individual components. On top of that, the catalogue is grouping IoT related components in relation to the developed solutions. This helps to identify related experience and teams. Moreover, the IoT catalogue also implemented an interactive project navigator that is presenting all the relations of the catalogue content, facilitating search and discovery of results, as presented in the following Figure 43. Moreover, the catalogue is presenting Key Performance Indicators to learn about the addressed business objectives as well as achieved results.

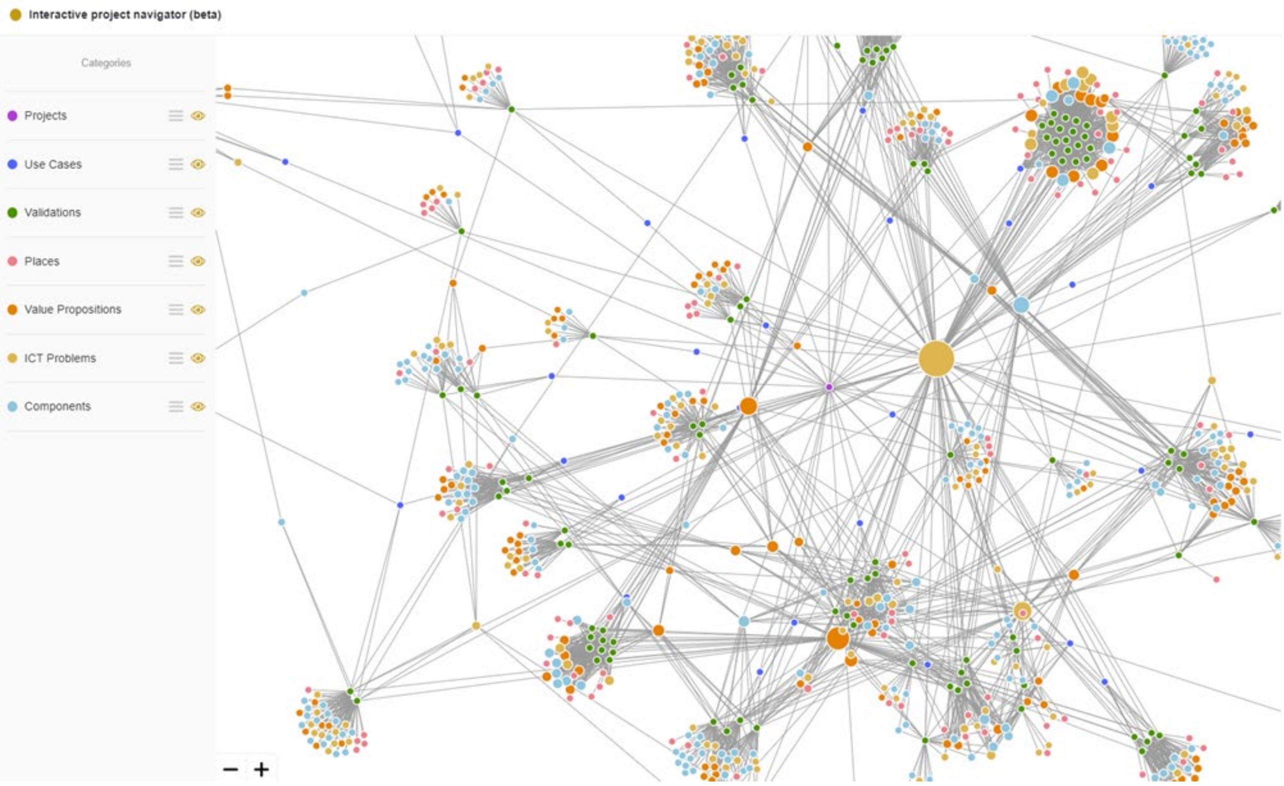

Figure 43: IoT catalogue interactive project navigator.

However, the following Table 7 is listing the deployed components per use case in the last reporting period, to give an overview about the solutions that are operational at IoF2020 project end. The term “component” is used for heterogeneous hardware and software items at diverse complexity level. The purpose is not to list at a similar abstraction level, but to provide an understanding what was finally deployed in real operational environments at the use case deployment sites. The number of devices is only presented for hardware type of components as this representation is rather inappropriate for software especially at the application layer.

Table 7: Deployed Components in the IoF2020 use cases.

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
1.1	Combine Harvester	Actuator	Combines three essential harvest functions – reaping, threshing and winnowing, where different types of harvesting products can be harvested with a head designed for that particular grain	1	1

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
1.1	Potato Planter	Actuator	Plants potatoes	2	2
1.1	Potato Harvester	Actuator	Harvest potatoes	2	1
1.1	Plow	Actuator	Cut, lift and turn over the soil to prepare a seedbed	2	1
1.1	Liqued fertilizer	Actuator	It fertilizes the soil, while the tractor is passing through the field	2	1
1.1	Herbicide application	Actuator	It applies herbicide in the soil, while the tractor is passing through the field	2	1
1.1	Fungicide application	Actuator	Applies fungicide in the soil, while the tractor is passing through the field	2	1
1.1	Fertiliser spreader	Actuator	Spreads the fertiliser	2	1
1.1	Bouwland Injecteur	Actuator	Actuates on the injector	2	1
1.1	Tracking/ locate Filler	Tracking system	Tracks the tractors on the field	2	1
1.1	Weather Station	Sensor	Measure and collects Weather data	3	1
1.1	Biomass Sensor	Sensor	Senses biomass	2	2
1.1	SoilScanner	Sensor	Senses the soil	2	1
1.1	Cropsensor	Sensor	Senses the crops	2	1
1.1	AgLeader	Application	Generates reports, informative charts and field maps to the end user based on the data from deployed sensors	N/A	2
1.1	365FarmNet	Application	Software for automated and complete documentation in the field and in the stable. It creates transparency about work processes and costs	N/A	2
1.1	Akkerweb/ FarmMaps	Application	Akkerweb assists farmers with targeted application of irrigation, fertilisation, crop protection and soil tillage	N/A	2
1.1	Crop-R	Application	Gets data from the Weather stations	N/A	2
1.1	Zoner	Application	Organizes, store, and analyse information in precision agriculture. The system carries out the analysis of satellite images, aerial imagery, yield monitor data and soil EC, terrain and other georeferenced data	N/A	2
1.1	Farm Works	Application	Allows the visualisation of precision farming data. It supports all types of data from planting to harvest, providing powerful maps and reports	N/A	2
1.2	Sentinel 2 (Satellite images)	Application	Nitrogen and Water Management based on Satellite images	N/A	1

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
1.2	Field Sensor	Sensor	Senses the Field	39	2
1.2	Cloud	Data plat-form	Shares Cloud Data	N/A	1
1.2	Server	Data plat-form	Advises on Nitrogen and Water man-agement, and generates new knowledge through data mining (ana-lysing multiple fields)	N/A	1
1.2	Rain gauges	Sensor	Measures precipitation	5	1
1.3	Sigfox soil mois-ture sensor	Sensor	Measure soil moisture and tempera-ture	1	1
1.3	Sigfox Meteo station	Sensor	Measure precipitation, air tempera-ture, air humidity, wind speed, wind direction, radiation	1	1
1.3	GPRS Meteo station	Sensor	Measure precipitation, air tempera-ture, air humidity, wind speed, wind direction, radiation	1	1
1.3	Yield monitor	Sensor	Track yield and gps-position during harvest	3	3
1.3	Telematic kit for combines	Gateway	Transmit combines canbus data (e.g. yield monitor) to cloud	1	1
1.4	Combine Har-vester	Actuator	combines three essential harvest functions – reaping, threshing and winnowing, where different types of harvesting products can be harvested with a head designed for that particu-lar grain	1	1
1.4	GeoJSON plugin	Software Li-brary (ADAPT Plugin)	Exporting Geospatial data in de ADAPT data model to GeoJSON files	N/A	1
1.5	Yield Measure-ment System	Sensor with electronic PCB (Printed Circuit Board)	Measure Yield	8	4
1.5	RFID Track & Trace Solution	Sensor	System for traceability from field to shed (RFID tags and RFID reader)	1	2
1.5	Improved Yield Measurement System	Sensor	Measure Yield (Camera system & LED lighting	2	2
1.6	Gaitron stations	Environmen-tal sensing stations	Measures the air temperature, air hu-midity, leaf wetness, wind direction and speed, solar radiation, precipita-tion, atmospheric	9	3
1.6	GaiaCloud	Cloud	Collect Sensor measurement made by the Gaitron stations to a Database	N/A	1

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
1.6	Gaiasense Dashboard	Web-based GUI	A web-based GUI which renders all the collected information along with the outcomes of the DSS models	N/A	1
1.6	NGSIv2 Translator	Data converter to NGSIv2	Convert gaiasense data to NGSIv2	N/A	1
1.6	Orion Context Broker	Orion Context Broker allows to manage the entire lifecycle of context information including updates, queries, registrations and subscriptions	[CRUD] NGSIv2 data (CRUD: Create, Retrieve, Update, Delete)	N/A	1
1.6	Context-Aware Decision Support & Data analytics	DSS system	[notify] user upon predefined incidents (e.g. sensed temperature <0)	N/A	1
1.6	IoT4Potato Application GUI	Web-based GUI	Visualise sensor Measurements, pest infestation risk, irrigation needs and farm calendar	N/A	1
1.7	Flow sensor sleeve	Sensor	Flow sensor protection	25	2
1.7	Flow sensor	Sensor	Air flow detection	25	2
1.7	TAG	Label NTAG213	Silo identification	6	3
1.7	Siloreader	Wireless device	Tag reader	7	7
1.7	PLC + CPU	Controller	Wire communication docking station trailer cabinet	7	7
1.7	Smart Silo Server	IoT Platform	Data logging of the silos, trailers and deliveries	N/A	1
1.7	Pepwave	Network Device	Connectivity from different trailers	7	1
1.8	SV-8CLoRaWAN	Gateway	Gateway- Lora, Wifi, LTE and Lightening arrestor	18	11
1.8	AS30	Sensor	Sensor- 2 levels moisture, ec, soil temp, solar irradiance, air temp, pressure, humidity, npk, soc	337	11
1.8	AS60	Sensor	Sensor- 3 levels moisture, ec, soil.temp, solar irradiance, airtemp, pressure, humidity, npk, soc	280	11

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
1.9	UAV	Drone	Perform flights	1	10
1.9	Hyperspectral imager	Sensor	Capture hyperspectral data	1	10
1.9	Hyperspectral image capture software	Software	Capture hyperspectral data	N/A	10
1.9	Hyperspectral image pro-cessing software	Software	Capture hyperspectral data	N/A	10
1.9	Hyperspectral image stitching software	Software	Capture hyperspectral data	N/A	10
1.9	Spectro Radiometer	Sensor	Calibrate hyperspectral imager	1	10
1.9	AgroSmart FMIS	Software	Provide the interface for data analysis	N/A	10
2.1	Sensolus tracker	GPS	Tracks	83	1
2.1	Sensolus geobeacon	Hardware	Provides indoor location, movement detection and zone detection. The Geobeacon is detected by the Sen-solus StickNtrack GPS / Beacon Pro once it is in reach of the beacon. As such, the indoor location is sent to the Cloud	3	1
2.1	Sigfox network	IoT/ LPWAN network	Communication, data transfer from sensors (tracker, geobea-con) to the Cloud	N/A	1
2.1	Sensolus cloud	Data storage	Generates reports, alerts. Monitors activity and share cloud data	1	1
2.1	Sensolus webapp	Data visuali-zation	Allows the visualization of the data coming from the Sensolus cloud	N/A	1
2.2	Receiver (Con-necterra Gen 2)	Base station receiver	Receive raw sensor data, process the data and send it to the could	4	4
2.2	Cow sensor (Connecterra Gen3.2)	Sensor (at-tacked to the cow collar)	Measure acceleration in 3 dimen-sions and transmit this data to the base station	313	4
2.2	Ida Platform (Connecterra)	Cloud	Process real time behaviour data from the farm and run artificial intelli-gence on the data and generate and send insights based on this data.	N/A	4
2.3	Milking Robot	Milking sta-tions/Sensor	Milking	4	2
2.3	Feeder Wagon/ Stations	Feeding sta-tions/Sensor	Feeding	6	2
2.3	Neck-Mounted Collars	Sensor	Monitoring activity/ eating/ ruminating	350	2
2.3	Ear Tags	Sensor	Monitoring activity	100	1

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
2.3	Pedometers	Sensor	Monitoring step count/laying/walking	100	1
2.4	RDQ tool	Low code software platform for web-devel-opment	Managing & calibrating IR devices	N/A	3
2.5	Pedometer for cattle	Sensor	Measures step count, lying time per animal	1285	4
2.5	Collar based Monitor	Sensor	Tracks animal position	60	1
2.5	ELD Machine Learning Algo-rithm #2	Software	Detects lameness	N/A	2
2.5	Cloud Based Machine Learn-ing platform	Software platform	Hosts the system software for data collection, machine learning and lameness record management	N/A	1
2.5	Mobile App	Mobile App	Provides the end user with a lame-ness lifecycle management, lame-ness alerts. Also feedback to retrain-ing the ML models	N/A	5
2.5	Vendor Dash-board	Web based Dashboard	Provides a vendor view of trial de-ployments	N/A	2
2.6	Ear Tags	Actuator	Enable reading cows ISO tag ID	2500	7
2.6	Master Unit (Microfeeder)	Gateway	Communication and temporary data storage	7	7
2.6	Mineral feeder	Sensor	Sensing and dosing	27	7
2.6	The Cloud	Database, IoT platform	Data storage	N/A	7
2.6	User Interface	Application	Monitoring and supervision	N/A	7
2.6	Big data	Office, Azure (Big Data)	Monitoring, remote-controlled soft-ware updating, and collection and analysis of "big data" from one farm or a given number of herds, maybe a particular geographical area	N/A	7
2.7	Smart Rumen Bolus	Sensor	Measure temperature, activity and pH	131	5
2.7	Application layer	End-user ap-plication	Alerts, events, tasks	N/A	5
2.7	Information man-agement and business logic layer	Server/Data-base	LoRaWAN network management / Moonsyst dataprocess	N/A	5
2.7	Physical layer	Gateway	Data forwarder	14	5
2.7	LoRaWAN net-work	IoT/LPWAN network	Low Power, Wide Area (LPWA) net-working protocol	N/A	5

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
3.1	Bluleaf DSS	End-user related application	Shares cloud data, reports analytics and monitors Irrigation, Fertigation, Moisture and Weather	N/A	2
3.1	Overall cloud service	Integration platform	Cloud platform which includes all the data collected by the sensors	N/A	2
3.1	IoT TH (Thermo-Hygrometer)	Sensor	Senses Temperature and Humidity	2	1
3.1	IoT soil moisture sensor	Sensor	Senses moisture in the soil	7	1
3.1	IoT rain gauge	Sensor	Measures precipitation	2	1
3.1	IoT anemometer	Sensor	Measures wind speed and wind pressure	2	1
3.1	IoT PAR (Photosynthetically Active Radiation)	Sensor	Senses photosynthesis based on light	2	1
3.1	IoT pyranometer	Sensor	Measures solar irradiance	1	1
3.1	LoRa IoT actuation node	Actuator	It allow to control and actuate on a specific point of the architecture	1	1
3.1	LoRa IoT soil moisture sensor	Sensor	Senses soil moisture	4	1
3.1	SynField (3 versions were deployed)	Data Logger	Logs environmental data and forwards it to a SynField Webserver	1	1
3.1	EC5	Soil Moisture Sensor (VWC)	Senses soil moisture	2	1
3.1	5TE	Electrical Conductivity + Temperature + Soil Moisture Sensor	Senses electrical conductivity, temperature, and soil moisture	1	1
3.1	WindMeter	Wind Meter Sensor	Senses speed of Wind	1	1
3.1	WindDirection	Wind Direction Sensor	Senses direction of Wind	1	1
3.1	RainMeter	Rain Meter Sensor	Senses Rain	1	1
3.1	RHTempSensor	Relative Humidity and Temperature Sensor	Senses relative humidity and temperature	1	1
3.1	Solenoid valves	3'' Solenoid Valves	Controls the water flow	2	1

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
3.2	Davis Weather Station	Sensor	Temperature, Humidity, Rain fall, Barometric pressure, Solar radiation, Wind speed and direction	9	5
3.2	Micro-Weather station	Sensor	Temperature and Humidity	10	3
3.2	Water-meter	Sensor	Flow and water meter	28	6
3.2	Electricity –meter	Sensor	Energy index (active and reactive)	7	5
3.2	Mobile phenol-ogy camera sen-sor prototype #2	Sensor	[Estimation] [Yield] (fruit density) [Map] [Vigor] (leaf area)	2	2
3.2	Foxed phenology camera sensor prototype #2	Sensor	[Measure] [Vigor] (leaf area and NDVI)	2	1
3.2	Cap Trap	Sensor	[Alert] [Insects] (eudemis)	1	1
3.2	Gateway	Gateway	Gateway LoRa to Ethernet protocol	2	1
3.2	Gateway	Gateway	Gateway LoRa to Ethernet protocol	3	1
3.2	Data Logger pro-totype	System with sensors, wireless de-vices, IoT platform, FI-WARE	Temperature, Humidity, Light, accel-erometer for shocks and Geolocalisa-tion	6	7
3.3	WSN Platform	Platform	Predicts Irrigation, market vol-ume/price, Monitors Leaf Wetness and Crop Growth and plagues, it also get the measurements for all sensors deployed	N/A	4
3.3	NIR sensor in Ol-ive Mill	Sensor	Measures protein, temperature, fibre, ash and moisture	2	2
3.3	Agriculture anal-ysis and control portal (Synelixis Web Portal and Hispatec Web Portal)	Web Portal	Shares Cloud data, supports SMS Alert, E-mail alert and Alarm configu-ration. It also predicts weather, dis-ease and evapotranspiration	N/A	4
3.3	ERP Agro His-patec	ERP (Plat-form)	Predicts Market Volume/Price, and share data with the Stakeholders	N/A	1
3.4	Temperature Management Ap-plication	End-user ap-plication	Generate Temperature Measurement Reports	N/A	1
3.4	Interface be-tween Location Management and Vizix	Interface	Transfer Temperature Sensor Data	N/A	1
3.4	CoatRack gate-way	API Gateway	Monitoring the flow of temperature data and authenticating API calls	N/A	1

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
3.4	Interface between Wenda IT and Vizix	Interface	Subscription Transfer Temperature Sensor and location data	N/A	2
3.4	NXP IoT Tracker Prototype 5	Module with SigFox Radio & Backend, GPS receiver, Temperature & Motion sensors, NFC interface	• Geolocation sensing using NMEA coordinates values from GPS receiver • Geolocation sensing using SigFox base station triangulation principles • Temperature Measurement • Free fall detection (using accelerometer) • Motion /No-Motion detection using accelerometer • Battery Voltage monitor (using ADC peripheral of microcontroller) • Wireless communication to backend (using SigFox transceiver) • Wireless communication with Smartphone to read out measured sensor parameters (using NFC interface)	12	230
3.4	Location Management Application	End-user application	Generate Location Measurement Reports	N/A	3
3.4	Interface between Location Management and Vizix	Interface	Transfer Location Sensor Data	N/A	1
3.4	Interface between Sigfox and Vizix	Interface	Transfer sensor information between the Sigfox platform and the Vizix IoT platform	1	1
3.4	Fourth NXP prototype	NXP Tracker module with SigFox, GPS receiver, Temperature & Motion sensors, NFC interface	Module with SigFox Radio & Backend, GPS receiver, Temperature & Motion sensors, NFC interface	12	8
3.4	External Places API interface of the Location Management Application	Here APIs	Interface to get geo information from the LocMan about "places nearby" a geo position where a tray was positioned	N/A	1
3.4	KIZY Tracker	Kizy Tracker (3G/4G) commercial	Kizy Tracking	200	60

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
		tracking device			
3.5	Sprayer Control System (SCS)	Control system (the brain on the sprayer)	Control System to manage spraying operations.	3	3
3.5	Specialty Crop Gateway (SCG)	Cellular modem	Tractor mounted gateway for other devices implementing the H3O Protocol granting them access to them to the FEDE's Cloud	4	3
3.5	H3O Protocol	Protocol	FEDE proprietary protocol. Implemented in SCS that allows communication between tablet in the tractor, the SCS and the SCG.	4	3
3.5	H3O Restful Web Services	Web service	Implements interface to allow connecting to FEDE Cloud, which is marketed under the name Fede Specialty Crops Platform (SCP).	2	1
3.5	Business Logic Kernel	Kernel	Implements the core business logic	1	1
3.5	Data Abstraction Layer	Data Abstraction Layer	Allows Business Logic Kernel to access data stored in databases	1	1
3.5	Sensors	Sensors	Several sensor to get data from the process	6	3
3.6	Bluetooth	Sensor	Data logger with temperature sensor and Bluetooth communication technology	26	33
3.6	Mobile API	SOFTWARE API FOR THIRD-PARTY INTEGRATION ON MOBILE APP	The Mobile APIs allow data exchanges between the Mobile App and the Verigo device	24	16
3.6	App Mobile	SOFTWARE APPLICATION	It allows the download of data collected by the Verigo device, the sending of the collected data to the platform, the possibility for users to insert feedback regarding the shipment status and the product itself	24	16
3.6	Web App	IoT Platform	It receives, elaborates and makes available to producers the data collected by the Verigo device and the Mobile App	26	17
3.6	Web API	Software Application	It allows data exchanges between the Mobile App and the Web App	24	16
4.1	Temperature and humidity sensor	Sensor	Measures temperature and humidity	5	1

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
4.1	CO2 sensor	Sensor	Measures CO2	3	1
4.1	Air speed sensor	Sensor	Measures the airflow	3	1
4.1	PAR sensor (sensor for photosynthetically active radiation)	Sensor	Senses photosynthesis based on light	2	1
4.1	Camera Bosch NUC-21012-F2	Hardware	Monitors de crop growth	15	1
4.1	Microcontroller (Raspberry Pi 3)	Microcontroller	Integrates the LoRa radio	2	1
4.1	Microcontroller + LoRa radio (PyCom LoPy4)	Microcontroller	Gets the data from the sensors	7	1
4.1	Linux PC	Computer	Computer running a Linux system	2	1
4.1	ArtNet to DMX/RDM converter	ArtNet to DMX converter	Connects the lighting system to the Artnet (which works with the internet) – DMX can be used to control the lighting system	4	1
4.1	Dynamic LED lighting modules	Lighting module	Provides artificial lighting to the crops	250	1
4.1	WLAN router	Router/Gateway	Allows connection with the cloud and the applications	2	1
4.1	POE Ethernet switch	Ethernet switch	Connects the component to the internet via cable	2	1
4.1	GrowView (monitoring and dashboard application)	End-user related application	It allows to register growth circumstances (meta-data) and growth results, also visualizing and exporting sensor data and camera images	N/A	1
4.1	Data backend + API + client library	Data backend + API + client library	API to core client (gateway communicating to data backend)	N/A	1
4.2	3D Printer	Printer	Pieces were manufactured in order to protect Temperature sensor, Humidity sensor and CO2 sensor	1	1
4.3	Mechanical intra-row weeder	Combination of; -Camera's -Hoeing actuators -Multiple sensors	Mechanical intra-row weeding. Crop counting. Crop parameter calculation Data logging	1	2
4.3	Farm management information system (FMIS)	Software package	As-applied GPS data visualization + processing AB Line + field outline management	1	1

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
4.3	Online geo-platform	Online decision support tool	Data storage Data processing Decision support Task-map generation	1	1
4.3	Meteobot Weather Station	Weather station	Measurement of environment parameters (Temp, RH, wind,…)	1	1
4.3	RTK-GPS receiver	RTK-GPS rover	2cm accurate world-wide positioning	1	1
4.4	SITI4farmer	User related application	consultation of the vineyard land registry, completion of the audit report integration with DIONISO	1	2
4.4	Cellar inspection app	User related application	consultation of the national production logbook integration with DIONISO	1	1
4.5	FINoT Agri Node	Sensor kit Controller	Acquire and transmit sensor data	2	9
4.5	FINoT Gateway (3G/ WiFi/ LoRA/ NB-IoT Version, AC/DC input)	Gateway	Send field data to cloud	1	9
4.5	FINoT irrigation controller (DC version)	Actuator controller	Implement irrigation scheduler that activates irrigation cycles	1	1
4.5	FINoT sensors	Air and soil sensors	Measure conditions	4	9
4.5	FINoT mini WS	Solar and rain sensor	Measure conditions	2	1
4.5	Flow meter	Sensor	Measure conditions	2	1
4.5	Solenoids	Actuator	Controls the irrigation	4	1
4.5	FINoT platform	Cloud-based IoT platform	Visualize basic IoT data	N/A	40
4.5	QUHOMA app	Cloud-based app	Smart farming application	N/A	40
4.5	PV panels	Panel, battery, case	Energy source	1	8
5.1	Fancom regular mash feeding computer	Sensor	Measure supplied feed; Measure feed type; Report number of animals present; report start day of round	1	2
5.1	Fancom regular dry feeding computer	Sensor	Measure supplied feed; Measure feed type; Report number of animals present; report start day of round	1	1
5.1	Fancom sensor mash feeding computer	Sensor	Measure supplied feed; Measure feed intake	2	1

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
5.1	Kamplan feeding computer	Sensor	Measure supplied feed; Measure feed type; Report number of animals present; report start day of round	1	1
5.1	Fancom climate computer	Sensor	Measure inside temperature; Measure ventilation rate; Measure outside temperature	2	1
5.1	Fancom climate computer	Sensor	Measure inside temperature; Measure ventilation rate; Measure outside temperature	1	1
5.1	Fancom management software	End-user related application	Log data; change climate and feed computer settings;	N/A	3
5.1	Stienen climate computer	Sensor	Measure inside temperature; Measure ventilation rate; Measure outside temperature	6	2
5.1	Stienen webtool	End-user related application; IOT platform	Report inside temperature; Report ventilation rate; report outside temperature	N/A	2
5.1	MS PigScale fattening pigs	Sensor	Measure pig weight	2	2
5.1	MS PigScale piglets	Sensor	Measure pig weight	1	2
5.1	Monnit API	IOT platform	Download climate sensor data	N/A	1
5.1	HF RFID tags	Other wireless devices	Report pig ID	500	1
5.1	LF RFID tags	Other wireless devices	Report pig ID	120	1
5.1	Nedap feeding station	Sensor	Measure feed intake; measure feed visits; measure pig weight	4	1
5.1	Nedap webtool	IOT platform	Download feed intake; download pig weight; report feed intake; report pig weight	1	1
5.1	PigWise RFID system (feeding)	Sensor	Measure presence at feeding system	4	1
5.1	PigWise RFID system (drinking)	Sensor	Measure presence at drinking system	8	1
5.1	Flowmeters	Sensor	Measure water flow rate	8	1
5.1	Flowmeter software	Sensor interface	Measure water flow rate; Save water flow rate	1	1
5.1	Weighing scale	Sensor	Measure pig weight	1	1
5.1	FTP synchronizer	Python script to synchronize data	Synchronize data farmer’s PC and FTP server	N/A	6

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
		among farmers' PC and FTP server			
5.1	Orion Context Broker	Publish/subscribe system	Receive real-time data from farmers; notify subscribers about new data	N/A	1
5.1	IoT Platform	IoT Platform	Elaborate data received from the farms + calculate inferred data + forward data to Orion + expose historical data through APIs	N/A	1
5.1	UWB Platform	UWB-based tag devices and UWB-based anchor devices	The UWB-based anchors estimate the position of tags by processing both distance and angle of arrival measurements.	16	1
5.1	Porphyrio Pig Business Intelligence Dashboard	Porphyrio Pig Business Intelligence Dashboard	End-user related application	N/A	4
5.1	Individual level dashboard	Individual level dashboard	End-user related application	N/A	4
5.2	Animal Scale (C1)	Sensor	[Measure] Animals weight	8	8
5.2	Silo scale (C2)	Sensor	[Measure] Silos weight	12	12
5.2	Water Consumption sensor (C3)	Sensor	[Measure] Water consumption	4	4
5.2	Environmental sensor node (C4)	Sensor	[Measure] Temperature, Humidity, Luminosity, CO2, Ammonia, Acceleration	62	62
5.2	Smart bracelets (C5)	Sensor	[Measure] Acceleration	2	4
5.2	Integral Farm Controller (C6)	Gateway	[Manage] Farm Information	4	4
5.2	Farm and slaughterhouse gateway (C7)	Gateway	[Collect & Manage] Environmental Sensor data	6	5
5.2	Slaughterhouse web server (C8)	Gateway	[Collect] Slaughterhouse meat quality information	1	1
5.2	Slaughterhouse connector (C9)	Gateway	Manage] Slaughterhouse meat quality information	1	1
5.2	Cloud Services (C10.4) Environmental Prediction Assistant	End-user related application	[Assess] End user in environmental optimal based on temperature predictions	N/A	4

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
5.2	SaaS (C10.2) Porphyrio® Broiler-Insight	End-user related application	[Assess] End user in 1. Data-Collection & Integration 2. Automatic Reporting 3. Benchmarking 4. Integrated health Module 5. Active management 6. Pro-active Management 7. Long term prediction of Key performance indicators	N/A	4
5.2	Cloud Services (C10.3) Poultry Chain Management Dashboard	End-user related application	[Assess] End user in 1. Carcass quality 2. Advanced data visualization on the whole chain	N/A	4
5.2	Cloud Services (C10.1) (Poultry Meat Chain Platform)	Platform	[Collect & Manage] All the data in the use case	1	1
5.3	EPCAT (EPCIS solution)	IoT Platform	manage events	N/A	3
5.3	IoF2020 Capturing Application for LeeO FMIS	IoT middleware	Capture IoT events	N/A	1
5.3	Proactive auditing dashboard	End-user application	Provide unified interactive dashboard to auditors and other users	N/A	3
5.3	OLIOT-gateway: Now an official FIWARE EPCIS-NGSI mediation gateway	Gateway	Translate NGSI data to EPCIS events	N/A	3
5.4	Weather and soil stations	Sensor	Senses soil temperature, rain, soil moisture, electrical conductivity and animal health	10	4
5.4	Weather stations	Sensor	Senses	2	1
5.4	IoT smart collars	Sensor	Location, trajectory and status of the animals (activity + temperature)	335	7
5.4	IoT BLE ear tags and IoT RFID ear tags	Sensor	Allows to identify the animals	690	2
5.4	IoT automatic scale	Sensor	Weights the animal	4	2
5.4	IoT multi sensor station	Sensor	Measures location, weight, acceleration, velocity and time	2	1
5.4	Orion Context broker	FIWARE	ORION (Context-Broker) is used to capture the information from the sensors, actuators, Third-Party web-services etc.	N/A	3015

UC	Short Description	Type of Component	Functionalities	# of Devices	Deployment Sites
5.4	Cow-calf farmer app	End-user related application	Provides information about location, and especially the distance between the calf and it's mother	N/A	3000
5.4	Feedlot app	End-user related application	Provides information to the farmers about animal's weight and growth rate	N/A	15
5.5	Volumetric sensor	Volumetric sensor with IoT communications capacities and Solar powered.	Measure silo inner; Temperature; Humidity; Content volume; RGB image; IR image.	110	3
5.5	Monitoring platform	Mobile and web cloud application for end-user (farmers and feed distributors) data gathering and visualization.	One web platform and one mobile app for smart devices. Online. Same service app.insylo.io, with access per location and global client.	N/A	43
5.5	Smart logistics platform	Smart logistics module for managing business workflows and logistics optimization	Development started at the end of this reporting period Work in progress (Due Feb 2021). Same service planner.insylo.io, with access per location and global client.	N/A	1
5.6	Smart Spot Gateway	Gateway	Air health monitoring (nh3, co, no, co2) and measurement of temperature and humidity and PM of the room	1	1
5.6	Ear tag	Sensor	Monitoring of heart rate, activity and temperature gradient	70	1
				8,602	

The total number of deployment sites needs to be discussed in more detail. When considering especially all end-users that are making use of solution related software applications like above on this page in use case 5.4 for the cow-calf farmer app, one can identify a massive reach out, taking into account the number of reached individuals. However, when aiming at the identification of the specific deployment sites that were used to specifically deploy IoT devices/hardware, the number deviates. As analysed in the last reporting period by the use cases in WP2, there were 212 individual deployment sites as abstracted from the final progress reports. Therefore, one needs to take into account this different perspective of reaching out to end-users with the deployment of either hardware or software-based solutions.

5 Standards applied in the IoF2020 Use Cases

The IoF2020 use cases were deploying diverse hardware and software components as well as related interfaces. A key challenge is to combine all those large or small systems for being able to assure a seamless operation of the IoT based solutions. Therefore, when analysing the use of standards, we were usually focusing on those standards that are addressing the interoperability of systems. The following Table 8 is providing and overview of related standards that were relevant in the use cases. This list shall service as a rather informative nature to check potential synergies for future collaboration. At the same time, it shall help solution developers to get an idea about relevant standards in a specific agri-food solution area. Therefore, it was kept at a high level and complementary to the smart data model initiative and the implemented data marketplace.

Table 8: Standards applied in the IoF2020 use cases.

UC	Standard	Type of Standard	Purpose of using the Standard
1.1	CAN-Bus	Communication	Send data from Yield/biomass sensor
1.1	3G	Communication	Send data from Weather stations
1.1	ISOBUS	Communication	Send data from different sensors (Weather stations, biomass sensors, on actuators, such as herbicide application)
1.1	AgroConnect (shape, ISO-XML)	Interoperability	Used on 365 FarmNet, Akkerweb/FarmMaps, Crop-R and Zoner
1.1	ADAPT (shape, ISO-XML)	Interoperability	Used on 365 FarmNet, Akkerweb/FarmMaps, Crop-R and Zoner
1.2	Interface 1 (HTTPS with JSON)	Interoperability	Information type: L1, L2
1.2	Interface 2 (OAuthV2 with HTTP)	Security	API Access management (authentication, get Token and check Token)
1.3	Interface 3 (NGSI/http with NGSI-LD)	Interoperability	Description of data model with information type: L1, L2 Temperature NGSI-LD
1.3	GPRS	Communication	Data integrated in Soya-DSS
1.3	2G/3G	Communication	Telematic kit on combine – Transmit combines canbus data for example from the yield monitor to the cloud
1.3	REST API with JSON based custom format	Interoperability	This is used to allow interoperability between Soya-DSS, Cross-platform mobile application, Management and visualization web dashboard, Bluleaf
1.3	REST API with Sysman proprietary compression algorithm	Interoperability	Proprietary interfaces to integrate multi-vendor weather sensors (Virtual data logger)
1.4	ISO11783:10 – ISOXML	Interoperability	Used for the demonstrator to showcase the round-trip from raw machine data to open-source & easy-to-use geospatial format (GeoJSON)
1.4	MQTT, REST	Communication	AGCO MongoDB cloud
1.5	MQTT	Communication	Eurotech telematics units coupled to CANbus machine to send data to the Microsoft Azure cloud (Interface harvester & AVR Connect)
1.5	Drone data standards with GeoTIFF and Shapefiles	File standard	Generates the drone data to be shown on the online cloud platform

UC	Standard	Type of Standard	Purpose of using the Standard
1.5	Cloud platform API/ REST-API in JSON	Interoperability	Allows to send and receive data from and to the Cloud
1.5	ISO-XML	Interoperability	API AVR Connect, which provide access to the product developed on this UC
1.6	3G	Communication	Make that the Deployed IoT stations can communicate with the cloud system
1.6	TCP/IP-HTTP	Communication	Cloud system offering access to the data from the IoT sensors
1.6	NGSIv2- data model and API (Orion Context Broker)	Interoperability	Gaiatron IoT stations sensed data, pest infestations alerts, weather forecasts.
1.6	JSON	Interoperability	Gaiatron IoT stations
1.7	HTTP request API	Communication	Universal database access
1.7	RS 232	Communication	Wired robust differential communication between trailer PLC and LoRa receiver
1.7	NFC	Communication	Low cost contactless short range identification technology
1.7	Qi	Communication	Wireless charging using inductive coupling
1.7	Ethernet	Communication	Wireless communication
1.7	3G	Communication	Wireless communication
1.7	WiFi	Communication	Wireless communication
1.7	RS-485	Communication	Wired robust differential communication between trailer PLC and LoRa receiver
1.7	SQLite DB HTTP request methods	Communication	Central database with HTTP API to enable access from any software platform
1.8	JSON	Interoperability	Data Transaction between Server and Cloud
1.8	MQTT	Communication	This is used between Gateway and the Cloud
1.8	HTTPS	Communication	The mobile application api is hosted on AWS as planned.
1.8	NoSQL Database	Data management and interchange	The database type and usage are as planned (Database)
1.9	ISO/IEC 24730	Communication	Drone manual control
1.9	MAVLink	Communication	Drone automated control and mission planning
1.9	WiFi	Communication	Data upload
1.9	ENVI-BSQ	Image Standard File Format	Hyperspectral imagers
1.9	Band image (BMP)	Image Standard File Format	Hyperspectral imagers
1.9	ROI spectra (CSV format)	Image Standard File Format	Hyperspectral imagers

UC	Standard	Type of Standard	Purpose of using the Standard
1.9	GEO-JSON	Geographic data Standard format	FMIS
2.1	Bluetooth	Communication	This is used on the Geobeacon for tracking purposes (indoor location, movement detection and zone detection)
2.1	GPS	Track and Trace (Positioning)	Track and Trace Beef cattle
2.1	REST/JSON API	Data interoperability	Deployment arranged from Sensolus server on AWS platform, accessible from anywhere with internet connection
2.2	Connecterra's Proprietary Radio Protocol	Communication	To maximize the battery life of a single charge to multiple years, a proprietary radio protocol is used to receive detections from the Ida sensor.
2.2	Azure Blob Storage REST API	Communication	Activity data collected by the Cow Sensor is uploaded to the Ida Platform by the Base Station using the Azure Blob Storage REST API.
2.2	Short Message Service (SMS)	Communication	To notify the farmer of insights that need immediate attention, farmers rely on push notifications via SMS.
2.2	Apache NiFi	Interoperability	In use to acquire contextual information for the Ida Platform from farm management systems by 3rd parties deployed at the farms (FMS Integration)
2.3	WiFi/GPRS	Communication	Data download to local on-farm PC, synchronised regularly with cloud storage.
2.3	ZigBee/WiFi/ Mobile	Communication	Data download to local on-farm PC, synchronised regularly with cloud storage. KING uses Afimilk base station interface for activity collars
2.3	Hard wired/ ZigBee/ WiFi	Communication	Data download to local on-farm PC.
2.3	Hard-wired	Communication	Data stored, analysed and displayed in bespoke database.
2.4	HTTPS	Communication	Secure internet-based transfer protocol
2.4	GS1 (Barcode EAN128)	Communication/ Identification	GS1 barcoding standard
2.5	Wifi	Communication	Part of ENGS onsite comms
2.5	RS485	Communication	Used by ENGS between receiver and PC
2.5	MQTT	Communication	Used to stream filtered data from ENGS trial sites to Machine Learning Software Platform
2.5	NGSI-LD	Interoperability	Lameness Detection Alerts remodelled to NGSI v2 Simplified Entity Relationship format (key-value)
2.5	FIWARE NGSI, GS1	Interoperability	NGSI Restful interface via FIWARE Orion Context Broker
2.5	GSMA IoT Security Guidelines	Interoperability	Partially realised in cloud-based architecture.

UC	Standard	Type of Standard	Purpose of using the Standard
2.6	RFID	Communication	Electronic ear tags follow the HDX/FDX for electronic ear tagging ISO standard 11784 and 11785 according to test methods given by point 7 in ISO standard 24631-1.
2.6	Wired data connection (RJ45)	Communication	A wired connection is used between the Master Unit and a router or switch
2.6	Wifi	Communication	WiFi is used if the Pitstop+ Manager is accessed from a device that is connected to the Internet via WiFi
2.7	LoRaWAN communication interface	LoRaWAN standard	Can join to other LoRaWAN network
3.1	JSON, REST API	Communication	RESTful JSON API for getting various data (sensor values, historical data) from the SynField server. Proprietary interface for sending and receiving data between the SynField devices and the server
3.1	HTTPS	Communication	Web-based client for inspecting gathered information
3.1	Bluetooth	Communication	This interface enables mobile devices to configure and inspect the SynField devices on-site
3.1	REST API, Sysman proprietary compression algorithm	Interoperability	Proprietary interfaces to integrate multi-vendor weather sensors (Virtual data logger)
3.2	HTTP REST with IETF	Communication	To gather on demand data
3.2	MQTT with OASIS	Communication	To gather continuous data
3.2	CoAP with IETF/ CoRE 6LoWPAN	Communication	To gather continuous data
3.2	DTLS with IETF/ TLS	Communication	Datagram Transport Layer Security
3.2	Ethernet/ISO/ IEC 8802-3	Communication	Local Area Network Protocol
3.2	WiFi	Communication	Wireless Local Area Network Protocol
3.2	ADSL	Communication	Digital subscriber line is a data communication technology enabling faster data transmission over copper telephone lines
3.2	Modem + GNSS 3GPP Rel.14 LTE Cat.M1 and LTE Cat.NB1 (LTE FDD: B1/B2/B3/B4/B5/B8/B12/B13/B18/ B19/B20/B26/B28, LTE TDD: B39 For Cat.M1 Only) EGPRS (850/900/ 1800/ 1900MHz) GNSS (GPS, GLONASS, BeiDou/ Compass, Galileo, QZSS)	Communication	The device automatically connects to the network with the best reception level choosing it among all the managed standards. The standards to which the device is compatible permit the communication worldwide. GNSS is used to localise the device

UC	Standard	Type of Standard	Purpose of using the Standard
3.2	Oma NGSI	Interoperability	Open API from FIWARE
3.2	OMA LWM2M	Interoperability	Devices management and remote firmware update. Supporting by Sensinact, LWM2M y ONEM2M
3.2	ETSI ISG CIM	Interoperability	Data model for data exchange
3.2	ETSI SAREF	Interoperability	Semantic interoperability and linked data
3.3	SOA – WEB Services	Communication	ERP Agro connects to the software that acquire the data from field in order to add, as input, in agronomic model
3.3	SOA – WEB Services	Communication	ERP Agro connects to the software that acquire the data from weather forecast in order to add, as input, in agronomic model
3.3	CSV formats	Interoperability/File Standard	The software that manage the NIR Sensors generates CSV files periodically. ERP agro connects directly to the corresponding folder in order to capture these files and makes the process for gathering the key data
3.3	WFS	Communication	ERP software uses multilayer geographical information using WFS protocol
3.4	HTTPS/REST with JSON	Interoperability	Interface to send temperature data to the Temperature Management Application
3.4	(Un)subscribe to a GRAI - JSON over HTTPS/REST	Interoperability	Interface to subscribe and unsubscribe to receive updates from IoT enabled trays
3.4	GRAI updates via JSON over HTTPS/REST	Interoperability	Interface to send updates for subscribed IoT trays
3.4	Low-Power Wide Area Network	Communication	For receiving & transmitting short data packets from module to backend. Sigfox positioning service to allow positioning of RTIs without the need for GPS. http://www.sigfox.com/en
3.4	Geo localization (GPS)	Communication	The acquired geolocation data by the GPS receiver is compiled into to a standard NMEA message, which is then interpreted to extract the required GPS coordinates
3.4	Vicinity Communication - NFC ISO14443 standard	Communication	ISO14443 Communication protocol(s) for short-range wireless connectivity to exchange digital content
3.4	Geo-positions and Zones interface between Location Management and IoT platform (Vizix) - GS1 EPCIS, XML, HTTP	Interoperability	Messages exchanged between the IoT platform (Vizix) and the Location Management Application via HTTP are based on the GS1 standard EPCIS. The messages are encoded as XML files and extended with custom XML tags (in accordance with the EPCIS specification) to enable the transfer of data not foreseen in the EPCIS standard
3.4	Smart Asset Management	GS1 Digital Link	Aiming to make the developed smart tray solution even more compelling, we agreed to put GS1 Digital Link to the test. For this purpose, we identified a

UC	Standard	Type of Standard	Purpose of using the Standard
			number of services and information resources a tray user most probably will be interested in.
3.5	H3O Protocol	Communication	running reliably (over Wi-Fi and Ethernet)
3.5	REST/API	Communication	Specialty Crop Platform (SCP) to external stakeholders
3.5	REST/H3O Cloud	Communication	Specialty Crop Platform (SCP) to SCG and SCS
3.5	Input/Output Controller (USART)	Communication	SCS to external third-party sensors
3.5	H3O Protocol	ASCII based proprietary protocol	Apart from internal machine to machine communication also successfully used to interface electronics developed by the IoF2002 partner Agricultural University of Athens
3.5	REST/API with JSON	Interoperability	Implemented and tested with third party API data exchange partners
3.5	REST/H3O Cloud	Interoperability	Running reliably (over cellular connection/GPRS or Wi-Fi)
3.6	BLE	Communication	From the device to the smartphone, the App functionalities are discovering, pairing and collecting data
3.6	WiFi - TCP/IP	Communication	Among the IoT Service Layer and the Mediation Layer, it enables the exposition of data and services offered by IoT Devices through well-known programmatic interfaces.
3.6	4G/UMTS	Communication	From the smartphone to the cloud (WAN)
3.6	API with REST and JSON format	Interoperability	This interoperability point enables the Application and Mediation Layers to consume public Geo-Services, enriching the applications with geospatial data
3.6	Using standard OAuth2 protocol	Interoperability	It is a cross-cutting interoperability point that facilitates the secure interchange of information between the different layers and actors
4.1	TCP/IP	Communication	Lighting control system, gateway of sensor network
4.1	ArtNet	Communication	Lighting control system
4.1	DMX	Communication	Lighting control system
4.1	WiFi	Communication	Sensor Gateway
4.1	RESTful API	Communication	Monitoring and dashboard application (GrowView) Sensor gateway Lighting control system
4.1	JSON	Interoperability	For data exchange between applications
4.1	HTTPS	Interoperability	For secure communication over network
4.1	SQL	Interoperability	For data storage (Microsoft Azure and AWS cloud)
4.1	REST API	Interoperability	For interfacing (GrowView with database and front-end)
4.2	WI-FI/ IEEE 802.11	Communication	Climate and soil control station
4.2	Ethernet/ IEEE 802.3	Communication	Climate and soil control station

UC	Standard	Type of Standard	Purpose of using the Standard
4.2	RS-232/ IEEE 1394	Communication	Climate and soil control station
4.2	SDI-12/ Serial-Digital Interface	Communication	Climate and soil control station
4.2	GPRS / Global System for Mobile communications	Communication	Transport measurement device
4.2	NGSI/ NGSI v2	Interoperability	FIWARE Orion Context Broker and FIWARE Cygnus
4.2	MQTT / MQTT v5.0 standard	Communication	
4.3	JSON, CSV	Interoperability	Data stored in 2 formats to maximize compatibility
4.3	TIF	File Standard/ Interoperability	Lossless image storage
4.3	ESRI Shape	File Standard/ Interoperability	GPS positions of measured plants
4.3	CSV	File Standard/ Interoperability	Weather data
4.4	REST API/ REST, JSON	Interoperability	Client server communication
4.4	REST API/ XM, REST, JSON	Interoperability	API get to download audit reports
4.5	LR-WPAN/ IEEE 802.15.4	Communication	FINoT Data Acquisition/ OSI Layer 1/2
4.5	LR-WPAN/ 6LoWPAN	Communication	OSI Layer 3/4/5
4.5	Sensors I/F / Modbus RTU	Communication	Soil sensors
4.5	Sensors I/F / I2C	Communication	Air sensors
4.5	Actuators I/F / Modbus RTU, Digital Inputs, Relay Outputs	Communication	Electrovalves / solenoids
4.5	Sensors I/F / Pulse counting	Communication	Flow meters
4.5	WSN DAQ/ IEEE 1451	Interoperability	IoT Gateways
4.5	Northbound APIs/ NGSI-9/NGSI-10 (NGSiv2)	Interoperability	FIWARE related internal communication
4.5	Southbound APIs/ MQTT	Interoperability	IoT Gateway to IoT Agent Communication
4.5	IoT2EPCIS/ EPCIS 2.0	Interoperability	FIWARE-EPCIS integration
5.1	CSV-format	Interoperability	Water Consumption Sensor Interface, Feed Consumption Sensor Interface, Feed consumption and weight interface, Climate Control interface, RFID Reader Interface, Pig weighing scale interface
5.1	Ethernet	Communication	Climate Control interface

UC	Standard	Type of Standard	Purpose of using the Standard
5.1	Wifi	Communication	Climate Control interface
5.1	XML-format	Interoperability	Climate Control interface/ Pig weight sensor interface
5.1	LLRP1 (over-IP)	Communication	This is a standard EPCglobal standard, RFID Reader Interface
5.1	LF and HF	Communication	(Standards RFID radio protocols, according to ISO norms) - RFID Tag interface
5.1	GPRS	Interoperability	Pig weight sensor interface
5.1	CAN	Communication	Feed consumption and weight interface
5.1	TCP/IP	Communication	Pig weighing scale interface
5.1	NGSIv2 JSON-format	Interoperability	Data Transfer Interface/ Orion Context Broker & IOT platform at LINKS
5.1	NGSIv2 REST API	Interoperability	Orion Context Broker & IOT platform at LINKS
5.1	FTP	Interoperability	Pig weight sensor interface, Climate control inter-faces,
5.1	EDI	Interoperability	EDI-Slacht
5.1	SOAP	Interoperability	EDI-Slacht
5.1	REST API	Interoperability	EDI-Slacht
5.1	ADIS-format	Interoperability	EDI-Slacht
5.2	First phase wired with Exafan proprietary pro-tocol / Second phase Wireless mesh over 2.4 GHz	Communication	Connected to the Integral Farm Controller
5.2	RS485	Communication	Connected to the Integral Farm Controller
5.2	Wireless, 802.15.4	Communication	Connected to Farm and Slaughterhouse Gateway
5.2	NGSI	Interoperability	Connection through FIWARE´s context Broker, Con-nection through FIWARE´s context Broker, Connec-tion between Porphyrio´s Farm Platform and Poultry Meat Chain Platform through FIWARE´s context Bro-ker
5.2	MQTT	Communication	Connection through FIWARE´s context Broker
5.2	Standard web service REST	Interoperability	Slaughterhouse data uploaded through this web ser-vice
5.3	EPCIS	Interoperability	EPCIS capture interface/EECC EPCAT EPCIS re-pository
5.3	NGSI	Interoperability	EPCIS capture interface/FIWARE Orion Context Bro-ker
5.3	EPCIS v1.2	Interoperability	EPCIS Capture/EECC EPCAT EPCIS repository
5.3	Custom standard	Interoperability	LeeO API
5.4	3G	Communication	Used in every IoT device except for ear tags
5.4	Bluetooth	Communication	Used for communication between ear tags and other devices, such as GPS collars, IoT weight scales, etc

UC	Standard	Type of Standard	Purpose of using the Standard
5.4	RFID	Communication	Used for communication between ear tags and other devices, such as GPS collars, IoT weight scales, etc
5.4	MQTT	Communication	Implemented in a FIWARE-based infrastructure
5.4	JSON	Interoperability	Implemented in a FIWARE-based infrastructure
5.4	LWM2M	Interoperability	Implemented in a FIWARE-based infrastructure
5.4	NGSI-10	Interoperability	Weather and soil stations / GPS collars / IoT weight scales / Multi-sensor stations
5.4	Serialized JSON data	Interoperability	Weather and soil stations
5.5	GPRS	Communication	Packet oriented mobile data standard on the 2G and 3G cellular communication network using multi-carrier features.
5.5	ISO 8601 Data elements and interchange formats – Information interchange	Communication	Representation of dates and times is an international standard to exchange date and time information between components.
5.5	SI - International System of Units	Communication	All the information will be stored according with the international System of Units to avoid data misunderstanding
5.5	6LoWPAN	Communication	Specification developed by the 6LoWPAN IETF group RFC 4944 oriented for wireless low-power radio communication at low data rates. The specification works over the IEEE 802.15.4 networks. We finally remove our support for 6LoWPAN, its deployment was extremely painful, so we decided to focus on GSM connectivity. We had RF interferences from farm machinery, or metal silos. As we had the need for sending large data packed offered bandwidth was really narrow for our purpose.
5.5	oauth2 and JSON	Interoperability	Securitization and standard data format to transmit data objects. oauth2 allows the access control to the information and JSON is standard of data transport between FIWARE components
5.5	NGSI9 and NGSI10	Interoperability	Cygnus play the role of connector between Orion Context Broker GE and many FIWARE storages data sources as MongoDB, CKAN, etc.
5.5	CoAP (Constrained Application Protocol)	Interoperability	Allows the implementation of RESTful application over reduced resources devices along the wireless sensor network. The transmission is based on the UDP protocol.
5.5	LWM2M	Interoperability	Open Mobile Alliance for M2M or IoT device management. Allows the management of the deployed devices.
5.5	MQTT	Interoperability	ISO standard (ISO/IEC PRF 20922) publish-subscribe-based messaging protocol. Manage the exchange information between the devices and the backend application

UC	Standard	Type of Standard	Purpose of using the Standard
5.5	HTML5	Interoperability	Current major version of the HTML standard used to implement the web applications.
5.6	HTTP REST	Interoperability	Smart Spot Gateway
5.6	Wi-Fi	Communication	Smart Spot Gateway
5.6	MQTT	Communication	Smart Spot Gateway
5.6	IEEE 802.15.1 (Blue-tooth 4.0)	Communication	Ear Tag and Smart Spot Gateway
5.6	OMA NGSI (OMA)	Interoperability	Open API from FIWARE
5.6	OMA LwM2M (OMA)	Interoperability	Devices management and remote firmware update. Supporting by SENSINACT, LwM2M y ONEM2M
5.6	ETSI ISG CIM (ETSI)	Interoperability	Data model for data exchange
5.6	ETSI SAREF (ETSI)	Interoperability	Semantic interoperability and linked data.

The IoF2020 use cases were also asked about issues with the used standards, protocols and typical devices used for IoT based solutions. Moreover, the use cases provided further details about their strategies and actions to tackle the experienced challenges as presented in the following:

- Use Case 1.1
  - Standardization is a must for UC 1.1 when aiming at data and information interoperability between soil scan services, the FMIS, the portals of the potato planter companies and terminals on the potato planters. The use case kept the Reference Model Agro as reference (also basis in Adapt).
- Use Case 1.2
  - There were no issues in relation to standards identified.
- Use Case 1.3
  - Brand/manufacturer specific data formats are showing varying headers for yield monitor and soil EC maps. The use case used “Implement upload forms”, which can handle various formats/ headers of UC partners. Examples of differing formats are (1) In the yield maps there are the combine position, speed, bar width, elevation, surface harvested, time and many others. This was also experienced when processing the yield maps of the Claas combine in Italy. (2) In EC soil maps there can be many other fields regarding elements content, position of the data, time and others. Therefore, there is the necessity to choose among the headers of a file which columns to upload.
  - Main indicator measured in eC soil mapping had to be adapted in the product. There is the possibility to invert the data during import process of soil data into the Soya-DSS implemented. Taking into account conductivity vs. resistivity, which is the exact opposite.
- Use Case 1.4
  - The ADAPT framework is not easy to use if you do not know C#.NET and agricultural semantics. It was investigated how to represent Agricultural data in easy-to-use data formats and decided to create a GeoJSON plugin. Created a geospatial tool that supports non-agricultural developers using Agricultural data, see https://github.com/ADAPT. Moreover, created a demonstrator how to use the tool, see YouTube link https://youtu.be/kMJbPfA1KD0
- Use Case 1.5
  - There were no issues in relation to standards identified.
- Use Case 1.6:
  - There were no issues in relation to standards identified.
- Use Case 1.7:

- Active TAG silo reader for air flow detection needs further development to be market ready. It needs to take into account different component design as well as antenna matching & tuning as well as 3D Modelling. This will be done after the project end. A special focus is also put on the active sensor tag.

- Use Case 1.8:
  - There were issues with overlapping or competing layer of various network communication. There was a need to increase the antenna and signal strength. While testing different IoT protocols and technologies such as Wi-Fi modules, Sigfox, Lora, Bluetooth, the connection seems to be unstable depending on the weakness or instability in the antenna design. The signal was increased and finally the issue for LoRaWAN was solved, improving its usage in environments with other networks.
  - While operating on ttn, devices get connected to the gateway with the highest signal strength and therefore, customers could lose their data, if the device is connected to other 3rd party gateways. This asked to add additional layers of communication protocols, simulating the environment to ensure gateway signals don't overlap as well as optimising gateway positions.
- Use Case 1.9:
  - The use case team implemented their solution based on widely used standards and did not encounter any gaps related.
- Use Case 2.1:
  - There were no issues in relation to standards identified.
- Use Case 2.2:
  - Farm management systems all use their own database architecture. Therefore, there is no standardised way to access farm data and no uniform data format. There was no reaction as a standardisation body is missing. However, the team gained experience in connecting various systems. The problem is considered complex because every supplier uses its own formatting standards and different software architectures. The use case developed an automated system that can connect to a range of farm management systems, process the data and store it into the use case related database, which is connected to the used IoT platform.
- Use Case 2.3:
  - All related platforms are proprietary and require specific APIs to export data. This results in a challenge to identify cost/benefit analysis for farmers. However, the technology integration can provide an improved early warning of illness. The challenge addressed was the quantification of the value of early intervention and persuading farmers to take action. Humans are considered as basic element of the feedback process.
- Use Case 2.4:
  - There were no issues in relation to standards identified.
- Use Case 2.5:
  - There were no issues in relation to standards identified.
- Use Case 2.6:
  - There were no issues in relation to standards identified.
- Use Case 2.7:
  - There were no issues in relation to standards identified.
- Use Case 3.1:
  - There were no issues in relation to standards identified.
- Use Case 3.2:
  - There were no issues in relation to standards identified.
- Use Case 3.3:
  - There were no issues in relation to standards identified.
- Use Case 3.4:
  - There were no issues in relation to standards identified.
- Use Case 3.5:
  - The use case did not directly impact standardization. However, in the reporting period the relevant use case team became members of the directive of CEMA, participate in AIOTI (especially Working Group 6) and are also very active in the Spanish ANSEMAT, all fora in which they actively participate

and drive the digital green transformation of agriculture with knowledge based on the multitude of experiences gained within the use case.

- Use Case 3.6:
  - Issues were experienced with the usage of FIWARE components, taking into account previous design decisions. The use of API models in REST could be applied without difficulties, and it was identified that the general use of FIWARE can offer benefits. However, at an advanced stage of solution development there are some limits in the adoption. Therefore, the modules have to be adapted and verify the benefits by having a use case based on data that is received on the platform at the end as history of registrations and therefore not as real time information (where the advantage of the technology would be more evident). In the last months of IOF2020 the use case is aiming at further adoption of FIWARE related components.
- Use Case 4.1:
  - There were no issues in relation to standards identified.
- Use Case 4.2:
  - There were no issues in relation to standards identified.
- Use Case 4.3:
  - The Steketee software is proprietary and requires custom communication. Steketee changed their software to provide more data in a format that is easily readable by GIS software, since having a machine, which produces data is only useful in the market if farmers can easily work with the data produced by the machine. The realised changes are facilitating the integration of the data in larger systems.
- Use Case 4.4:
  - Land use data is not standardised. Each Region adopts different standards. The use case duplicated the software to access same category of data (from agricultural point of view). The use case is aware of the difficulties since the beginning of the project but there was no alternative. The use case decided to use different regional data (webservice, asynchronous download) to understand the limits of the different options.
- Use Case 4.5:
  - The use case was aiming at the EPCIS-FIWARE integration, based on GS1, OMA, EP-CIS 2.0 standards. However, there is not a standard way for incorporating EPCIS XMLs to Orion Context Broker. These are seen as two separate services while IoT data are now belonging to EPCIS & CBV 2.0 standard. A new service gateway that integrates EPCIS-based EPCAT server with FIWARE's Orion Context Broker was required. The service is now prototyped and business development activities will open up the relevant horizons for all relevant stakeholders in use case 4.5.
- Use Case 5.1:
  - EPCIS is a GS1 standard that enables trading partners to share transparency data about the physical movement and status of products as they travel throughout the supply. To spread the concept and the adoption of transparency in data, it is really important to integrate the EPCIS infrastructure with as much external services/ standard/ tools as possible. The collaboration among UC5.1 and UC5.3 have demonstrated the possibility to integrate the NGSI protocol with the EPCIS one. Since UC 5.1 and UC5.3 have collaborated to integrate the FIWARE Orion Context Broker system with the EPCIS infrastructure, demonstrating the applicability of the EPCIS standard to data shared through the FIWARE Orion Context Broker. At the beginning of the collaboration the team had to sign a lot of data sharing agreements to enable the data exchange between use cases. For collaboration of such type, it is preferable to work with open data or data agreements established at the beginning of the project, to avoid to sign a lot of sharing agreements to exchange data at the moment of starting the collaboration. Nevertheless, the result of the collaboration has led to the design of a mediation gateway for the integration among the two standards, the results have been published in a journal accordingly.
  - FIWARE is working to the standardization of a set of data models to be used in different domains. They have already defined data models from smart cities to smart environment, from smart energy to smart agri-food. The data models are still under construction and not all the entity have been completely defined. The use case was interacting with FIWARE community, presenting the UC5.1 data models and integrating some entities in the smart data models. However, it was difficult to define a data model, flexible enough to be able to be adopted in different context of the same domain (e.g., to be used in different farms, respect to the ones used at the moment of its definition). For this reason, it

is important to deploy analysis of the domain before defining a new data model, and base it on standards, like smart data models. Specifically, LINKS has contributed to smart data models, publishing on Github the entities defined in UC5.1 data model.

- Use Case 5.2:
  - There were no issues in relation to standards identified.
- Use Case 5.3
  - The use case team used well established standards but also contributed to (1) sensor data standardization in EPCIS (please refer to: https://www.gs1.org/sites/default/files/june_2020_exec_summary_0.pdf) and (2) WP3 standardization of UC data model (please refer to the report "D3.5: Synergies across Use Cases - data models in the meat trial").
  - Need for additional sensor data transmission with in EPCIS. The use case actively participated in GSMP EPCIS 2.0 working group, EECC is prototyping the normative changes. The prototyping is ongoing, and the standard ratification is imminent.
- Use Case 5.4:
  - There were no issues in relation to standards identified.
- Use Case 5.5:
  - There were no issues in relation to standards identified.
- Use Case 5.6:
  - There were no issues in relation to standards identified.

As presented before, most of the use cases were rather using available standards in relation to the IoT based solutions, for facilitating interoperability and appropriate cost benefit rations. However, specifically use cases 1.4, 5.1 and 5.3 were strategically contributing to the development of standards. This was specifically based upon the involvement of partners involved in AEF, AgGateway and GS1 standard development organisations. At the same time, several use cases contributed to the effort of the smart data model initiative to validate related pre-normative data models.

6 IoT related Platforms used in the IoF2020 Use Cases

The IoF2020 use cases were deploying diverse IoT related platforms that were receiving, aggregating, and analysing data generated by IoT devices, while those platforms are also distributing such data and providing information and knowledge generated accordingly. However, the definition of “IoT platforms” is rather open and allows to consider many systems to be included in this perspective. As identified by the AIOTI, IoT platforms shall be considered as technology enabler in the first stage when aiming at the realisation of IoT marketplaces[6]. Moreover, Gartner is defining an IoT platform as an on-premises software suite or a cloud service (IoT platform as a service [PaaS]) that monitors and may manage and control various types of endpoints, often via applications business units deploy on the platform. The IoT platform usually provides (or provisions) Web-scale infrastructure capabilities to support basic and advanced IoT solutions and digital business operations[7].

To provide an overview of the main IoT platforms used in the use cases the following Table 9 is listing the deployed IoT platforms per use case, providing a short description and the combination with services/ devices in the use cases.

Table 9: IoT Platforms used in the IoF2020 use cases.

UC	IoT Platform	Short Description	Combination with Services/ Devices
1.1	AgLeader SMS software	Generates reports, informative charts and field maps to the end user based on the data from deployed sensors	Sensors (herbicides, water, fertilizers, harvesters, planters), Services (365FN Arable, AkkerWeb, Crop-R and Zoner)
1.2	Bosch/Hiphen	Data collected from different sensors, send it to the cloud, and provide it to the Arvalis App	Satellite data, Climate Sensor, Farm Gateway, Plant Sensor, RGB Camera
1.2	LoRaWAN	Communication network to connect IoT devices	Farm Gateway by Bosch and Hiphen
1.2	FIWARE Orion Context Broker	ORION (Context-Broker) is used to capture the information from the sensors, actuators, Third-Party web-services etc	Orion Context Broker combined ith using the FIWARE IdM KeyRock, PEP Proxy and Big Data Analysis Cosmos
1.3	Sigfox	Send data from sensors to Cloud	Sensors (Sigfox weather sensors) Weather Data
1.4	AGCO IoT platform	Logging and transmitting CAN-bus data (ADAPT and ISO-XML)	Combine Harvester
1.5	Microsoft Azure cloud	Eurotech telematics units coupled to CANbus machine sending data to the Microsoft Azure cloud	Sensors (AVR Harvester, Drones, AVR Connect)
1.6	Gaiasense Cloud	Cloud system offering access to data from IoT sensors – farm logs, etc.	Gaitron stations, Gaiasense dashboard/ web service, Orion Context Broker
1.7	Smart Silo Server	data logging of silos, trailers, deliveries	Sensors/ silo readers (flow sensor sleeve, flow sensor, Silo reader), Gateway (Pepwave - Peplink) and Tag readers (Silo Reader) and microcontroller (PLC + CPU)
1.8	AWS IoT Core	Data Transaction between Server and Cloud	Sensors (AS30, AS60 and SV-8CLoRaWAN)
1.9	AgroSmart FMIS	FMIS based on multiple IoT data sources and automated AI analysis	Drone, Hyperspectral imager and Spectro Radiometer

[6] AIOTI; European IoT challenges and opportunities 2019–2024. Last accessed in March 2021: https://aioti.eu/wp-content/uploads/2019/09/AIOTI-Priorities-2019-2024-Digital.pdf

[7] IoT Platforms definition in the Gartner Glossary: https://www.gartner.com/en/information-technology/glossary/iot-platforms

UC	IoT Platform	Short Description	Combination with Services/ Devices
2.1	Sigfox network	Communication, data transfer from sensors (tracker, geobeacon) to the Cloud	Sensolus tracker, Sensolus geobeacon, Sensolus cloud, Sensolus webapp
2.2	Ida Platform (Microsoft Azure)	Cloud platform based on Microsoft Azure services	Cow sensor (Connecterra Gen3.2), Receiver (Connecterra Gen2), Ida Notification Service to send SMS messages to farmers
2.3	Zigbee Network	Different sensors use Zigbee to communicate and send data to local on-farm PC, synchronised regularly with cloud storage	Milking Robot, Feeder Wagon/Stations, Neck-Mounted Collars, Ear Tags and Pedometers
2.4	RDQ tool	Tool to remote support dairy quality measurements, as a first step towards the planned future IoT platform for Managing milk-testing om milk collection trucks	Milk Scanner devices (Delta Instruments CombiScope FTIR 600HP and FOSS CombiFoss 7), 4PROCES-based Customer Portal
2.4	LIMS (Laboratory Information Management System)	Scans the reference samples by barcode	Milk Scanner devices (Delta Instruments CombiScope FTIR 600HP and FOSS CombiFoss 7), 4PROCES-based Customer Portal
2.5	WIT cloud platform	Hosts the system software for data collection, machine learning and lameness record management	Neck collar, pedometers, Mobile App, Vendor Dashboard and ELD Machine Learning Algorithm
2.6	Azure IoT Hub	The Azure IoT hub and MS SQL are used for data handling and storing	Mineral feeder, Master unit (used as Gateway), Ear Tags, user interface (Pitstop+ Manager) and Big data (Microsoft Azure)
2.7	Moonsyst LoRaWAN server / Loriot server / Mooncloud	Moonsyst smart rumen monitoring system in combination with LoRaWAN data transfer	Smart Rumen Bolus, Application layer (Mooncloud software release 2.0), Information management and business logic layer (Moonsyst LoRaWAN server / Loriot server / Mooncloud), Gateway (Kerlink iStation)
3.1	Synelixis SynField Platform	SynField is a combination of software and hardware engineering to offer services on IoT, telecommunications and cloud technologies	SynField Data Logger
3.1	FIWARE Backend Device Management GE (IDAS)	IDAS IoT Agents translate IoT-specific protocols into the NGSI context information protocol	Devices that provide data which needs to be translated to NGSI
3.1	LoraWan Network	Communication network to connect IoT devices	Lora IoT devices (actuation node, soil moisture sensor)
3.1	Sigfox	Communication network to connect IoT devices	weather and soil moisture sensor
3.1	Sysman Cloud	Integration platform	Sysman P&S Sensors (soil moisture sensor, rain gauge, anemometer, pyranometer)
3.2	Wenda platform	Platform that allows to manage, analyse and share temperature and track	Sensors (Davis Weather Station, Micro-Weather station, Water-meter, Electricity

UC	IoT Platform	Short Description	Combination with Services/ Devices
		& trace data from production to consumer, supporting the most common tracking devices and monitoring systems	–meter, Mobile phenology camera sensor prototype, Foxed phenology camera sensor prototype, Cap Trap) Wenda Jodyn Live - datalogger
3.2	LoRaWAN	Communication network to connect IoT devices	Gateways (Lorrier LR2, Kerlink)
3.3	FIWARE Orion Context Broker	IDAS IoT Agents translate IoT-specific protocols into the NGSI context information protocol and Orion Context Broker is a message broker	Sensors (FOSS ProFoss for oilseed meals, ECH2O 5TE GROUND SENSOR, ECH2O EC-5 MOISTURE SENSOR) and FIWARE Backend Device Management (IDAS)
3.3	SynField platform	SynField is a combination of software and hardware engineering to offer services on IoT, telecommunications and cloud technologies	Various attached sensors
3.3	LoRaWAN	Communication network to connect IoT devices	LoRa Devices – Wellness
3.4	Vizix	IoT Platform to track physical assets throughout their supply chains. Supports sensor agnostic data collection, reporting, and provides data to different consumers in different formats.	CoatRack gateway, NXP Tracker via Sigfox Network, Wenda IT, Temperature Management application and Location Management application, KIZY Tracker
3.4	Sigfox	Communication network to connect IoT devices	NXP Tracker prototype with SigFox, GPS receiver, Temperature & Motion sensors, NFC interface Communication network to connect IoT devices
3.5	FEDE Cloud/ Fede Speciality Crops Platform (SCP)	Sensors will send data to the FEDE Cloud which data can be used by the SCG and SCS, all of this is possible because this cloud offer a H3O Restful Web Service	Sensors, Services (Business logic Kernel, Data Abstraction Layer, Restful Web Services), Gateway/Modem (Speciality Crop Gateway (SCG)), Control System (Sprayer Control System)
3.6	WENDA platform	It receives, elaborates and makes available to producers the data collected by the Verigo device and the Mobile App	Sensor (VERIGO+POD ONE), Services (Mobile API, Web API and Mobile App)
4.1	AWS Cloud and Microsoft Azure	The AWS Cloud with Microsoft Azure receives the data from the sensors implemented on the vertical farm and provides it to the interface called GrowView	Sensors (Temperature, humidity, CO2, Airspeed, PAR) Hardware (Camera, Raspberry Pi 3, PyCom Lopy4, Wlan Router, POE Ethernet switch) Services (GrowView – monitoring and Dashboard application, Data backend + API + client library)
4.2	FIWARE Orion Context Broker	The Orion Context Broker will receive data from the sensors, and then use AgroConnect and the BigData Analysis to generate and process data and then send to the user application	FIWARE BigData Analysis – Cosmos. Data from sensors
4.3	AgLeader SMS	GPS data visualization + processing AB Line + field outline management	Sensors (Mechanical intra-row weeder, Meteobot Weather Station, RTK-GPS receiver)

UC	IoT Platform	Short Description	Combination with Services/ Devices
4.3	Akkerweb/ Farmmaps	It performs different functions such as Data storage, Data processing, Decision support,Task-map generation and Showing data from the Weeding machine and the growth model	Sensors (Mechanical intra-row weeder, Meteobot Weather Station, RTK-GPS receiver)
4.4	FIWARE Backend Device Management IDAS	Connect objects to gather data or interact with them, using one of the existing IoT Agents that are part of IDAS: IoTAgent-LoRaWAN, IoTAgent-JSON, IoTAgent-LWM2M, IoTAgent-UL or IoTAgent-node-lib	Sensors (WINEGRID WP1100, WINEGRID BP1000 and WINEGRID E-BUNG), Services (ABACO siti4farmer, e-auditor cellar, e-loyalty)
4.4	LoRA WAN	Communication network to connect IoT devices	Sensors (WINEGRID WP1100, WINEGRID BP1000 and WINEGRID E-BUNG)
4.4	DIONISO	allows to collect the amount of information coming from the actors of the supply chain in a single large digital platform available to operators, who will be able to count on a high degree of automation of certification processes, with the advantage of timeliness, certainty of information and personalization	SITI4farmer (Abaco), Cellar inspection app (Uqido)
4.5	FINoT platform	Cloud-based IoT platform	Sensors (FINoT Agri Node, FINoT Gateway, FINoT irrigation controller, Air, soil, solar and rain sensor, flow meter, solenoid), Services(QUHOMA App)
5.1	Stienen webtool	Report inside temperature; Report ventilation rate; report outside temperature	Sensor (Stienen KL6000), Stienen Climate system
5.1	Monnit Cloud Platform: iMonnit	Download climate sensor data	Monnit sensors
5.1	Nedap webtool	Download feed intake; download pig weight; report feed intake; report pig weight	Sensor (Nedap feeding station)
5.1	LINKS VIRTUS IoT platform	Elaborate data received from the farms + calculate inferred data + forward data to Orion + expose historical data through APIs	Collects data from the platforms of all the specific companies (Stienen, Nedap, Fancom, Monnit,...)
5.1	FIWARE Orion Context Broker	Receive real-time data from farmers; notify subscribers about new data	PORPHYRIO Smart Farm Assistant, FIWARE IdM, FIWARE AuthZForge, FIWARE PeP Proxy
5.2	FIWARE Orion Context Broker + FIWARE IoT Agent	Gets the data from other FIWARE components (FIWARE IoT Agent) which are directly connected to the sensors, and sent it to FIWARE Cygnus in order to process the data to be shown to the user	FIWARE Key Rock, Mosquitto, FIWARE Cygnus, Sensors

UC	IoT Platform	Short Description	Combination with Services/ Devices
5.3	EPCAT (EPCIS solution)	manage events	EECC EPCAT EPCIS repository, EPCIS capture web application (M2M connector, Webservices), sensors from UC 5.1
5.3	FIWARE Orion Context Broker	Oliot-MG is a mediation gateway which translates information from NGSI based IoT platform to EPCIS based IoT platform. This enables capturing state change in FIWARE context broker in the form of EPCIS Event	Proactive auditing dashboard, EPCAT, and Oliot Gateway
5.4	FIWARE Orion Context Broker	FIWARE Based Cloud solution	Sensors (Weather and soil stations / GPS collars / IoT weight scales / Multi-sensor stations), IoT collars devices, IoT ear tags devices, IoT smart scale, Weather stations
5.4	Sigfox	Communication network to connect IoT devices	Used in every IoT device except for ear tags (Weather and soil stations / GPS collars / IoT weight scales / Multi-sensor stations)
5.5	FIWARE Orion Context Broker	Cygnus play the role of connector between Orion Context Broker GE and many FIWARE storages data sources as MongoDB, CKAN, etc.	Sensors (INSYLO Volumetric sensor) Services (INSYLO Remote Monitoring platform) and FIWARE GE-Cygnus
5.6	FIWARE Orion Context Broker	ORION (Context-Broker) is used to capture the information from the sensors, actuators, Third-Party web-services etc	Smart Spot Gateway
5.6	LoRaWAN	Communication network to connect IoT devices	Smart Spot Gateway

It can be summarised that the 33 IoF2020 use cases were deploying diverse types of IoT platforms that are representing e.g. open source initiatives, proprietary platforms, commercial services for IoT related communication as well as full PaaS environments like Microsoft Azure or AWS. However, just as a figure, the 33 use cases were deploying 54 IoT platforms. Of course, the complexity of those platforms differs significantly and in relation to the specific use case requirements.

The combination of IoT platforms, IoT devices and the related IoT solutions is also presented for each use case in the IoT-catalogue (www.iot-catalogue.com). At the same time, this will also facilitate the access to the related use case team for future collaboration within the community of stakeholders.

7 Use Case specific IoT based Solutions for Reuse and Replication of Results

Besides the reuse of external devices, components, or platforms, the IoF2020 use cases were also developing specific results that can be reused for the replication of IoT bases solutions. The teams involved in the use case are providing those results on different terms of usage, while usually offering those kind of results based on fair, reasonable, and non-discriminatory (FRAND) terms.

If external parties have a specific interest in the reuse and deployment of those results and or the usage of commercial services offered by use case related partners, they can identify related organisations either in the IoT catalogue (www.iot-catalogue.com) or the use case catalogue available via the IoF2020 website (www.iof2020.eu). The following Table 10 is listing the IoT based solutions for Reuse and Replication that were developed by the use cases.

Table 10: IoT based Solutions for Reuse and Replication of Results realised by the IoF2020 use cases.

UC	IoT based Solution	Reference Architecture	Reuse of external Components	Number of Installations
1.3	Dynamic crop model + weather data on site for irrigation fine tuning	From our IT-partner Sysman, on the market with their Bluleaf system, Sysman also engineers the Sigfox sensors which we implemented in our UC 1.3	Sigfox weather sensors	5
1.3	Real-time quality mapping during harvest	Based in technology from Dinamica Generale (NIRS) and combines from different manufacturers (Claas, New Holland, Case)	Dinamica Generales NIR on board kit	> 25
1.5	Telematics Device Eurotech	MQTT data transfer	-	50
1.5	Drone Based Analysis	-	-	50
1.6	IoT4Potato smart-farming solution	The overall solutions is based on set of components that consist the “Information Management Adapter (IMA)”. As it is presented in the functional architectural view in attached figure the IMA framework follows a layered architectural design approach where the main functionality is to translate data derived and modelled by the gaisense system to NGSIv2.	The FIWARE Generic Enabler Orion Context Broker is one of the core components utilised for ensuring interoperable data sharing. Data translators, instantiating the FIWARE IoT-agent paradigm can potentially be reused. The implemented translator converts gaiasense data to NGSIv2.	9
1.7	RFID and smart tags	NTAG RFID	ST25R	Single reader per trailer for multiple tags
1.7	LoRa wireless connection	LoRa point2point	Semtech chips	One per sensing module and one per trailer equipped with the authentication solution

UC	IoT based Solution	Reference Architecture	Reuse of external Components	Number of Installations
1.7	Wireless charging	Qi protocols	Chips, coils	one 'to be charged' per sensing module and one charging station (loader) per trailer equipped with the authentication solution
1.7	Smart Silo Server	HTTP API	Docker server + DB architecture	one server installation for complete IoT solution with multiple handheld readers, trailers and tags.
1.8	Gateways and sensors	LoRaWAN based	Hardware	Up to 200 farm sites
1.9	UAV	Corresponds to Semi-Autonomous Level One Control for indirect receipt and direct retransmission of imagery and/or data	DJI Matrice 600 PRO, Ronin-MX, DJI TB48S Battery, others	Single solution operated by qualified service provider team
1.9	Data acquisition hardware	Hyperspectral camera for 400-1000 nm at 3nm imaging and data collection SBC (Single-board Computer) architecture	BaySpec OCI-F-1000HR 400-1000 nm, 16 mm lens, SBC and accessories	Single solution operated by qualified service provider team
1.9	Data acquisition hardware	Hyperspectral camera for 500-900 nm snapshot imaging and data collection SBC (Single-board Computer) architecture	Senop HSC-2	Single solution operated by qualified service provider team
1.9	Data acquisition hardware	Hyperspectral camera for 450-800 nm snapshot imaging and data collection SBC (Single-board Computer) architecture	MosaicMil	Single solution operated by qualified service provider team
1.9	Data acquisition hardware	Satellite based opto-electronic multispectral sensor surveying Earth surface in the visible, near infrared (VNIR), and short-wave infrared (SWIR) spectral zones, including 13 spectral channels.	Sentinel-2	Publicly available spectral data source.
1.9	Data processing software	Big Data cluster for batch data processing and automation	BaySpec CubeCreator 2100, BaySpec CubeStitcher 1010, Amazon AWS, Amazon S3	Single installation in a cloud-based service provider
1.9	Data analysis and visualization software	Continuous Machine learning model training, inference and visualization in cloud-based service	Scikit-Learn, Tensorflow, Amazon AWS, Amazon EC2, Amazon S3 cloud-based services	Single installation in a cloud-based service provider

UC	IoT based Solution	Reference Architecture	Reuse of external Components	Number of Installations
2.1	Sensolus tracker	Data is made accessible by other parties via API access. Parties interested in knowing the location or geozone or motion of cows or even other animals like sheep.	Sigfox Network	4 farms / end-user sites
2.2	We have a custom solution written in C++ /C# with the base station sending sensor events to Azure Event Hub and Azure Blob	We have used the lambda architecture for streaming data into the cloud for fast analysis as the hot path and offline processing (catching up) as the cold / warm path	We have built a custom solution using the Azure Event Hub and Azure Blob SDK	100+
2.3	Bespoke	N/A	N/A	N/A
2.4	RDQ Tool	RDQ-tool is now only used for fluid dairy products and FTIR measurements. Plan is to extend the RDQ-tool also for dairy powders and NIR measurements.	None	4 (including Qlip)
2.5	Early Lameness Detection as a Service vendor dashboard	IoF2020 reference architecture	FIWARE Orion Context Broker	Dashboard is deployed in WIT infrastructure and accessed by vendors via a Progressive Web Application
2.6	Pitstop+ Manager	Pitstop+ Manager is for the backend programmed in Python, using Azure IoT hub and MS SQL for data handling and storing, and asp.NET for the frontend, which is a PWA with all the advanced functions this technology provides.	-	8
3.2	IoT Platform for Winegrowing and Wine production monitoring and control	LoRaWAN Network	FIWARE	-
3.2	IoT Platform to track sensitive goods	IoT platform supporting any hardware via API	The adjustments made on the Platform UI and on the mobile App can be used for any other track & trace use case	-
3.3	Olive Production Manager	IoT devices installed on the fields and irrigation advisory board (DSS)	IoT devices and software	The installations done at the end-users' sites are no reusable,

UC	IoT based Solution	Reference Architecture	Reuse of external Components	Number of Installations
				however the deployed technologies are reusable.
3.3	Olive Oil Quality Manager	IoT devices installed on the Olive Mills and Extractability and Quality board (DSS)	IoT devices and software	The installations done at the end-users' sites are not reusable, however the deployed technologies are reusable.
3.4	PT 5 Smart IoT tracker	Modular IoT architecture	The tracker can be used for any application that needs geo-tracking and sensing (shock, temperature, battery voltage) functionalities. It is low cost & low power solution which is scalable and provide easy maintenance features.	50 smart tray deployments
3.4	Smart Tray and Tracker as Hardware Solution	Hardware Architecture	The Smart Tray in combination with an IoT Tracker is reusable up to 5 times taking into account an average duration of food chain cycles. However, the tracker can be unmounted, opened and the battery can be exchanged.	In Total ~300 Smart Trays
3.4	Geo-positions and Zones interface between Location Management and IoT platform.	GS1 EPCIS & CBV	The possibility to communicate geo-positions as polygons was added to the GS1 (EPCIS) CBV Standard	With the publication of EPCIS/CBV 2.0 in beginning 2021 this functionality is open to all stakeholders.
3.5	SCG (Specialty Crop Gateway)	IoF2020 reference model	H3O Protocol Gateway REST + JSON	121
3.5	SCS (Sprayer Control System)	IoF2020 reference model	H3O Protocol Gateway REST + JSON	212
3.5	SCP (Specialty Crop Platform)	IoF2020 reference model	H3O Restful Web Services REST + JSON Web2py (open-source framework)	1686
3.6	IoT Platform to track sensitive goods	IoT platform supporting any hardware via API	The adjustments made on the Platform UI and on the mobile App can be used for any other track & trace use case	25

UC	IoT based Solution	Reference Architecture	Reuse of external Components	Number of Installations
3.6	Mobile App	-/-	The mobile app can be connected to any Bluetooth device do download ambient data	13
4.1	Vertical Farming solution	Proprietary solution, to be combined with environmental control systems	-/-	1
4.2	API-REST development	JSON	Private	1
4.2	Nazaries Services to FI-WARE harvester	JSON	Private/ Open	7
4.2	Labview to FI-WARE harvester	Labview-JSON	Private/ Open	1
4.2	Metos (Pessl) services to FI-WARE harvester	JSON	Private/ Open	1
4.2	Context broker subscription to MongoDB	API-REST	Private/ Open	1
4.2	Greenhouse Model as a Service GMaaS	Matlab Production Server	Private	1
4.2	User Interface	NodeJS	Private	1
4.3	Farmmaps map visualisation	GIS application	N/A	N/A
4.3	Crop growth model	Matlab	Open source growth model (adapted)	N/A
4.4	Vineyard / cellar audit	JSON	Communication with DIONISO	1
4.4	Sensor in the cellar	ARkit	Watgrid sensors	1
4.5	Smart Farming management platform	FIWARE	FIWARE Generic Enablers: Orion, QuantumLeap, IoT Agent	18
4.5	End user Management App	Android App architecture	Android Libraries, Android smart phones	18
4.5	Traceability service	EPCIS	GSDN Data pool	1
4.5	Smart Irrigation	-	COTS valve controllers	7
4.5	Microclimate data	-	COTS Humidity, Temperature, soil moisture etc. Sensors	18
4.5	Weather forecast data	RestFul	Internet weather station API	18

UC	IoT based Solution	Reference Architecture	Reuse of external Components	Number of Installations
5.1	IoT platform	3D reference architecture, ISO IEC JTC1 SC41	FIWARE Orion context broker, FIWARE security components, open standard communication protocols (XMPP, MQTT, NGSI)	5
5.2	Poultry Platform	FIWARE Orion Context Broker	FIWARE Generic Enabler	1
5.2	Poultry Platform	FIWARE – IdM KeyRock	FIWARE Generic Enabler	1
5.2	Poultry Platform	FIWARE Cygnus	FIWARE Generic Enabler	1
5.2	Poultry Platform	FIWARE PEP Proxy	FIWARE Generic Enabler	1
5.2	Poultry Platform	FIWARE IOT Agent	FIWARE Generic Enabler	1
5.3	https://iof.epcat.de/ (platform)	EPCIS	EPCAT, pig event model, olive event model	3
5.4	IoT collars devices	Proprietary	Hardware COTS device	7
5.4	IoT ear tags devices	Proprietary	Hardware COTS device	5
5.4	IoT smart scale	Proprietary	Hardware COTS device	2
5.4	Weather stations	Proprietary	Hardware COTS device	2
5.4	Cloud solution	FIWARE based	FIWARE Open Source	7
5.5	INSYLO	Enable data syndication through NGSI data modelling	FIWARE GE Context Broker – Orion	-
5.6	Smart Spot	FIWARE	Integrated device with FIWARE platform. This allows scalability, integration of more sensorics, for example, a gateway is used for environmental control in vineyards.	70

The use case specific solutions were deployed in use case specific test and validation sites. Those sites are representing a high variety of stakeholders, from farms to diverse stakeholders along the agri-food chain. On top of that, the solutions were deployed in real-world operational scenarios under certain test conditions. Therefore, the use case teams were able to analyse related costs/benefits as well as validated end-user requirements accordingly. As listed in the table above, that led to over 2,500 installations of reusable IoT based solutions in diverse agri-food sectors and European regions.

8 Conclusions

The IoF2020 project was realising 33 so called use cases. In those use cases, teams from different organisations were implementing diverse IoT based solutions in specific agri-food sectors. The strategic objective was to learn from those use cases in terms of challenges, technical issues and potential opportunities that can be realised with the addressed solutions. Those 33 teams had an individual interest to realise their IoT based solutions, while IoF2020 considers the experience gained as valuable outcome for a larger stakeholder community to learn and facilitate future deployments in similar as well as extended settings.

Accompanying to the specific implementation of the 33 use cases, WP3 was analysing the addressed solutions, architectures, data models and how to facilitate the replication of results, by identifying and developing key elements that will help other teams with future implementations. A key element is the IoT catalogue that is compiling all use cases in one repository that is going far beyond a simple listing of results, but being built on the interrelations of use cases, teams, components, solutions, value propositions, ICT problems, functions, targets, as well as key performance indicators, presenting use case results in terms of performance and impact. The catalogue is available to the public and enables interested parties to search from different perspectives, while the linked content helps to learn about relevant IoT technologies that are of relevance, but hard to identify in this large body of knowledge.

This was also the reason that WP3 was working on key reusable aspects that were of general interest for the use cases. The motivation was to realise results that can evolve at market speed and are rather flexible than perfectly matching all requirements. The data model initiative is addressing an agile standardisation process that shall help to work on pre-normative standards. The service monetization open-source initiative is providing an enabler to combine proprietary services with a larger user audience, what is considered as growing requirements when analysing the increase of data collected along the agri-food chain and the interest of stakeholders to monetize as well as to authorise the access to their data. This goes hand in hand with the data marketplace initiative, while this combines two aspects. On the one hand, different standards and code lists were compiled that are of special interest for technology providers, developing IoT bases systems in the agri-food domain. On the other, the work on the data marketplace was a joint initiative in collaboration with the FIWARE Foundation, GS1 and AgGateway. Despite their different fields of action, the strategic collaboration helped the different parties to discuss potentials for synergies and preparing memorandum of understanding for future collaboration. Finally, it can be highlighted that the work on security, privacy and trust by design was clearly showing that there is an urgent need for that in each and every IoT related initiative. Depending on the specific use case, the complexity and risks were highly varying. However, a significant amount of threats can be addressed by usual guidelines, while the SPT support team highly recommends to start an initial SPT analysis as soon as possible, even if it is rather simplistic than sophisticated. There will remain certain threats that require expert know-how to find an appropriate way to manage threats in terms of technology and costs, while those shall be managed in terms of damage potential, reproducibility, exploitability, discoverability and affected users. Therefore, it needs to be highlighted that decisions on how to handle threats are rather informed management decisions than obvious technological choices.

Moreover, in the last reporting period of IoF2020, WP3 was asking all use cases to identify the deployed components, standards applied, IoT platforms used and IoT based solutions for potential reuse and replicability. The presented listings for the use cases are confirming the heterogeneity of the use cases as well as the addressed trial areas. Specifically, the arable and meat trials were building their work on decades of standardisation, when looking for instance at the GS1, UN/CEFACT, or AEF initiatives. This is specifically due to the equipment used for daily operation or also based on traceability requirements like requested for cattle, taking into account experiences with mad cows' disease. A lot of development were also done in the dairy, fruits and vegetable sectors, while the solutions are merely using market ready IoT devices like sensors and actuators that are generally complying to ETSI related standards, while usually the integration of basic components are challenging the teams for the specific use case purpose.

Just in terms of figures, IoF2020 deployed thousand of devices that were deployed at thousands of sites. At the same time, usually use cases were using more than one IoT platform, while those are at diverse complexity level. Therefore, IoF2020 provides a large body of knowledge that also includes the deployment of reusable and replicable solutions with hundreds and thousands of implementations, while interested parties can contact the use case teams for future collaboration. This was also the reason to use the SmartAgriHubs project portal (https://www.smartagrihubs.eu/portal/) to make reusable results of WP3 available also beyond the end of IoF2020.

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