D3.3 DEMETER Reference Architecture (Release 2)

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1 Executive Summary

DEMETER aims to lead the Digital Transformation of the European Agrifood sector based on the rapid adoption of advanced technologies, such as the Internet of Things, Artificial Intelligence, Big Data, Decision Support, Benchmarking, Earth Observation, etc., in order to increase performance in multiple aspects of farming operations, as well as to assure the viability and sustainability of the sector in the long term. It aims to put these digital technologies at the service of farmers using a human-in-the-loop approach that constantly focuses on mixing human knowledge and expertise with digital information. It also aims to be compliant with the EU data strategy and recent initiatives which promote the commercialization and exploitation of data. DEMETER focuses on interoperability as the main digital enabler, extending the coverage of interoperability across data, platforms, services, applications and online intelligence, as well as human knowledge, and the implementation of interoperability by connecting farmers and advisors with providers of ICT solutions and machinery.

To enable the achievement of the above objectives, and to promote the targeted technological, business, adoption and socio-economic impacts, a key aspect is the DEMETER Reference Architecture (RA); this will drive the rest of the technologies developed to achieve the lofty objectives targeted. This deliverable describes the revised release of the DEMETER Reference Architecture as updated based on the experience and the lessons learned from the implementation of the DEMETER enablers and tools for the first round of pilots as well as from an updated state-of-the-art review examining the relevant recent projects and initiatives. To this end, it presents these relevant initiatives and projects as well as a summary of the experiences from the DEMETER implementation as distilled from the partners via the use of questionnaires. It then describes in detail the updated DEMETER RA, first by presenting its key concepts and then through several viewpoints (i.e., high-level, functional, process, data, deployment, and business views). Afterwards, it presents the interfaces among the core RA building blocks and finishes by presenting the updated RA instantiations that will have been implemented for the 20 DEMETER pilots (as part of the first round of pilot implementations).

2 Acronyms

ACS	Access Control Server
AI	Artificial Intelligence
AIM	Agricultural Information Model
AIS	Agricultural Interoperability Space
AKIS	Agriculture Knowledge Information Systems
API	Application Programming Interface
AWS	Amazon Web Services
BDTI	Big Data Test Infrastructure
BDVA	Big Data Value Association
BSE	Brokerage Service Environment
CAP	Common Agricultural Policy
CEF	Connecting Europe Facility
CEP	Complex Event Processing
CIM	Context Information Management
CSV	Comma-Separated Values
DEE	DEMETER-Enhanced Entity
DEF	Diesel's Exhaust Fluid
DEH	DEMETER Enabler Hub
DIAS	Data and Information Access Services
DM	Data Management
DSS	Decision Support System
EC	European Commission
EO	Earth Observation
ERP	Enterprise Resource Planning
ETSI	European Telecommunications Standards Institute
EU	European Union
FADN	Farm Accountancy Data Network
FAIR	Findability, Accessibility, Interoperability, and Reusability
FG-DPM	Focus Group on Data Processing and Management
FIE	Functional Interoperability Enabler
FMIS	Farm Management Information System
FMS	Farm Management System
GeoJSON	Geospatial Java Script Object Notation
GEs	Generic Enablers
GIS	Geographic information system
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSMA	Global System for Mobile Communications
GUI	Graphical User Interface
HPC	High-Performance Computing
HTTP	Hypertext Transfer Protocol
IACS	Integrated Administration and Control System

IdM	Identity Management
IDS	Industrial Data Space
IDSA	International Data Space Association
IEC	Industrial Internet Consortium
IoT	Internet of Things
IRRM	Interface Resource Registry Management
ISG	Industry Specification Group
ISO	International Organization for Standardisation
ITU	International Telecommunication Union
JRC	Joint Research Centre
JSON	Java Script Object Notation
LoRA	Long Range
LPIS	Land Parcel Identification System
MBB	Model Building Block
METS	Metadata Encoding and Transmission Standard
MIM	Minimal Interoperability Mechanism
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
NB-IOT	Narrowband Internet of Things
NCDX	Nordic Cattle Database Exchange
NGSI	Next Generation Sensors Initiative
NGSI-LD	Next Generation Sensors Initiative - Linked Data
NIVA	New IACS Vision in Action
NoSQL	Non-relational Structured Query Language
OASC	Open Agile Smart City
OMA	Open Mobile Alliance
PEP	Policy Enforcement Point
PPP	Public-Private Partnerships
PREMIS	Preservation Metadata Implementation Strategies
RA	Reference Architecture
RAF	Reference Architecture Framework
RDF	Resource Description Framework
REST	REpresentational State Transfer
SaaS	Software as a Service
SDG	Sustainable Development Goals
SIE	Semantic Interoperability Enabler
SME	Small and Mid-size Enterprises
SOCS	Stakeholders Open Collaboration Space
SPARQL	SPARQL Protocol and RDF Query Language
SQL	Structured Query Language
SR	Service Registry
SRIDA	Strategic Research, Innovation And Deployment Agenda
UAV	Unmanned Aerial Vehicle
UN	United Nations

WI-FI	Wireless Fidelity
WP	Work Package
XML	eXtensible Markup Language

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4 Introduction

This deliverable presents the second release of the DEMETER Reference Architecture as it has been updated since its initial inception in D3.1 and it incorporates the experience and lessons learned from the development of the DEMETER components and enablers and its implementation/integration for the first round of DEMETER pilots, as well as the influences from related initiatives and projects which both influenced the updates presented in this document. This updated architecture is used to integrate all the enablers and the technologies developed in all the DEMETER work packages.

More specifically, the rest of this document is structured as follows.

Section 5 presents the motivation behind the architecture revisions, such as being compliant with the newest related initiatives and strategies as well as the wealth of experience gained from the development and implementation of DEMETER. Aiming to facilitate the easy comparison of the changes between D3.1 and this document, it then presents an overview of the changes and updates that were made to the DEMETER Reference Architecture.

Section 6 provides an update to the state of the art since the original release of the DEMETER architecture in D3.1. It focuses on the new initiatives present in Europe and worldwide, such as the European Strategy for Data, the GAIA-X initiative, the Common European Agricultural Data Space. Then, it presents several relevant European AI projects and other initiatives.

Section 7 presents the questionnaires that were given to, first, the DEMETER pilots and second to the developers in order to ask for potential changes to the architecture derived from their practical experience with using the DEMETER architecture and its related tools.

Section 8 presents the updated main concepts of the DEMETER architecture: the DEMETER Stakeholders Open Collaboration Space and Agricultural Interoperability Space, both accessed by users through the DEMETER Dashboard, as well as the DEMETER Enabler HUB.

Section 9 presents the updated DEMETER Reference Architecture through several viewpoints (the same ones as in D3.1):

- subsection 9.1 gives an updated high-level view of the entire architecture;
- subsection 9.2 presents the updated functional viewpoint of the RA and describes the main components of the DEMETER system as updated;
- subsection 9.3 presents the updated process view and explains the system processes and how the components communicate to deliver the foreseen features, functionality elements and mechanisms;
- subsection 9.4 describes the updated data viewpoint, highlighting the data flows and the components needed to manage the main data processes;
- subsection 9.5 presents the updated deployment viewpoint mainly dealing with the topology and connections of software components on the physical layer when applications are deployed;
- subsection 9.6 presents the updated business viewpoint of the architecture, which will guide the application development and support the decision-making process.

Section 10 presents an updated view of the main interactions and dependencies between the core components of the architecture and an updated high-level description of the interfaces that need to be in place between these components.

Section 11 presents details on how the evolved state of the art related initiatives can map to the revised DEMETER Reference Architecture.

Section 12 presents specific instantiations of the revised Reference Architecture for all DEMETER pilots as updated since pilot round one.

Finally, Section 13 concludes the document and Section 14 provides the respective references used.

The architecture presented in this deliverable will be complemented and completed by the following deliverables as they become available, and which detail the updated reports regarding the various DEMETER tools and enablers:

- D2.3 DEMETER data models and semantic interoperability mechanisms – Release 2 (April 2021)
- D2.4 DEMETER data and knowledge extraction tools – Release 2 (May 2021)
- D3.4 DEMETER technology integration tools – Release 2 (June 2021)
- D4.3 Decision Support, Benchmarking and Performance Indicator Monitoring Tools – Release 2 (May 2021)
- D4.4 Decision Enablers, Advisory Support Tools and DEMETER Stakeholder Open Collaboration Space - Release 2 (June 2021)

5 Motivation for and overview of Reference Architecture Revisions

In this section, we present the motivation behind and an overview of the changes and updates that were made to the DEMETER Reference Architecture. The goal is to present an overview of what will be presented in the next sections of this deliverable and to summarize the key changes to the architecture (since the original release in D3.1) together with the drivers that led to these changes.

Starting with the motivation behind the architecture updates, firstly, these deal with new tech developments and initiatives prevalent since last year. These are primarily driven by the new European Strategy for Data, which puts emphasis on the data as an essential resource for economic growth, competitiveness, innovation, job creation and societal progress in general; this is achieved by being able to gather the necessary data (e.g., via monetization of said data by their providers), their analysis and their usage. Several projects and initiatives exist such as GAIA-X, which promotes a federated view on data usage, and the new Common European Agricultural Data Space, which aims to take the European data strategy to the domain of smart agriculture. In addition, we also consider other relevant projects and initiatives (which are all presented in Section 6) in order to drive the updates to the DEMETER RA.

Secondly, another source of input that drove these updates is from the experiences derived by the DEMETER project and its partners and the knowledge obtained from the deployment of the initial components and enablers of the DEMETER project during the first round of pilots and the experience with using these components and the instantiations to the various pilot sites and applications. To this end, we have received input from the pilot users (and the pilot developers) regarding any changes to the architecture and the way that data and the DEMETER enablers are used, both via peer-to-peer communication throughout the year, but more formally by distributing a questionnaire that asked for their experiences and suggested changes as well as issues with the integration of DEMETER enablers. In addition, since we wanted to check if there any plans for the commercialization of data, as this is a direction foreseen by the newest EU initiatives, we also included questions relating to their usage of such data and the potential to commercialize their own data. Like the pilot questionnaires, we also distributed questionnaires to the technical partners responsible for the development of the various DEMETER enablers. These focus on their experiences regarding the development of their enablers and whether they follow the principles of the DEMETER architecture and potential architecture revisions that would be desired and to a lesser degree to the commercialization of data. This process and the results of the processed questionnaires are presented in Section 7.

Regarding the methodology used to design the Reference Architecture of DEMETER based partly on the ISO/IEC/IEEE 42010 International Standard [TIIT], this methodology has not changed, therefore we still present the architecture in this document through its various viewpoints and by presenting the interfaces for the various components. We also revisited the architecture technical requirements, but overall decided that the general requirements for the Reference Architecture should not change, as for the more specialized ones that deal with specific components of the architecture, these will be addressed in D3.4 which will offer an updated view on the architecture tools and components as developed by the DEMETER WP3. However, in this document, we do document some of the changes as they relate to the general RA.

Having examined the motivation for the changes, we then present in Sections 8 and onwards the changes to the architecture, and we summarize in brief the most important of these in this section, so that the reader is aware of these. Thus, we present a brief description of the main RA changes as they are currently implemented in the DEMETER system, since what was envisaged in D3.1.

Overall, the key ideas of the architecture have not changed to any significant degree since D3.1. That is because we had already foreseen to create a modular architecture that allows the composition of systems and apps from various enablers: these enablers either provide the necessary data or the necessary processing capabilities (e.g., analytics, decision support, visualization) needed to compose complete applications. In addition, key to the DEMETER architecture is the Agricultural Information Model (AIM) developed, which provides a common ontology in order to allow all enablers to communicate with one another. To this end, another category of DEMETER enablers allows for the translation of various data formats (as needed) to and from the AIM model and format and these allow the communication of the various components to each other. Finally, the key concepts of DEMETER that enable the delivery of the project's objectives and targeted outcomes have not changed. More specifically, the DEMETER Stakeholders Open Collaboration Space (SOCS), focuses on resolving the needs of the farmers and provides an endpoint for them to access DEMETER, while the Agricultural Interoperability Space (AIS), focuses on delivering a full set of interoperability mechanisms to develop, validate and then deploy the solution, providing an endpoint for the developers and advisors to access DEMETER. Both of these are instantiations of the DEMETER Dashboard which is the entry point to the DEMETER ecosystem for all DEMETER Stakeholders, enabling them to access SOCS and AIS. The dashboard allows access to the DEMETER Enabler HUB (DEH), which centralises the full description of all the components, devices, services, data sources, platforms, etc. that are accessible for exploitation and ultimately for deployment and which provides the tools and facilities that allow to compose DEMETER enabled apps and systems from the various enablers registered in it. The key concepts are presented in Section 8.

However, while there are few changes to the overall RA design, several changes have been made to various components of the architecture as can be seen in Section 9 of this document, which presents the various architecture views.

First, some updates have been done to some key components of the hub and the DEMETER key components. For example, examining Figure 33 from D3.1, the deployment facilities of DEMETER are now offered by the Brokerage Service Environment (BSE) whose job is to facilitate the deployment of DEMETER enabled apps from various enablers, as it allows them to discover their endpoints and communicate with each other. In addition, the BSE also provides the compatibility checker for the various enablers that want to register with DEMETER through the hub. The runtime facilities are provided by the DEH client enabler. The hub (DEH) itself has also been slightly updated, as the compatibility checker is now part of the BSE instead and a few other minor changes have been done to it as described in Section 9.2. Furthermore, the hub now offers a Resource Consumption Monitoring component tied with the accounting component to enable any commercialization model for data and enablers in general as required. By doing this, DEMETER is in line with the newest initiatives, such as GAIA-X or the European data strategy, as they should allow the commercialization of data and services.

Second, some of the core enablers have been updated and the communication core enabler has been completely removed as it is not necessary. Due to the usage of AIM and the ability of enablers to directly talk to one another as they are discovered via the DEH, this meant that having a dedicated communications enabler has been unnecessary for the integration of the DEMETER enabled apps; and thus, this enabler has been removed from the core DEMETER enablers in the revised RA. Other core enablers have been renamed, e.g., the Access Control Service (ACS) enabler is the new instantiation of the Security Protection core Enabler (as presented in D3.1). This updated view is presented in Figure 29 (which presents the core DEMETER enablers) as well as in the high-level view of the architecture.

Third, some updates have been done to the advanced enablers presented in D3.1. In this document, we give an updated (and significantly) expanded list of advanced enablers developed for DEMETER and its pilots, which can be found in Section 9.2 (Functional view).

Fourth, the remaining views of the architecture have been updated appropriately in order to support the changes described to the high-level and the functional views of the architecture as well as the key components and enablers of the architecture. Supporting privacy and data governance to incentivize the sharing of data by the providers is also partly enabled by these changes.

In addition, some (relatively small) updates have been reported in the interfaces section as well, which also reflect the experience obtained from the deployment of DEMETER tools and enablers and their integration into the various DEMETER pilots. This is reported in Section 10 of this document.

Finally, the updated instantiations of the architecture views for the various DEMETER pilots, in view of the changes in the architecture are presented in Section 12.

6 Additions to Related State of the Art Review

In this section, we present an update to the state of the art since the original release of the DEMETER architecture in D3.1. More specifically, the new initiatives which are described in this section are informed and driven by the European Strategy for Data; some key directions of which are presented in the first subsection here. Then we present two key initiatives: first, the GAIA-X initiative which promotes a federated view on data usage and, second, the Common European Agricultural Data Space, which aims to take the European data strategy to the domain of smart agriculture. Then, we present several relevant European AI projects (e.g., AI4EU), followed by several other relevant projects and initiatives.

The mappings of these initiatives to the revised DEMETER Reference Architecture are discussed in Section 11, after the updated RA presentation.

6.1 European Strategy for Data

The EU considers digital transformation as one of the key aspects that will drive new businesses and business growth in general. However, this depends "on establishing effective frameworks to ensure trustworthy technologies, and to give businesses the confidence and means to digitise." Access to and the ability to use data are essential for innovation and growth of said businesses. Therefore, Europe recognises that data is an essential resource for economic growth, competitiveness, innovation, job creation and societal progress in general. The European Commission has launched during 2020 the Data Strategy [EUDataStrategy] as well as the White Paper on Artificial Intelligence [WPAI], which puts emphasis on notions such as "ethical AI" as a driver in the usage and processing of data. Both aim towards ensuring the global competitiveness of Europe and data sovereignty by fostering the creation of a single market of data. The European Commission (EC) proposes a European data governance, which is fully in line with EU values and principles. The so-called European Data Governance[1] promotes the creation of common European data spaces at the centre of this strategy with the aim of making available shared data sources for a domain of application with clear rules, policies, compliance with regulations and technical means to ensure data and service interoperability. These data spaces will ensure the availability and accessibility of more data for companies and the society, via the exchange of usage of data across several sectors and EU member states, while empowering data owners (individuals, companies) in control of their data. Now, of special interest for DEMETER is the data space focusing on agriculture data.

In practical terms, the European Data Governance will provide 1) mechanisms to reuse public sector data not available yet as open data; 2) mechanisms for trustworthy data sharing schemas in the data spaces; 3) ways to facilitate and foster the sharing of data for individuals and businesses and to use the data across sectors and borders.

This directive is driven by the growth in data generation and the economic (projected) growth that this would lead to, as increased data generation and usage would lead to increased economic value. These EU projections for the year 2025 [EUDataStrategy] are shown in Figure 1.

[1] https://ec.europa.eu/digital-single-market/en/european-data-governance

Figure 1. Projected figures regarding data volume and economic impact in the EU for year 2025.

Now, to get back to the main point of interest of the new data strategy, the key idea is to create a single European (most likely federated) market for data coming from several sectors and sources. This will be facilitated by the new European rules that will ensure, in particular, privacy and data protection and that “the access and use of data are fair, practical and clear”.

In addition to setting these clear and fair rules on access and re-use of data, the EU is also investing in next-generation tools and infrastructures to store and process data, to enhance the European cloud capacity. Furthermore, the goal is to enhance interoperability[2] and, thus, allow pulling together European data in key sectors, while also “giving users rights, tools and skills to stay in full control of their data”.

To facilitate all these, several topics of the work programme of the new Horizon Europe Framework and the Digital Europe Programmes are dedicated, in fact, to the creation of data spaces and the technology to support them; they also focus on trustworthiness, data sovereignty and data sharing mechanisms. The EC is going to invest billions of euros to support the creations of these data spaces as well as promoting the usage of trustworthy cloud infrastructures and related services. It is therefore a good opportunity to place DEMETER at the core of this strategy as one of the pillars to enable data spaces for agriculture.

The EC has also appointed several High-level Expert Groups related to these topics. On the one hand, the High-level Expert Group on Artificial Intelligence [EGAI], following the launch of the European Artificial Intelligence Strategy, is formed by more than 50 experts providing advice for the implementation of its strategy on AI. This expert group has already published several documents related to ethics and trustworthy AI, policy and funding recommendations at a European and at sectoral level. On the other hand, the High-level Expert Group on Business-to-Government Data

[2] Interoperability is a key aspect of this strategy, however, it is not clear if a common model would cover all this data and different initiatives mentioned in this section take different approaches.

Sharing [EGB2GDS] is formed by more than 20 experts and has published a report[3] on this topic, including a set of policy, legal and funding recommendations.

6.2 GAIA-X

The **GAIA-X** project [GAIA-X] aims towards the creation of a federated, open European data infrastructure, enabling the interconnection of centralised and decentralised data infrastructures to turn them into a homogeneous, user-friendly system. Thus, GAIA-X will define the technical principles which foster the implementation of the European Data Strategy. Data Sovereignty, i.e. the execution of full control and governance by a data owner over data location and usage, is one of the core principles of GAIA-X. The requirement of data sovereignty has led to the following high-level requirements for a GAIA-X implementation:

- Openness and transparency: specifications will be accessible to all GAIA-X participants, technical steering and roadmap definitions are conducted in a public process.
- Interoperability: participants can interact with each other in a defined way. Self-description and policies are used to manage interactions between data providers and data consumers.
- Federation: standardized access and multiple decentralized implementations operated by autonomous providers.
- Identity and trust systems to manage the interaction between GAIA-X participants, without building upon the authority of a single corporation or government.

The core architectural elements in GAIA-X are *assets, participants,* and *catalogues*. Participants are natural or legal persons that can act as a provider, consumer, data owner, and visitor. Providers can host multiple user accounts. Assets can either be a *Node,* a *Service*, a *Service Instance,* or a *Data Asset*. Hereby, a node is in general a computational resource like a data centre or an edge computing device, and nodes can be organized in hierarchies. Services can be deployed on nodes and describe a cloud offering. A service instance is the concrete realization of a service running on a node. All nodes, services, and service instances are associated with a provider. Data assets are data sets that can be either searched, provided, or consumed by either another service or a participant, are hosted on a node, and are owned by a participant. GAIA-X data assets are content- and structure agnostic and provide metadata and a self-description. Self-descriptions that describe the characteristics of assets and participants, and catalogues are the elements that implement the publication and discovery assets and participants.

The architecture of GAIA-X fosters the development of digital ecosystems and structures them into *Infrastructure Ecosystems* and *Data Ecosystems*. The infrastructure ecosystem comprises hereby services to transfer, process, and store data. Stakeholders of the infrastructure ecosystem can be cloud service providers, edge clouds, HPC providers, etc. Under the data ecosystem, actors along the data value chain are summarized. This could be for example data providers, data owners, data consumers, or smart service providers.

Following the global European data strategy, described earlier, GAIA-X aims to become a Data Ecosystem and Infrastructure covering in that way the European values and standards and its architecture is being driven by the overall mission. GAIA-X's architecture utilizes both information technology and digital processes to realize the connection among all participants belonging to the

[3] Available at: https://ec.europa.eu/digital-single-market/news-redirect/666643

European digital economy. Through the leverage of standards that now exist, open technology, and concepts, it realizes easy-to-use, open, quality-assured and consistent services and data that are characterized by innovation. GAIA-X aims to become a facilitator bringing interoperability and interconnection among the several participants both for data and services.

As known, Digital Sovereignty characterizes the ability or power to make decisions concerning digital processes, infrastructures, digital processes, or the way that data are moved, structured, built, and managed. The GAIA-X architecture provides technical solutions to establish Digital Sovereignty following EU standards.

Digital Sovereignty, which is a case of Data Sovereignty, represents full control, execution, and governance by a Data Owner on fields such as data location and usage. GAIA-X can enable the participation of Providers and Consumers in a digital sovereignty ecosystem via the application of core architectural principles that are described below. GAIA-X, as shown in Figure 2, uses technological approaches such as:

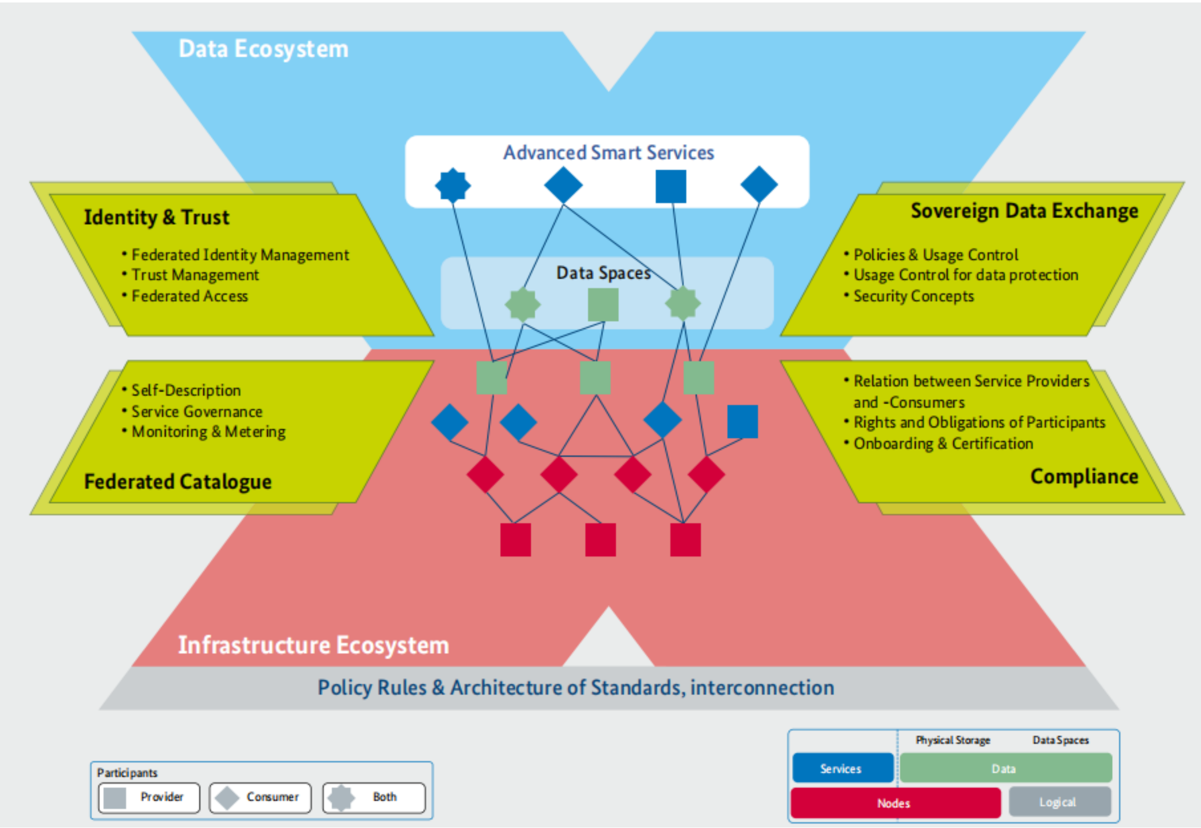

Figure 2. High-level representation of GAIA-X architecture that shows the major architecture components and functions that are followed by the Federation Services.

a) Federation, that supports standardized access to GAIA-X and implementations in a decentralized way, providing a rich digital ecosystem. Each component enhances security policies in the different resources and endpoints of the system.

b) Self-Descriptions and Policies, that provide the common elements on a technical level related to the selection, coordination and initiation of the interactions between Consumers and Providers.

More specifically, the Self-Descriptions stand for GAIA-X offerings and Policies the stand for requirements. If those two matches, then they can start to interact with the GAIA-X ecosystem.

c) Identity and Trust, which helps GAIA-X Participants to verify if their interaction with others and also the services they use is reasonable, authentic, and backed by Self-descriptions and Policies.

As far as the architecture principles is concerned, we describe below the essential principles gathered from the architectural vision and objectives and stand for the main (core) that this architecture follows:

1) Openness and Transparency: The documentation by GAIA-X technologies and the documentation and architectures could be accessed in a worldwide level from the Participants. Everything, such as the roadmap of GAIA-X, technical steering of GAIA-X takes place in public and the cooperation with private sector players will be uncovered.

2) Interoperability: Each participant will interact with all the other participants in a well-specified way. Although the architecture describes the technical means to succeed in that, it is questioning and operates far from the specific implementations.

3) Federated Systems: GAIA-X (Figure 3) identifies clearly a federated system that comes from autonomous Providers, connected with a specified set of standards, legal rules and frameworks. Federation also includes decentralization and distribution.

4) Authenticity and Trust: A secure digital environment can be enhanced without building upon the authority of the government or a single corporation. This can be achieved with an identity management system with a specified declaration, revocation of trust, and mutual authentication.

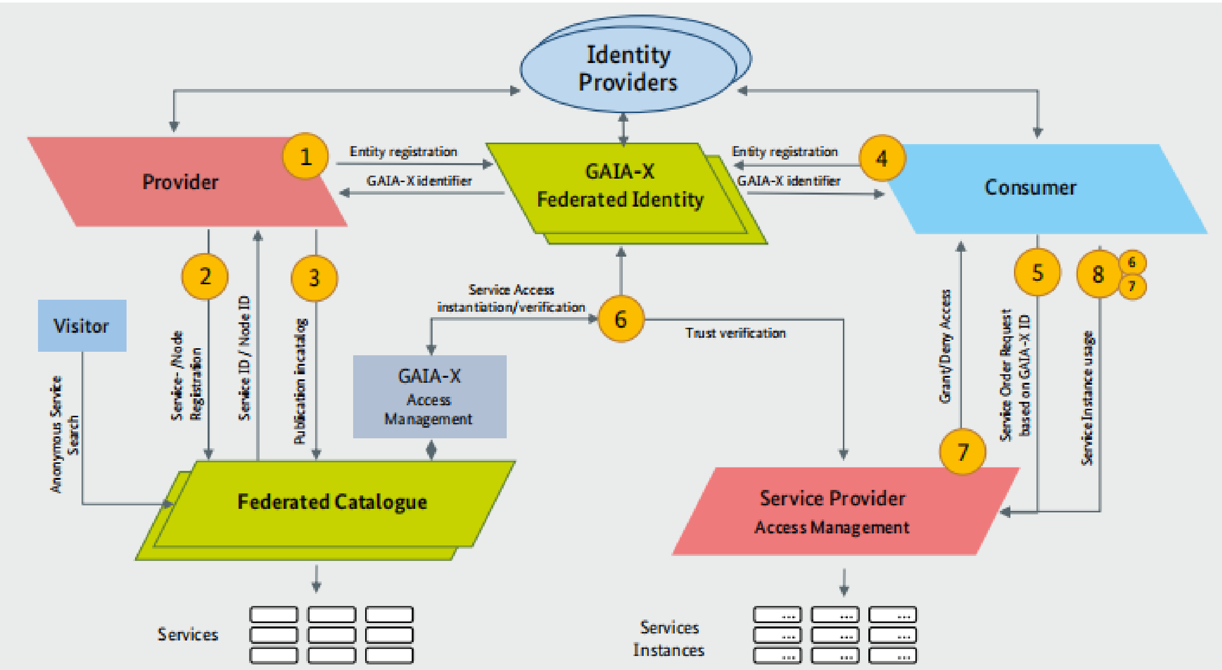

Figure 3. High-level description of the Federated Identity Model

6.3 Common European Agricultural Data Space

Creating a common data space for agricultural data is in its infancy right now. However, the directions where this data space is going have been discussed in a recent workshop,[4] where questions about the federation and usage of agricultural data have been examined. More specifically, the goal was to gather expert views on how to support the implementation of a Common European data space in the agriculture sector following the general strategy for data that has been discussed earlier in this report (see Section 6.1).

The questions posed in this workshop revolved around whether the federation of some of the Farm Management System (FMS) platforms and other data platforms is feasible, what is needed to implement a European Data Space from a technical point of view (e.g., interoperability mechanisms), whether data are available and suppliers of data ready to share them in federated data platforms. Furthermore, whether there exist such data sharing platforms, which public data might be useful to such an endeavour.

Currently the landscape of existing data platforms including four main sources of Agri data: data from machinery suppliers, alliances and data sharing platforms, open data (e.g., sat and weather data) and other data sources, as displayed in Figure 4 below.

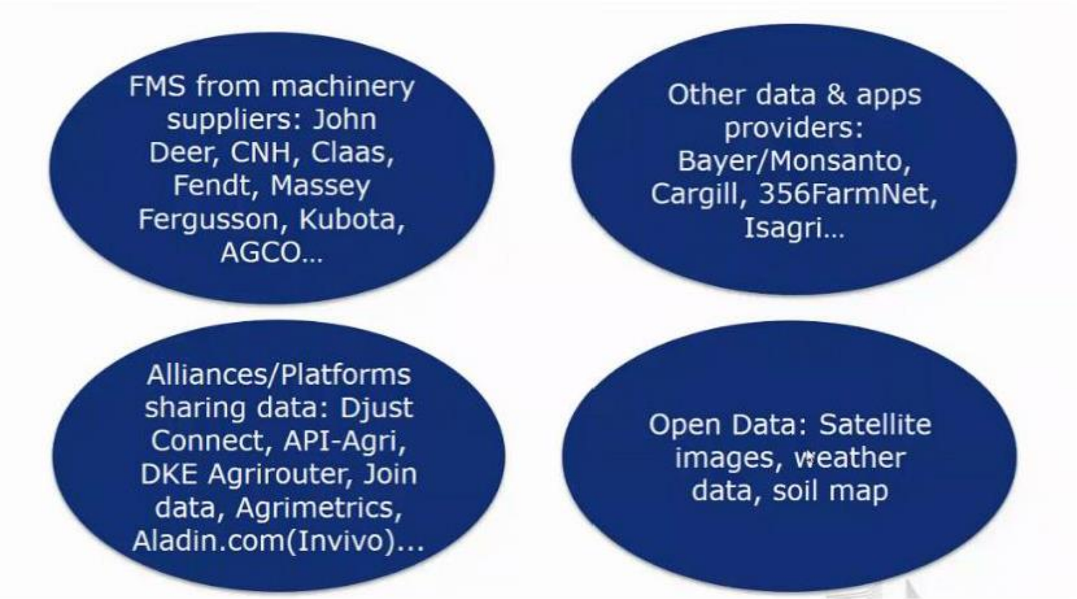

Figure 4. The landscape of existing data platforms

A key objective of the workshop and the initiative, in general, is the drive to aggregate or federate all these data platforms to facilitate data exchange, to increase end-user flexibility and to better use the potential of data in the agricultural sector. In order to address this, issues like data interoperability, data governance, and business models about the usage and procurement of the data is necessary; in addition, resolving challenges that deal with incentivizing actors to be willing to share their data and participate in this data space.

Now, the design of the technical specifications of this Data Space is still to be defined. For example, the lack of interoperability mechanisms is one of the biggest technical hurdles. While the federation

4 https://ec.europa.eu/digital-single-market/en/news/expert-workshop-common-european-agricultural-data-space-0

of FMS and other data platforms is technically feasible, however, the lack of architectures and standards for syntactic and semantic interoperability, which are not widely implemented, forms an essential barrier. Some current projects (e.g., ATLAS or DEMETER) work towards alleviating this problem. Other issues are the role of public data and the contribution to the "common good", for example as regards to R&I spending or policy monitoring. To this end, the data space should provide data sharing tools and platforms, data governance frameworks and in general necessary improvements to the quality, availability, interoperability of data in specific sectors and across sectors.

Some participants raised the necessity of using the FAIR (findability, accessibility, interoperability, and reusability) principles when it comes to the access, management and use of data. Key in the usage of data is the data sovereignty aspect: e.g., companies want to stay in control over the flow of their data and there is a lot of potential also in linking data at a cross-domain level. Therefore, focusing on the sovereignty aspect, IDSA emphasised an imbalance: on the one hand everyone talks about interoperability, about data exchange, about data sharing, about data-centric services, but the topic of data ownership, data security and data value, in general "the ability of a natural or legal person to exclusively and sovereignly decide concerning the usage of data as an economic asset" has not been sufficiently addressed. This falls within the business models aspect that was discussed in the workshop. In Figure 5, IDSA presented their view on using multiple enablers to create the digital ecosystems while preserving the necessary data sovereignty.

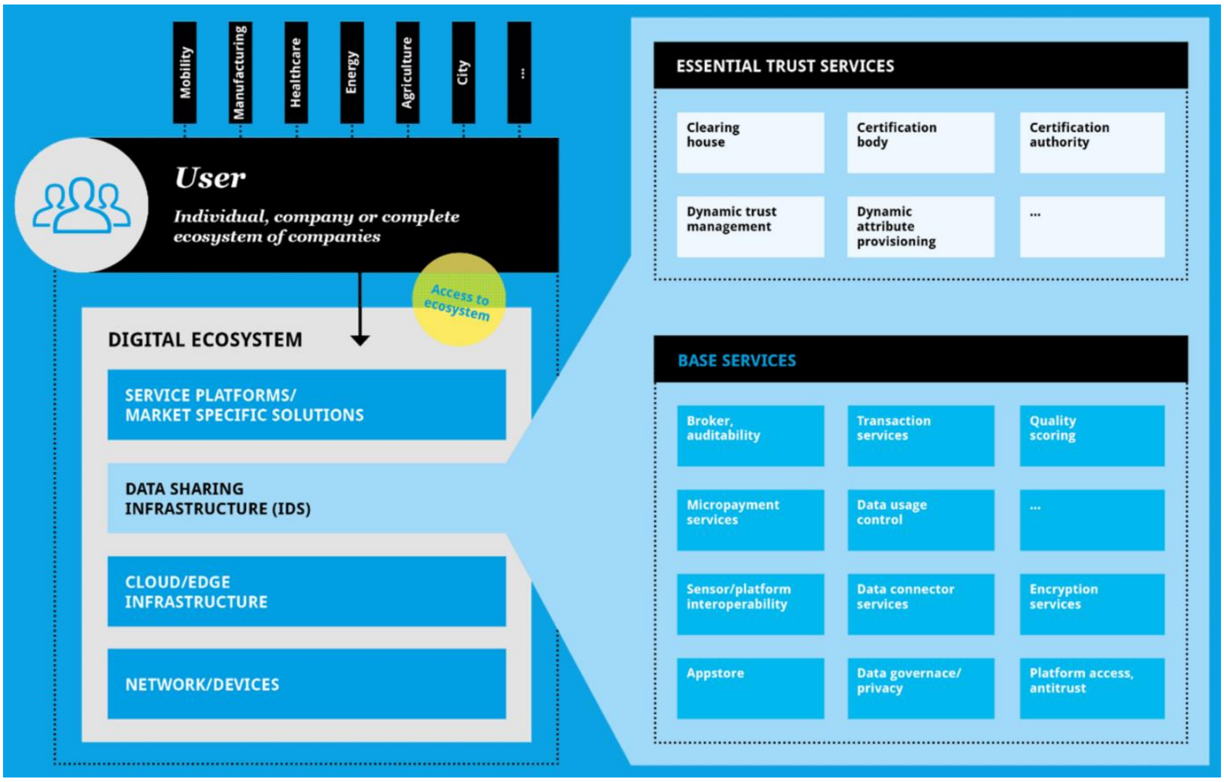

Figure 5. IDSA view using multiple enablers to create the digital ecosystems

Another participant, DKE-Data, presented their experience from the data exchange platform which links data from various providers such as agricultural engineering companies and is open to other machinery providers as well as to software and hardware providers. They claim that a move towards customer-specific agricultural data-storages, because farmers do not want necessarily to store data in the apps they use, gives them the freedom to work with the data and chose the app that they prefer and to also use data from various source (most prominently open data) rather than dealing with a single centralized storage platform. This view is presented in Figure 6.

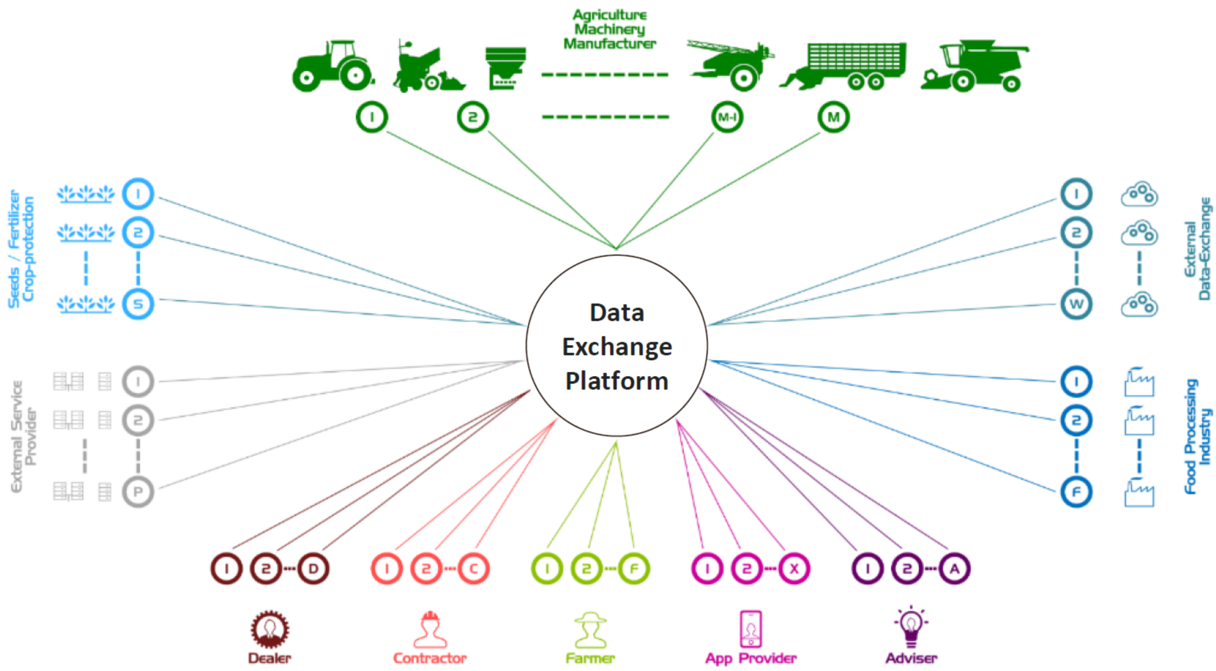

Figure 6. European Agricultural Data Space. Conceptual view proposed by DKE based on their experience with dealing with customer agricultural data

To sum up, the most important challenges that seems to require answers related to data sovereignty and the ability to control one's data, the business model that the data space and providing/consuming data would entail as well as the data interoperability aspect as well.

6.4 The AI4EU Project and other Relevant European AI projects

We present here the AI4EU project, its mapping to the DEMETER RA as well as a few other projects following in the same logic as AI4EU or, in fact, using it.

6.4.1 Description of the AI4EU Project

One of the main European AI initiatives aims not only at the creation of an Artificial Intelligence On-Demand Platform but also an ecosystem, where all relevant actors (SMEs, industries, research institutions, and citizens) across the EU can participate and collaborate, being these objectives the main goals of the AI4EU project[5] [AI4EU]. As this initiative strongly focuses on the collaboration of different actors, the platform will serve as a nexus by providing documentation and resources, easing the connection and exchange between partners as well as a discussion area and identification of new collaboration opportunities like seed funding for new innovative projects.

[5] https://www.ai4eu.eu/

The ACUMOS-based platform, which is one of the main goals of the project, will give access to all kinds of resources needed for the creation of AI-related solutions, covering the entire process of AI-based developments, including AI-services, datasets, components, computing resources, etc. To reach a wider target, this platform will be easily accessible, offered as a web platform, and follow a service-oriented approach. Additionally, it has been designed to be extensible, scalable, and interoperable, offering tools for the collaborative creation of AI solutions based on many state-of-the-art technologies. This platform also offers computational resources, which help to cover the whole lifecycle (not only the design and implementation) of the creation of AI-based solutions, including those that have high computational requirements.

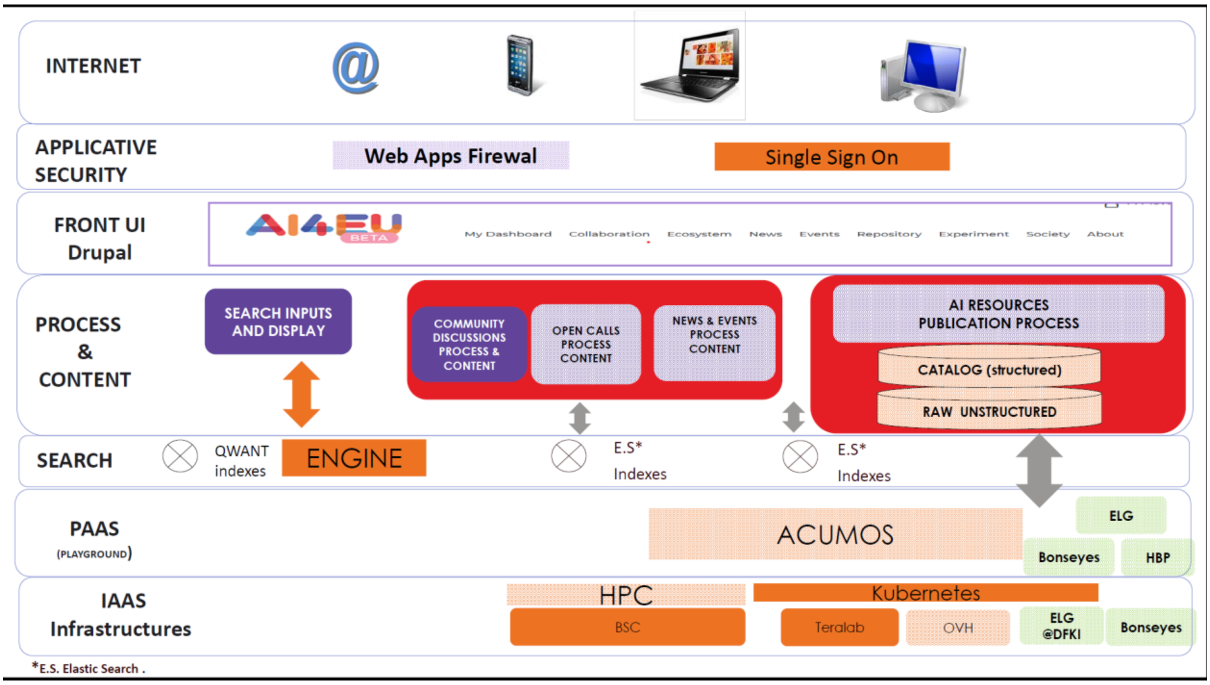

Figure 7. AI4EU reference architecture

AI4EU follows a multi-disciplinary and cross-sector approach, with respects to its applicability, in order to address all the possible scenarios. This can be seen in the different AI4EU pilots, reflecting the applicability of the platform to the different domains identified, as illustrated in Figure 8.

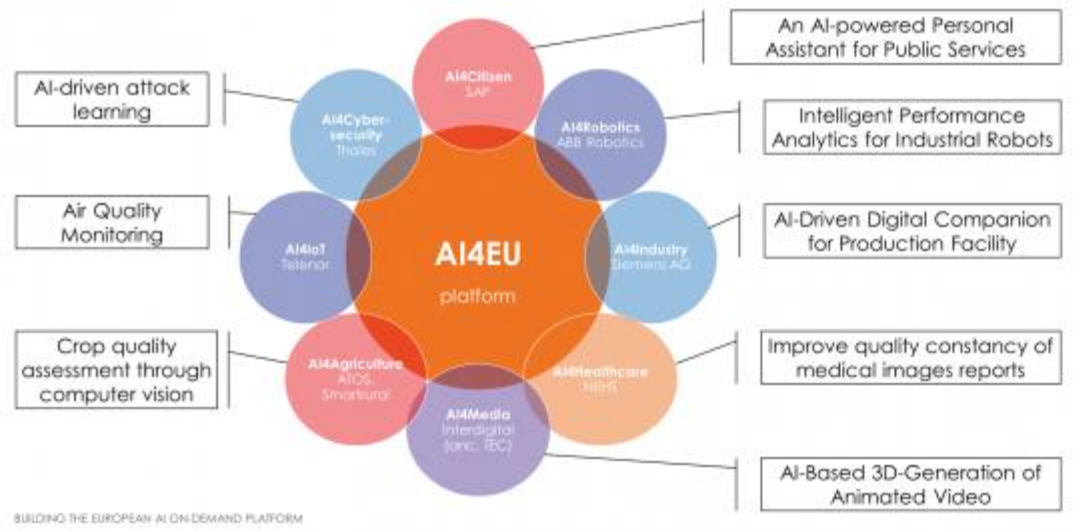

Figure 8. Domains covered by the AI4EU pilots[6]

From all the fields of application of the AI4EU pilots, there is one that might be of special interest for DEMETER, as it is focused on the agricultural area. That pilot[7], focused on crop quality assessment, is focused on the development of components that will help on estimating both the quantity and quality of grape production in vineyards. These components include models that will use photos taken in the field, satellite imagery and other data sources, such as weather data, field characteristics and will be deployed in the ACUMOS-based platform. Additionally, the resources of the pilot will also be published in both the AI4EU catalogue and the model repository. Another critical issue of the expected outputs of this pilot is the creation of an open discussion group for AI in agriculture in the AI4EU platform, where different agro-technological resources might be shared and discussed.

AI4EU offers a long-term roadmap, as during and after the end of the project, it is being complemented by a set of ICT-48 and ICT-49 projects that seek to reinforce the strategy of the EC regarding Artificial intelligence democratization (via providing resources, continuing the solutions provided, or helping companies to improve their processes, products and services through the Digital Innovation Hubs that will also help to spread the cope of this project, reaching all the potential actors interested in participating for one of these initiatives).

6.4.2 Other related projects: AI4Copernicus, AIPlan4EU, AI4EO

This section presents projects which follow along the same lines and logic as the AI4EU project. For each project, we describe its key aims and the approach taken where such information is available.

AI4Copernicus [AI4CO] aims to make the AI4EU AI-on-demand platform the platform of choice for users of Copernicus data along the value chain (scientists, SMEs, non-tech sector). AI4Copernicus will achieve this by exposing AI4EU resources on DIAS (data and information access services) platforms, making it easy to obtain computing power and large EO data, as well as to access training material

[6] Image available at: https://www.ai4eu.eu/pilot-experiments
[7] https://www.ai4eu.eu/ai4agriculture

and expertise. AI4Copernicus proposes to reinforce and optimise the AI4EU platform service offering with AI4Copernicus datasets, tools and services relevant to Copernicus data to facilitate the use and uptake of the platform resources in domains of high economic and societal impact, such as in Agriculture, Energy, and Security. A series of 4 open calls have been planned, leading to 8 small-scale experiments (smaller, single-beneficiary experimental projects targeting technology-advanced users) and 9 use-cases (larger-budget projects, involving at least one non-technology user). The open calls will necessitate the utilisation of DIAS platforms, Copernicus data, the AI4EU platform, and the services and resources that will be provided by the AI4Copernicus project. Through organizing, facilitating, and mentoring these Open Calls, AI4Copernicus will reach out to new user domains and boost the use of the AI4EU platform. More specifically, AI4Copernicus aims to: (1) Expand and deepen the integration of AI4EU with DIAS platforms to enrich the AI4EU service offering and enable far-reaching innovation; (2) Kickstart the innovation cycle by incentivising diverse AI4EU and Copernicus communities to solve real problems of business and societal value; and (3) Drive the evolution, uptake, and impact of all involved platforms: AI4EU and the DIAS platforms, especially WEkEO, CREODIAS and MUNDI.

https://cordis.europa.eu/project/id/101016798

Automated Planning and Scheduling is a relevant technology for many application areas that need quick, automated, and optimal decisions, like agile manufacturing, agrifood, or logistics. The **AIPlan4EU** [AIPLAN] project will bring AI planning as a first-class citizen in the European AI On-Demand (AI4EU) Platform by developing a uniform, user-centred framework to access the existing planning technology and by devising concrete guidelines for innovators and practitioners on how to use this technology. To do so, we will consider use-cases from diverse application areas that will drive the design and the development of the framework and include several available planning systems as engines that can be selected to solve practical problems. We will develop a general and planner-agnostic API that will both be served by the AI4EU platform and be available as a resource to be integrated into the users' systems. The framework will be validated on use-cases both from within the consortium and recruited with cascade funding; moreover, standard interfaces between the framework and common industrial technologies will be developed and made available.

https://cordis.europa.eu/project/id/101016442

AI4EO [AI4EO] is an initiative by the European Space Agency's Φ-lab, to better connect the artificial intelligence (AI) and Earth observation (EO) domains. The AI4EO initiative looks to foster innovation in Earth Observation, through the application of AI techniques. The impact of AI in this domain has large environmental, societal, and economic implications, and the merging of these two domains can yield in actionable insights for scientists, as well as political and economic decision-makers.

https://ai4eo.eu/

6.5 DataBench - Big Data and AI Pipeline Framework - related to BDVA and DAIRO models

The DataBench project [DataB] has created a Framework for Big Data [BigData] and AI Pipeline descriptions based on the Big Data Value Association (BDVA) reference architecture. In order to get an overall perspective on Big Data and AI systems, the usage of a top-level generic pipeline has recently been introduced by the DataBench project as a complementary data and control flow perspective for the description and analysis of technologies used in the context of a Big Data and AI

Application. The DataBench project also uses this to relate to technical benchmarks and business benchmarks, as supported by the DataBench Toolbox.

The Big Data and AI Pipeline Framework is based on the elements of the BDV (Big Data Value Association) Reference Model. To have an overall usage perspective on Big Data and AI systems, a top-level generic pipeline has been introduced, which allows to understand the connections between the various parts of a Big Data and AI system in the context of an application flow. The following figure depicts this pipeline, following the Big Data and AI Value chain.

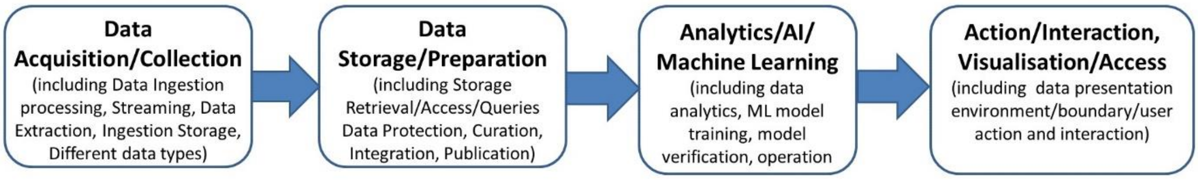

Figure 9. Top level Generic Big Data and AI Pipeline pattern

As it can be seen in Figure 9, this pipeline is a high-level view. Therefore, it can be easily specialised in order to describe more specific pipelines, depending on the type of data and the type of processing (e.g., IoT data and real-time processing). The 3D cube in figure below depicts the steps of this pipeline in relationship with the type of data processing and the type of data being processed.

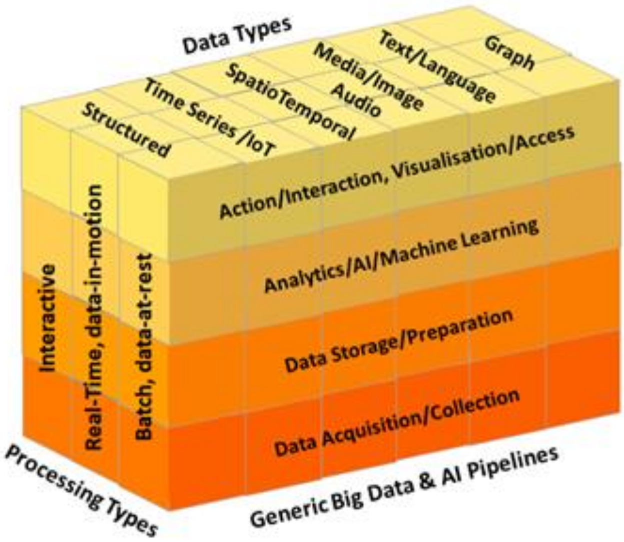

Figure 10. Top level Generic Big Data and AI Pipeline cube

As seen in Figure 10, the type of data processing, which has been identified as a separate topic area in the BDV Reference model, is orthogonal to the pipeline steps and the data types. This is due to the fact that different processing types, such as Batch/data-at-rest and Real-time/data-in-motion, can span across different pipeline steps and can handle different data types, as the ones identified in the BDV Reference Model, within each of the pipeline steps. Thus, there can be different data types like structured data, times series data, geospatial data, media, Image, Video and audio data, text data, including natural language data, and graph data, network/web data and metadata, which can all imply differences in terms of storage and analytics techniques.

Other dimensions can similarly be added for a multi-dimensional cube, e.g. for Application domains, and for the different horizontal and vertical technology areas of the BDV Reference model, and for the technology locations of the Computing Continuum/TransContinuum – from Edge, through Fog to Cloud and HPC [OPENF]– for the actual location of execution of the four steps, which can happen on all these levels. The same orthogonality can also be considered for the area of Data Protection, with privacy and anonymization mechanisms to facilitate data protection. It also has links to trust mechanisms like Blockchain technologies, smart contracts and various forms for encryption. This area is also associated with the area of CyberSecurity, Risk and Trust.

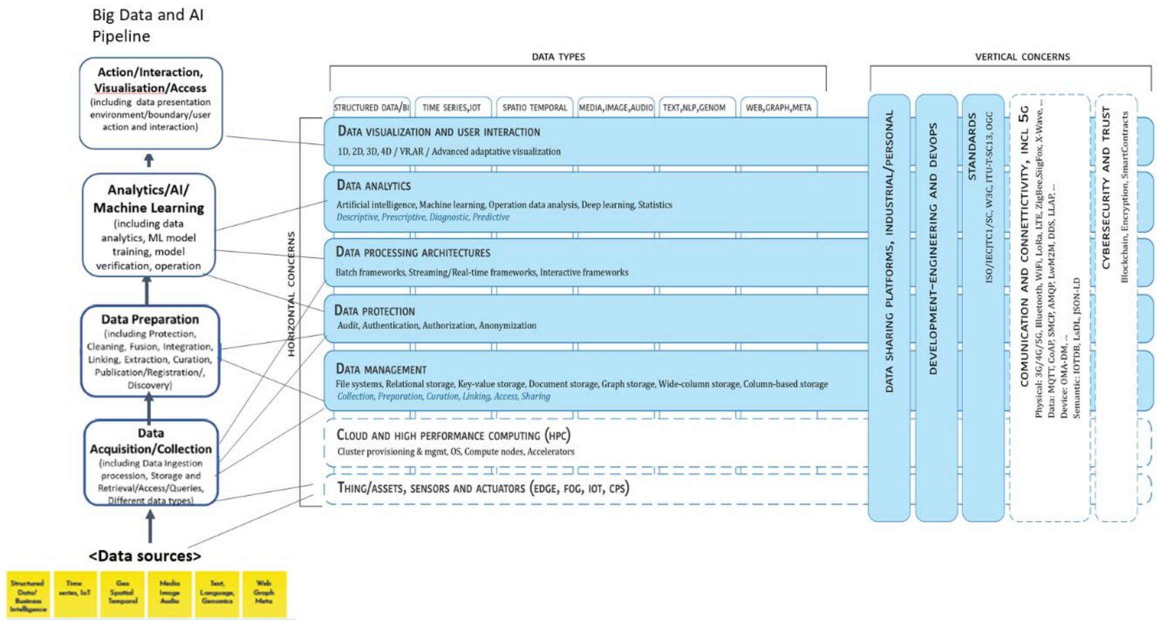

Figure 11. Big Data and AI Pipeline using technologies from the BDV reference model

The BDV Reference Model shown in Figure 11has been developed by the BDVA, taking into account input from technical experts and stakeholders along the whole Big Data Value chain as well as interactions with other related Public-Private Partnerships (PPPs). An explicit aim of the BDV Reference Model in the SRIA 4.0 document is to also include logical relationships to other areas of a digital platform such as Cloud, High Performance Computing (HPC), IoT, Networks/5G, CyberSecurity etc.

The following text describes the steps of the Big Data and AI Pipeline showed to the left of the BDV Reference model in Figure 11, with lines related to the typical usage of some of the main technical areas.

Data Acquisition/Collection

This step includes acquisition and collection from various sources, including both streaming data and data extraction from relevant external data sources and data spaces. It includes support for handling all relevant data types and also relevant data protection handling for this step. This step is often associated with the use of both real-time and batch data collection, and associated streaming and messaging systems. It uses enabling technologies in the area using data from things/assets, sensors and actuators to collect streaming data-in-motion as well as connecting to existing data sources with data-at-rest. Often, this step also includes the use of relevant communication and messaging technologies.

Data Storage/Preparation

This step includes the use of appropriate storage systems and data preparation and curation for further processing. It also includes data storage and retrieval in databases such as SQL and NoSQL, that include key-value, column-based storage, document storage, graph storage and storage structures. This area contains many benchmarks to test and compare various data storage alternatives. Also, there is interaction with various data platforms and data spaces for broader data management and governance and is linked to handling associated aspects of data protection.

Analytics/AI/Machine Learning

This step handles data analytics with relevant methods, including descriptive, predictive, and prescriptive analytics and the use of AI/Machine Learning methods and algorithms to support decision making and transfer of knowledge. For Machine learning, this step, includes the subtasks for necessary model training and model verification/validation and testing before actual operation with input data. Earlier step of data storage and preparation will provide data input both for training and validation and test data, as well as operational input data.

Action/Interaction, Visualisation and Access

This step (including the data presentation environment that allows user actions and interaction) identifies the boundary towards the environment for action/interaction, typically through a visual interface with various data visualisation techniques for human users and through an API or an interaction interface for system boundaries. This is a boundary where interactions occur between machines and objects, between machines, between people and machines and between environments and machines. The action/interaction with the system boundaries can typically also affect the environment to be connected back to the data acquisition/collection step, collecting input from the system boundaries.

The above steps can be specialised depending upon the different data types used in the various applications and can be set up differently according to processing architectures, (e.g. batch, real-time/streaming or interactive). Furthermore, with Machine learning there will be a cycle starting from training data and later using operational data. The steps of the Big Data and AI Pipeline Framework are also harmonised with the ISO SC42 AI Committee standards[8]. It is harmonised with the steps of Collection, Preparation, Analytics and Visualization/Access steps within the Big Data Application Layer of the recent international standard ISO 20547-3 Big data reference architecture within the functional components of the Big Data Reference Architecture[9] [EUBD]. Figure 12 presents how the Big Data and AI Pipeline can also be related to the recent AI PPP [JOIV] Ecosystem and Enablers (from SRIDA AI).

[8] ISO/IEC JTC 1/SC 42 committee on Artificial intelligence. Retrieved from https://www.iso.org/committee/6794475.html

[9] European BDVA Strategic Research and Innovation Agenda v4.0. (2017, October). Retrieved from http://www.bdva.eu/sites/default/files/BDVA_SRIA_v4_Ed1.1.pdf

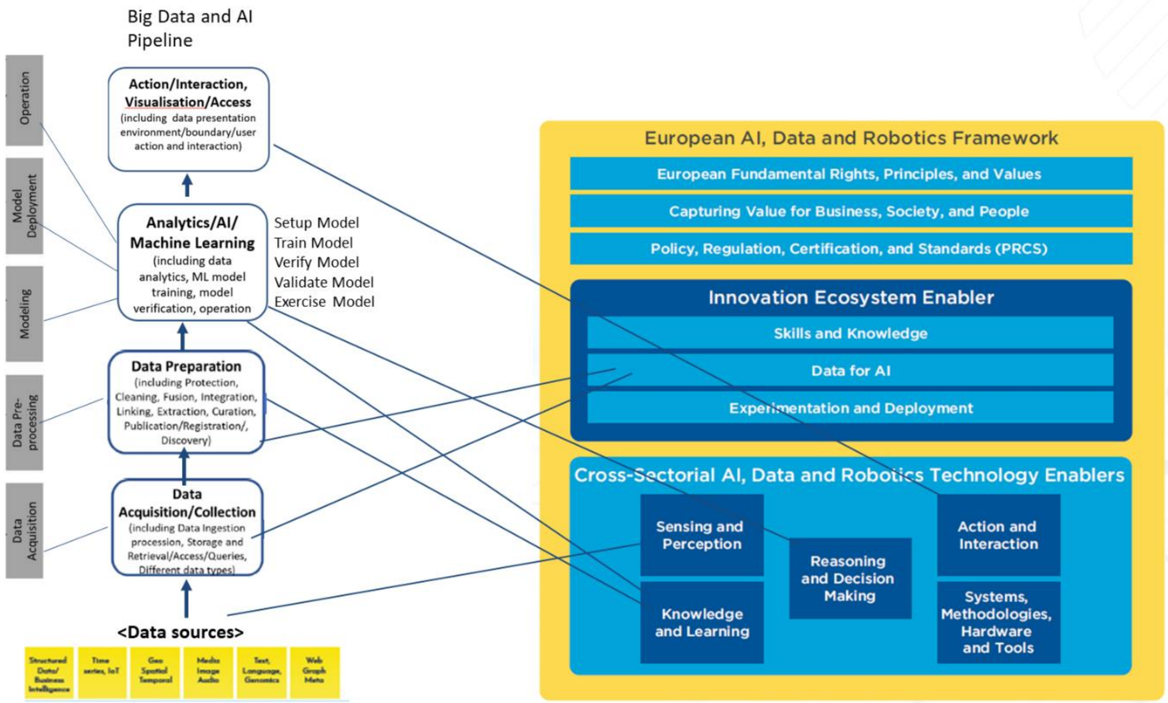

Figure 12. Big Data and AI Pipeline and the European AI and Robotics Framework

The steps of the Big Data and AI Pipeline can relate to the AI enablers as follows:

Data Acquisition/Collection: using enablers from Sensing and Perception technologies, which includes methods to access, assess, convert and aggregate signals that represent real-world parameters into processable and communicable data assets that embody perception.

Data Storage/Preparation: using enablers from Knowledge and learning technologies, including data processing technologies, which cover the transformation, cleaning, storage, sharing, modelling, simulation, synthesizing and extracting of insights of all types of data both that gathered through sensing and perception as well as data acquired by other means. This procedure will handle both training data and operational data. It will further use enablers for Data for AI which handles the availability of the data through data storage through data spaces, platforms and data marketplaces to support data driven AI.

Analytics/AI/Machine Learning: using enablers from Reasoning and Decision making which is at the heart of Artificial Intelligence. This technology area also provides enablers to address optimisation, search, planning, diagnosis and relies on methods to ensure robustness and trustworthiness.

Action/Interaction, Visualisation and Access: using enablers from Action and Interaction – where interactions occur between machines and objects, between machines, between people and machines and between environments and machines. This interaction can take place both through human user interfaces as well as through various APIs and system access and interaction mechanisms. The action/interaction with the system boundaries can typically also be connected back to the data acquisition/collection step, collecting input from the system boundaries (Figure 13).

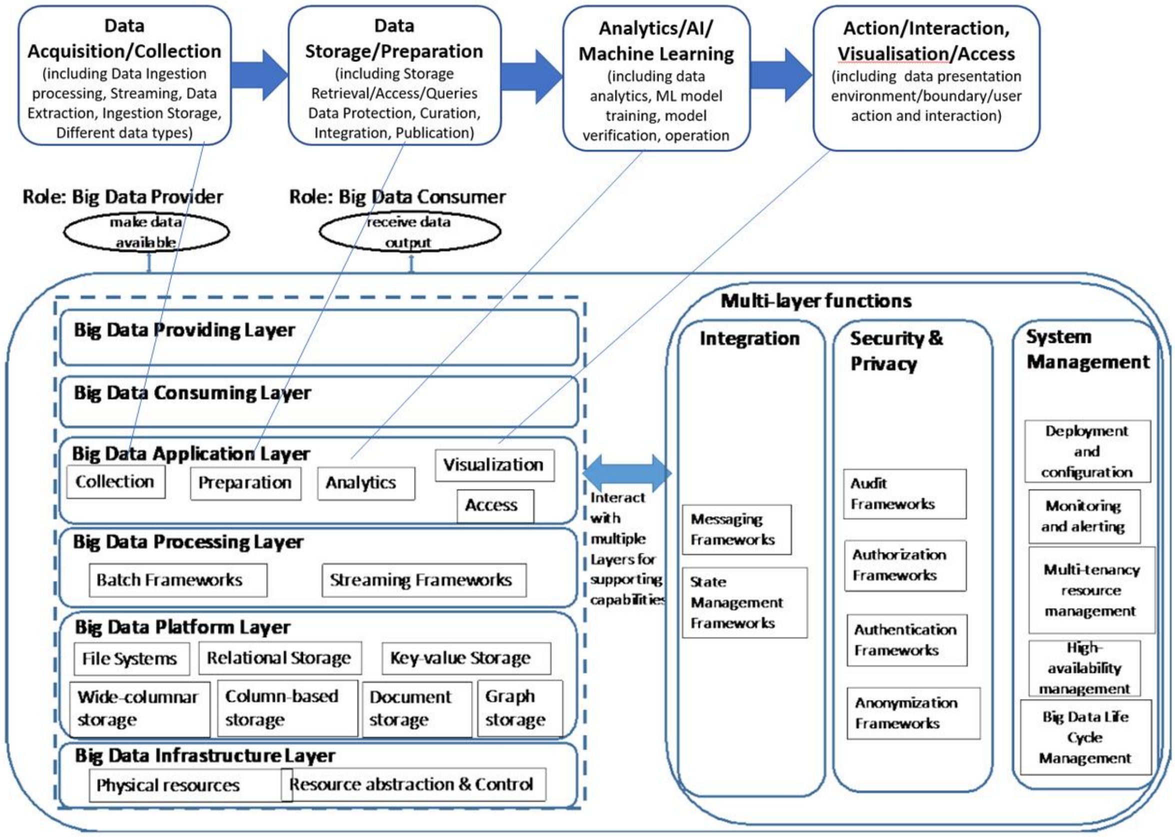

Figure 13. Big Data and AI Pipeline and the ISO 20547-3 Big Data Reference Architecture.

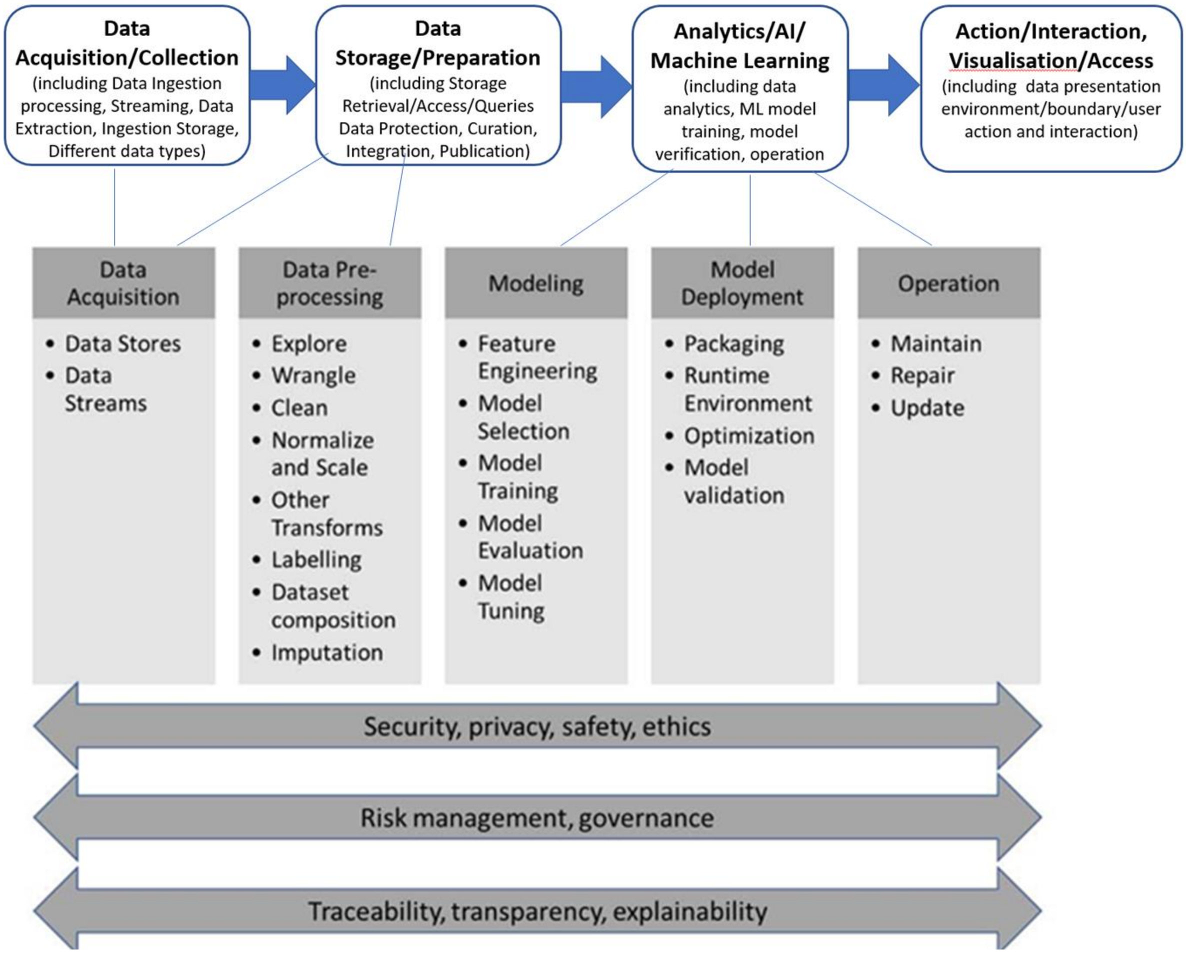

Figure 14. Big Data and AI Pipeline and the steps in ISO/IEC 23053 standard

The pipeline steps are also harmonised with the emerging pipeline steps in the ISO SC42 AI standard ISO/IEC 23053 “Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML)” (Figure 14). This describes a Machine learning pipeline with the related steps of Data Acquisition, Data Pre-processing, Modelling, Model Deployment and Operation.

6.5.1 Big Data and AI Pipelines in Agri and DEMETER context

This section presents example pipelines which handle different data types. Specifically, they handle IoT data, Graph data and Earth Observation/Geospatial data. Each pipeline is mapped to the four phases of the top level Generic Big Data and AI Pipeline pattern 2. All these pipelines have been developed in the DataBio project[10], which was funded by the European Union’s Horizon 2020 research and innovation programme. DataBio focused on using Big Data to contribute to the production of the best possible raw materials from agriculture, forestry and fishery/aquaculture for the bioeconomy industry to produce food, energy and biomaterials, while also considering responsibility and sustainability issues. The pipelines that are presented below are the result of

[10] Databio, Data-Driven Bioeconomy project. Homepage URL: https://www.databio.eu/

aggregating Big Data from the three focused sectors (agriculture, forestry and fishery) and intelligently process, analyse and visualize them.

The Pipeline for Linked Data Integration and Publication has been adapted an extended further in the DEMETER project. Also, other pipelines as shown in the following can be considered for further highlighting and elaboration in the DEMETER project.

6.5.2 Pipeline for IoT data real-time processing and decision making

The "Pipeline for IoT data real-time processing and decision making" has been applied to three pilots in the DataBio project from the agriculture and fishery domain, and, since it is quite generic, it can also be applied to other domains. The main characteristic of this pipeline is the collection of real-time data coming from IoT devices to generate insights for operational decision making by applying real-time data analytics on the collected data. Streaming data (a.k.a. events) from IoT sensors are collected in real-time (for example: agricultural sensors, machinery sensors, fishing vessels monitoring equipment).

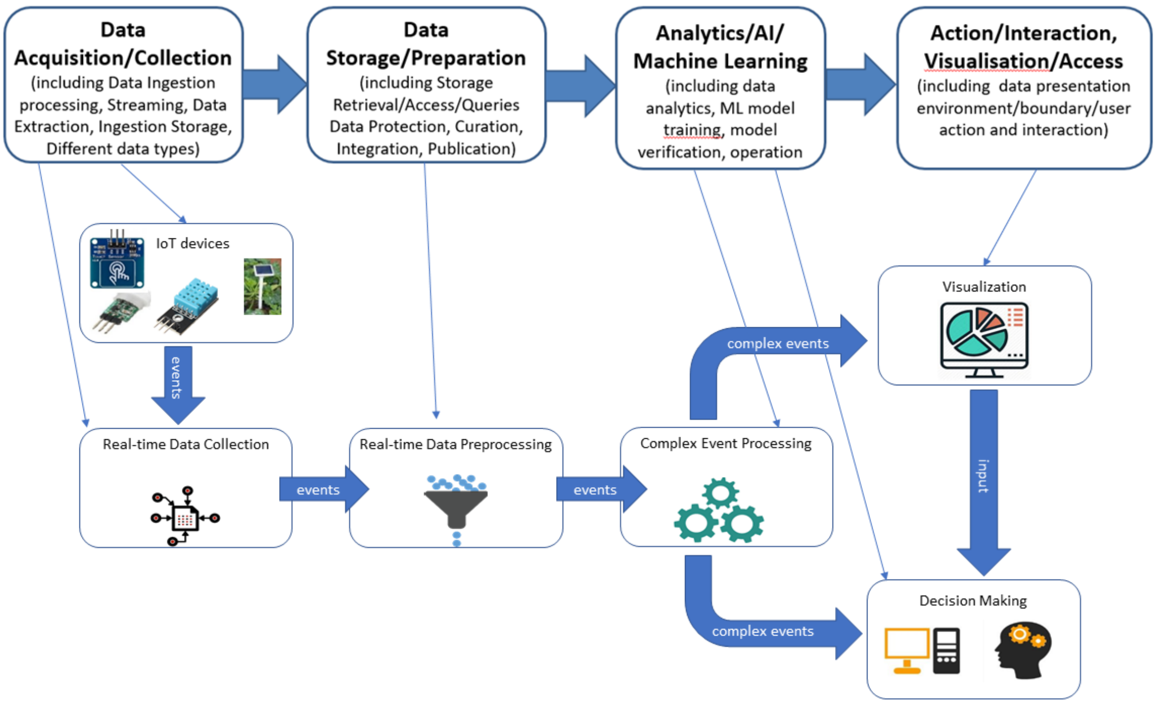

Figure 15. Mapping of "Pipeline for IoT data real-time Processing and decision making"

These streaming data (a.k.a. events) can then be pre-processed in order to lower the amount of data to be further analysed. Pre-processing can include filtering of the data (filtering out irrelevant data and filtering in only relevant events), performing simple aggregation of the data, and storing the data (e.g., on cloud or other storage model, or even simply as a computer's file system) such that conditional notification on data updates to subscribers can be done. After being pre-processed, data enters the complex event processing (CEP) component for further analysis, which generally means finding patterns in time windows (temporal reasoning) over the incoming data to form new more complex events (a.k.a. situations or alerts/warnings). These complex events are emitted to assist in decision-making processes either carried out by humans ("human in the loop") or automatically by actuators, e.g., sensors that start irrigation in a greenhouse as a result of a certain alert. The situations can also be displayed using visualization tools to assist humans in the decision-making process. The idea is that the detected situations can provide useful real-time insights for operational management (e.g., preventing a crop pest or machinery failure).

Figure 15 illustrates the steps of the pipeline for real-time IoT data processing and decision making that we have just described and their mapping to the steps of top level Generic Big Data and AI Pipeline pattern that have been previously presented in Figure 9.

6.5.3 Pipeline for Linked Data Integration and Publication

In DataBio project and some other agrifood projects, Linked Data has been extensively used as a federated layer to support large scale harmonization and integration of a large variety of data collected from various heterogeneous sources and to provide an integrated view on them.

This has been further extended within the DEMETER project.

The triplestore populated with Linked Data during the course of DataBio project (and few other related projects) resulted in creating a repository of over 1 billion triples, being one of the largest semantic repositories related to agriculture, as recognized by the EC innovation radar naming it the "Arable Farming Data Integrator for Smart Farming". Additionally, projects like DataBio have also helped in deploying different endpoints providing access to the dynamic data sources in their native format as Linked Data by providing a virtual semantic layer on top of them. This action has been realised in the DataBio project through the implementation of the instantiations of a 'Pipeline for the Publication and Integration of Linked Data", which has been applied in different uses cases related to the bioeconomy sectors. The main goal of these pipelines instances is to define and deploy (semi-) automatic processes to carry out the necessary steps to transform and publish different input datasets for various heterogeneous sources as Linked Data. Hence, they connect different data processing components to carry out the transformation of data into RDF format[11] or the translation of queries to/from SPARQL[12] and the native data access interface, plus their linking, and including also the mapping specifications to process the input datasets. Each pipeline instance used in DataBio is configured to support specific input dataset types (same format, model and delivery form).

A high-level view of the end-to-end flow of the generic pipeline and its mapping to the steps of the Generic Big Data and AI Pipeline is depicted in Figure 16. In general, following the best practices and guidelines of Linked Data Publication[13], the pipeline takes as input selected datasets that are collected from heterogeneous sources (shapefiles, GeoJSON, CSV, relational databases, RESTful APIs), curates and/or pre-process the datasets when needed, selects and/or creates/extends the vocabularies (e.g., ontologies) for the representation of data in semantic format, processes and transforms the datasets into RDF triples according to underlying ontologies, performs any necessary

[11] "RDF Schema 1.1 W3C Recommendation," 2014. Retrieved from: https://www.w3.org/TR/2014/REC-rdf-schema-20140225/
[12] https://www.w3.org/TR/rdf-sparql-query/
[13] https://www.w3.org/TR/ld-bp/

post-processing operations on the RDF data, vi) identify links with other datasets, and publishes the generated datasets as Linked Data and applying required access control mechanisms.

The transformation process depends on different aspects of the data like the format of the available input data, the purpose (target use case) of the transformation and the volatility of the data (how dynamic is the data). Accordingly, the tools and the methods used to carry out the transformation were determined firstly by the format of the input data. Tools like D2RQ[14] were normally used in case of data coming from relational databases, tools like GeoTriples[15] were chosen mainly for geospatial data in the form of shapefiles, tools like RML Processor[16] for CSV, JSON, XML data formats, services like Ephedra[17] (within Metaphactory platform) for Restful APIs.

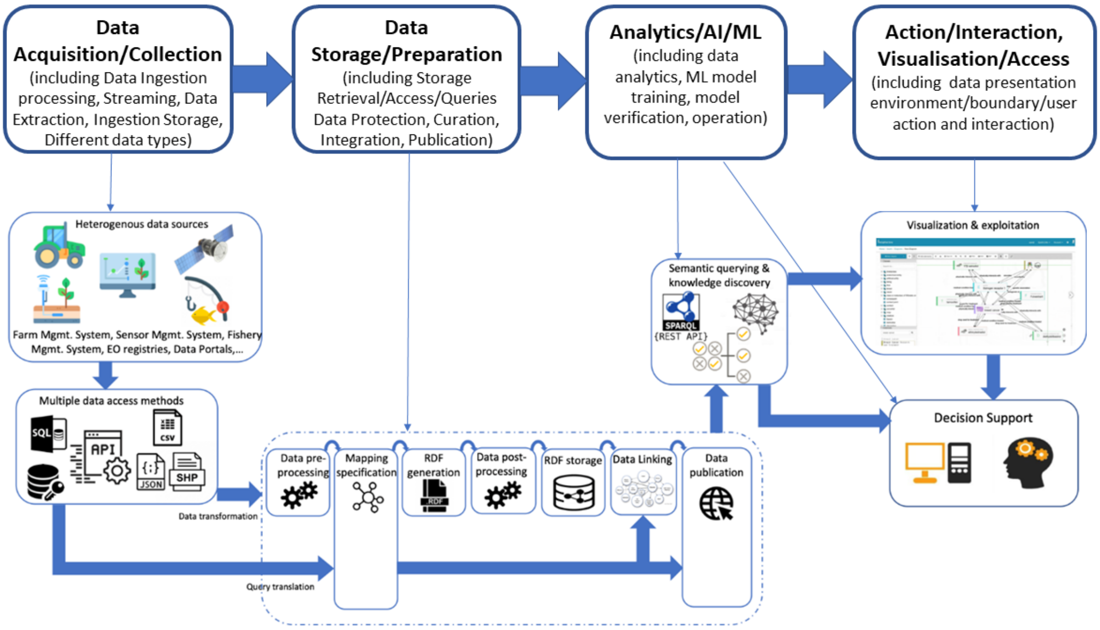

Figure 16. Mapping of “Pipeline for Linked Data Integration and Publication”

Figure 16 presents the steps of the pipeline for Linked Data Integration and Publication” that we have described above and their mapping to the steps of top level Generic Big Data and AI Pipeline patterns that have been previously presented in Figure 9.

6.5.4 Pipeline for Earth Observation and Geospatial Data Processing

The pipeline for Earth Observation and Geospatial data processing, developed in the DataBio project, depicts the common data flow among six project pilots, four of which are from the agricultural domain and two from the fishery domain. To be more specific, from the agricultural domain there are two smart farming pilots, one agricultural insurance pilot and one pilot that provides support to the farmers related to their obligations introduced by the current Common

[14] http://d2rq.org/
[15] http://geotriples.di.uoa.gr/
[16] https://github.com/RMLio/RML-Processor
[17] https://metaphacts.com/ephedra

Agriculture Policy. The two pilots from the fishery domain were in the areas of: a) oceanic tuna fisheries immediate operational choice, and b) oceanic tuna fisheries planning.

Some of the characteristics of this pipeline include the following:

- Its initial data input is georeferenced data, which might come from a variety of sources such as satellites, drones or even from manual measurements. In general, this will be represented as either in the form of vector or raster data. Vector data usually describes some spatial features in the form of points, lines or polygons. Raster data, on the other hand, is usually generated from imaging-producing sources such as Landsat or Copernicus satellites.
- Information exchanged among the different participants in the pipeline can be either in raster or vector form. Actually, it is possible and even common that the form of the data will change from one step to another. For example, this can result from feature extraction based on image data or pre-rendering of spatial features.
- For visualisation or other types of user interaction options, information can be provided in other forms like: images, maps, spatial features, time series or events.

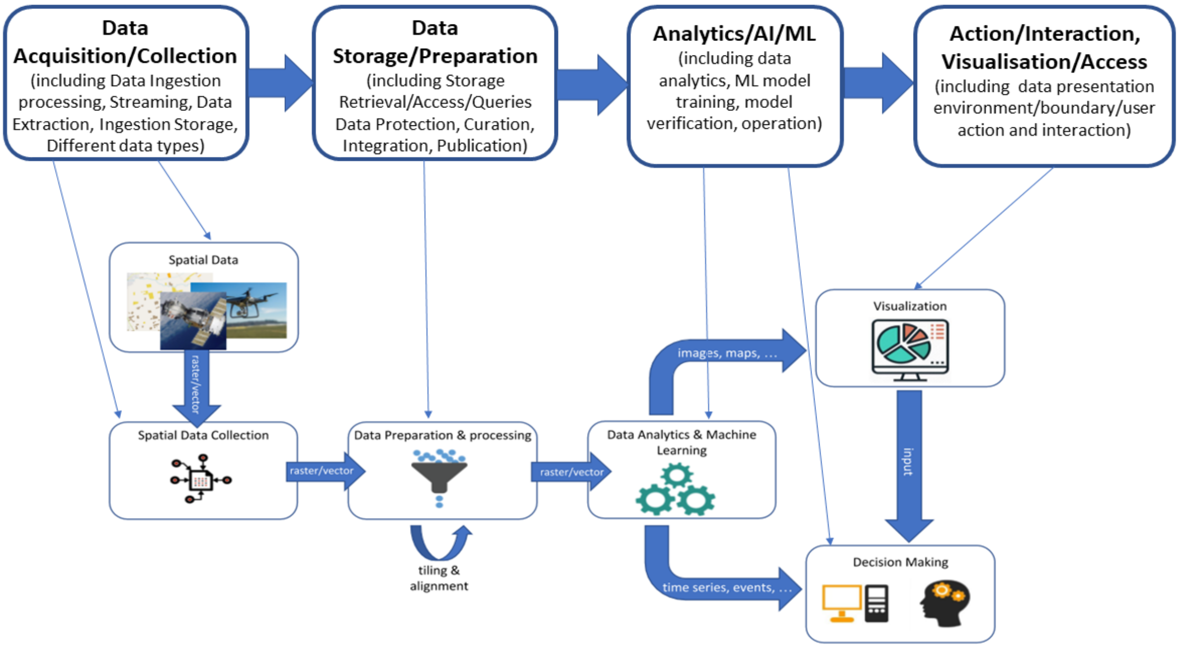

Figure 17. Mapping of “Pipeline for Earth Observation and Geospatial Data Processing”

Therefore, this pipeline can be considered as a specialization of the top level Generic Big Data and AI Pipeline pattern, presented in Section 2, as it concerns the data processing for Earth Observation and Geospatial data. The mapping between the steps of these two pipelines can be seen in Figure 17.

6.6 Minimal Interoperability Mechanisms (MIMs) – OASC – Synchronicity - dRural

Minimal Interoperability Mechanisms (MIMs) [MIMS] are universal tools for achieving interoperability of data, systems, and services between organisations. As they are based on an inclusive list of baselines and references, MIMs take into account the diverse backgrounds of these organisations and allow interoperability based on a minimal common ground, as can be seen in Figure 18 Implementation can be different, as long as crucial interoperability points in any given technical architecture use the same interoperability mechanisms. The MIMs are vendor-neutral and technology-agnostic, meaning that anybody can use them and integrate them into existing systems and offerings. The Living-in.EU (LI.EU) declaration[18] and initiative ensure that local priorities are considered when scaling digital solutions. The LI.EU technical specifications (called MIM+) take existing EU policies into account (including INSPIRE, CEF and EIF); it refers to established standards where available (such as geospatial, food, farming, energy, water etc.); and it aligns with the emerging UN SDG framework in U4SSC, which includes both indicators and architectures. It also links to markets in other global regions which are important for the EU, including Japan and India. Backed by suppliers in Europe and elsewhere, including the well-known hyperscalers, but with distinct terms and conditions in line with EU priorities and policies.

MIMS has originated from Smart City projects/platforms – like Synchronicity[19]– and been promoted by the OASC – Open Agile Smart City organisation, presented in Table 1 – and also followed up by projects in other areas – such as dRural[20] on Platform interoperability for rural areas.

Each community is different from one another, which is reflected by their approach to digital transformation: But while differing in many respects, cities also share common needs:

1. Increasing efficiency and effectiveness of government
2. Driving down costs of innovation and procurement
3. Policy-making based on more and better data
4. Stimulating the local economy and innovation ecosystem

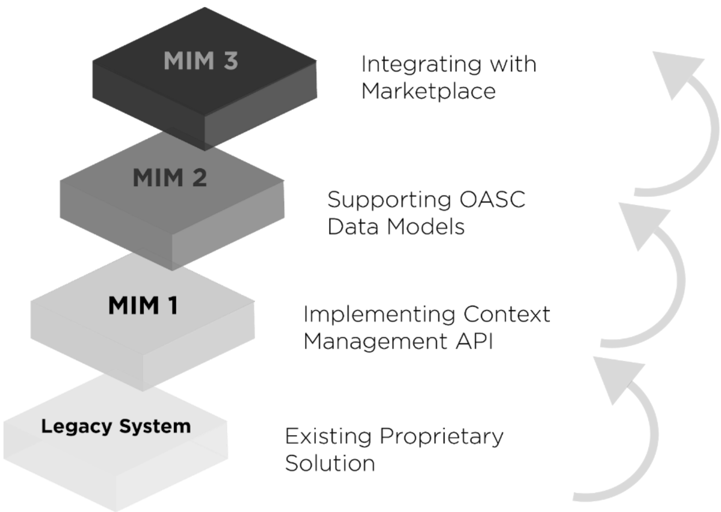

Figure 18. Using MIMs to ensure interoperability of legacy systems and solutions

Unlocking the Benefits of Interoperability

Minimal Interoperability Mechanisms (MIMs) are universal tools for achieving interoperability of data, systems, and services between cities and suppliers around the world. As they are based on an

[18] https://www.living-in.eu/declaration
[19] https://synchronicity-iot.eu/
[20] https://drural.eu/

inclusive list of baselines and references, MIMs consider the diverse backgrounds of cities and communities and allow cities to achieve interoperability based on a minimal common ground.

Implementation can be different, if crucial interoperability points in any given technical architecture use the same interoperability mechanisms.

The MIMs are vendor-neutral and technology-agnostic, meaning that anybody can use them and integrate them into existing systems and offerings.

Table 1. OASC Minimal Interoperability Mechanisms

MIM	MIM Name	Interoperability Point	Description
1	OASC Context Information Management MIM	Context Information Management API	This API allows to access to real-time context information from different cities.
2	OASC Data Models MIM	Shared Data Models	Guidelines and catalogue of common data models in different verticals to enable interoperability for applications and systems among different cities.
3	OASC Ecosystem Transactions Management MIM	Marketplace API	The Marketplace API exposes functionalities such as catalogue management, ordering management, revenue management, Service Level Agreements (SLA), license management, etc. Complemented by marketplaces for hardware and services.

The underlying baselines and standards supporting the MIMs are listed in Table 2 below. These standards and baselines will be curated transparently and in a continuous process by OASC.

Table 2. OASC MIMs: Underlying Standards and Baselines

MIM	Name	Standards & [Baselines]	Reference
1	OASC Context Information Management MIM	ETSI NGSI-LD API[21], OMA NGSI, ITU-T SG20/FG-DPM [FIWARE NGSI]	Reference Architecture for IoT-Enabled Smart Cities (SC-D2.10)
2	OASC Data Models MIM	[SAREF, FIWARE, GSMA, schema.org, SynchroniCity RZ + partner data models]	Guidelines for the definition of OASC Shared Data Models (SC-D2.2) Catalogue of OASC Shared Data Models for Smart City domains (SC-D2.3; to be released)
3	OASC Ecosystem	[TM Forum Business	Basic Data Marketplace

[21] https://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp31_NGSI_API.pdf

	Transaction Management MIM	Ecosystem API, FIWARE Business Ecosystem and Marketplace Enabler API, SynchroniCity API]	Enablers (SC-D2.4) Guidelines for the integration of IoT devices in OASC compliant platforms (SC-D2.6)

Initially, OASC featured three Minimal Interoperability Mechanisms (MIMs):

- Context Information Management
- Common Data Models
- Marketplace Enablers (Ecosystem Transaction Management)

Two additional MIMs have been proposed and accepted as work items:

- Personal Data Management
- Fair Artificial Intelligence

6.7 CEF Digital: Connecting Europe Facility

The major goal of CEF Digital [CEF] is to provide means to help businesses and public administrations make the most of the digital world, by increasing the interconnection between trans-European networks. CEF Digital promotes the adoption of common digital standards by: (a) Providing technical support to business and public administrations in their digital transition; (b) Helping them develop secure, interoperable digital services; (c) Providing funding to projects that can contribute to a more connected Europe.

This support comes in the form of Building Blocks. A Building Block is an open and reusable digital solution that can take the shape of a framework, a standard, a software, a software as a service (SaaS), or any combination thereof. The list of the Building Blocks currently available in CEF Digital is depicted in Figure 19.

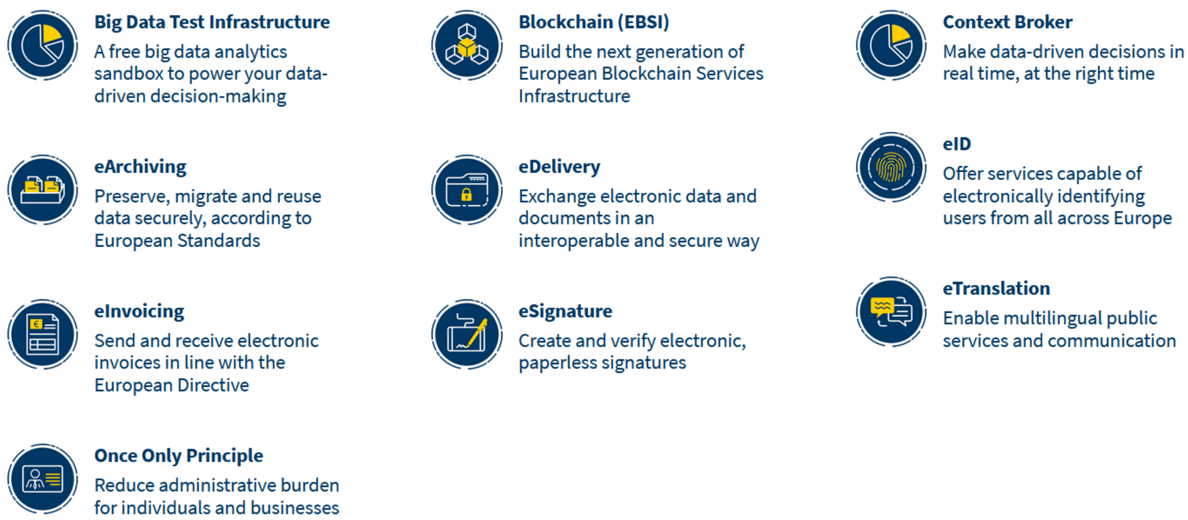

Figure 19. List of Building Blocks available in CEF Digital (Source[22])

[22] https://ec.europa.eu/cefdigital/wiki/display/CEFDIGITAL/CEF+Digital+Home

Among these Building Blocks, there are three of them clearly related to DEMETER, described below:

1. **Context Broker**: its goal is to gather data in real-time from smart applications and sensors, to support decisions at the right time. Based on FIWARE [FIDP], its Data Broker assembles information from different systems, reducing costs and time in the development of context information-based platforms and solutions. Its architecture is described in Figure 20 below.

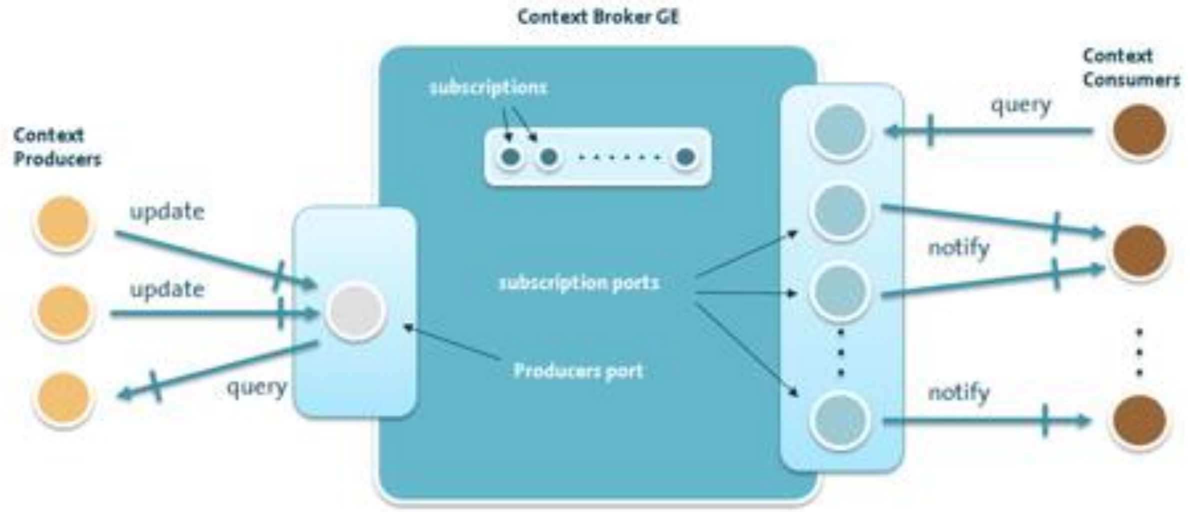

Figure 20. Overview of the CEF Context Broker architecture

CEF Context Broker enables the publication of context information by entities, referred as context producers, that is available to other entities, referred as context consumers, which are interested in processing this context information. Applications or even other platform components may play the role of context producers, context consumers or both. On the other hand, updates on context information are considered as events that can be handled by applications or platform components that subscribe to those events. The CEF Context Broker supports two ways of communications: push and pull towards both context producers and the context consumers, and it provides the FIWARE NGSI API [FIDC] to applications adopting the context producer, context provider or context consumer roles.

2. **Big Data Test Infrastructure (BDTI)**: a free online sandbox where users analyse Big Data sets and test data-driven decision-making. The BDTI offers: (i) A test infrastructure that allows users to request a virtual testing environment built on the Amazon AWS stack which provides a pre-configured and ready to use environment for analytics experiments; (ii) A data source catalogue that provides a centralised repository of reliable data sources-mainly open-by maintaining a consolidated list of available data sources which users can include in their data analytics use cases. The catalogue also provides guidelines on how to create the interconnection with datasets provided by the data sources listed in the catalogue, explaining how to develop technical interfaces using APIs; (iii) A Big Data and analytics software catalogue that provides to the users the possibility to search and download analytics software for implementing Big Data use cases.

3. **eArchiving**: a secure infrastructure to reserve, migrate and reuse data securely, according to European standards. The core of eArchiving is formed by Information Package specifications which describe a generic format for storing bulk data and metadata in a platform-independent, authentic, and long-term understandable way. The specifications are ideal for migrating long-term valuable data between generations of information systems, transferring data to dedicated long-term digital repositories, or preserving and reusing data over extended periods of time and generations of software systems. The eArchiving specifications are based on common, international standards for transmitting, describing and preserving digital data. The main standard is the Reference Model for an Open Archival Information System (OAIS Reference model) which has Information packages as its basis. The main standard for transmitting Information Packages is the Metadata Encoding and Transmission Standard (METS), and the main standard for preserving Information Packages is Preservation Metadata Implementation Strategies (PREMIS). eArchiving offers the following set of components: (i) Open and platform-independent specifications for creating time resistant packages of crucial data and metadata; (ii) Open-source software components to demonstrate how data can be exported, preserved and reused according to the specifications; (iii) Standardised guidance and training on issues around long-term data management and digital archiving.

6.8 OpenDEI – Reference Architecture for Platform Interoperability within and across sectors

The OPEN DEI [OPEND] cross-Industry Digital Platforms federation[23] of the OPEN DEI project provides useful insights to the most relevant work in the field of Reference Architecture for building Digital Platforms to support the Digital Transformation journeys in the four sectors targeted by OPEN DEI (i.e. manufacturing, agriculture, energy, and healthcare).

The OPEN DEI RAF is built upon 6 main underlying principles (INTEROPERABILITY, OPENNESS, REUSABILITY, AVOID VENDOR LOCK-IN, SECURITY and PRIVACY and SUPPORT TO A DATA ECONOMY) – as follows:

Underlying principle 1: INTEROPERABILITY THROUGH DATA SHARING - Syntactic interoperability between two or more systems is achieved by means of using common data formats and communication protocols. Semantic interoperability between two systems, on the other hand, is achieved when the information exchanged can be interpreted meaningfully and accurately at both ends, producing useful results as defined by the end-users of both systems. *Recommendation 1: OPEN DEI RAF should foster technical interoperability at syntactic and semantic levels, via the use of data sharing mechanisms, grounded on well-established standards and design/implementation patterns.*

Underlying principle 2: OPENNESS - In the context of data-driven services, the concept of openness mainly relates to data, data/API specifications and software. *Recommendation 2: OPEN DEI RAF should ensure a level playing field based on open-source datasets/software/standards and demonstrate active and fair consideration of the coverage of functional needs, maturity and market support and innovation.*

[23] https://www.opendei.eu/case-studies/d2-1-reference-architecture-for-cross-domain-digital-transformation/

Underlying principle 3: REUSABILITY - Reuse means that system architects confronted with a specific problem seek to benefit from the work of others by looking at what is available, assessing its usefulness or relevance to the problem at hand, and where appropriate, adopting solutions that have demonstrated their value elsewhere. This requires the involved stakeholders to be open to sharing its interoperability solutions, concepts, frameworks, specifications, tools and components with others. *Recommendation 3: OPEN DEI RAF must support reusing and sharing of data and solutions, enabling cooperation in the collaborative development of data models and solutions when implementing Digital Transformation pathways.*

Underlying principle 4: AVOID VENDOR LOCK-IN When establishing Digital Platforms, system architectures should focus on functional needs and defer decisions on technology if possible in order to minimize dependencies on vendors, to avoid imposing specific technical implementations or products on their constituents and to be able to adapt to the rapidly evolving technological environment. The OPEN DEI RAF should be able to support the adoption of concrete open standard technologies to use for the effective sharing of data for example, while at the same time choose technologies that will not impose any specific technical implementation and avoid vendor lock-in. The functioning of an implementation-independent technology requires data to be easily transferable among different sub-systems independently of how and who has implemented those subsystems, in order to support the free movement of data. This requirement relates to data portability - the ability to move and reuse data easily among different applications and systems, which becomes even more challenging in cross-border scenarios. *Recommendation 4: OPEN DEI RAF should foster access and reuse of their digital services and data irrespective of specific technical implementations or products.*

Underlying principle 5: SECURITY and PRIVACY - To establish trust between different security domains requires a common data-sharing infrastructure based on agreed standards, policies and rules that are acceptable and usable for all domains. In addition to secure solutions, it is necessary to build a trusted ecosystem that includes identification, authentication, authorization, trust monitoring and certification of solutions. *Recommendation 5: OPEN DEI RAF must define a common security and privacy framework and establish processes for digital services to ensure secure and trustworthy data exchange between the involved stakeholders and in interactions with organization and businesses.*

Underlying principle 6: SUPPORT TO A DATA ECONOMY - Common data sharing infrastructures should come with marketplace functions enabling data providers to publish their offerings associating terms and conditions which, besides data and usage control policies to be enforced, may include different formulas for payment: single payment, subscription fees, pay-per-use, etc. In order to support monetization of data, it should also include the necessary backend processes supporting data usage accounting, rating, payment settlement and billing. Standards enabling the publication of data offerings across multiple compatible marketplaces will be highly desirable. *Recommendation 6: OPEN DEI RAF must define a data marketplace framework enabling parties to publish open and priced data, supporting the creation of multi-side markets and innovative business models which bring support to the materialization of a Data Economy.*

The Reference Architecture Framework (RAF) proposes reusability as a driver for interoperability, recognizing that the data-driven services for DT should reuse information and services that already exist and may be available from various sources inside or beyond the organizational boundaries of the adopting organizations. Information and services should be retrievable and be made available in interoperable formats (e.g. adhering to FAIR principles[24]). To this end, the core reusable Model Building Blocks (MBBs), mainly representing information sources and services, should make their data or functionality accessible through well-defined services supporting data-oriented and event-driven interactions. The reusable building block approach finds a suitable application by mapping solutions against the conceptual building blocks of a Reference Architecture that allows reusable components to be detected, which also promotes rationalization.

The OPEN DEI project has defined the approach for designing a common Reference Architecture Framework able to describe the Cross-Domain Digital Transformation.

The extensive use of sensors and connected devices is a common scenario in the implementation of many Digital Transformation solutions and in many industrial sectors. The huge amount of available data is able to cover many business scenarios. Data-driven pipelines and workflows management is nowadays crucial for data gathering, processing, and decision support. To deal with this complexity OPEN DEI has adopted the following 6C architecture, adapted from the one suggested by the German *Industrie 4.0* initiative [REF], and based on the following pillars (using a bottom-up reading):

- **Connection**, making data available from/to different networks, connecting systems and digital platforms, among several IT cultures and cross organizations' boundaries, start from the capability to make data available from/to different physical and digital assets. Different devices or sensors are used to acquire a variety of IoT data, but also many systems are based on unstructured or multi-media files. Data and information may also come from existing IT systems, using sector-specific protocols or more common standards coming from the Internet of Things (IoT) world used to realize data transfers.

- **Cyber**, modelling and in-memory based solutions to convert data into information, leveraging several information conversion mechanisms. Digital representations (of assets, data and information) will be then shared with upper layers of the pyramid in order to improve the self-healing properties of the overall system.

- **Computing**, storing, and using data on the edge or on the cloud. Many of modern digital platforms use a combination of cloud and edge computing models, based on driving factors for establishing more centralized and powerful computation capabilities, or faster, connectivity friendly and secure computing at the edge of the digital networked platform. The forces fuelling the demand for distributed computing technologies are advancing rapidly. This will create a paradigm shift for organizations moving along new digital transformation pathways, with potential changes affecting all players in the target business ecosystem.

- **Content/Context**, correlating collected data for extracting information, creating a digital space for data- information continuum, not something to push out to one side of the adopted information architecture. Modern businesses need a comprehensive approach with the end goal of driving the data (processing) and information needs. However, exploiting data is not as straightforward. Thus, data needs to be acquired (captured, entered via a data

[24] https://www.go-fair.org/fair-principles/

pipeline) and processed with a goal and context in mind, making it information, which essentially is about processed data, before moving to the next levels.

- **Community**, sharing data between people and connecting stakeholders for solving collaboration needs. Networked organizations will be able to collect and share knowledge and opportunities in the widest number of sectors so that its members can make the right decisions. The community around organizations could become increasingly important to collect and share information in a push-pull fashion.
- **Customization**, personalizing by following each user's perspective creates added value to data and at the same time match their expectations. Multiple strategies can make it possible to address all aspects of the end-user expectations and empower an individual to progress through platform functionalities in a natural way. Democratizing access to data is a promising approach to help unlock the value of data, but even the most advanced technology is of little value if people do not embrace it. This is a lesson that many businesses have learned the hard way; to avoid pitfalls, it is crucial to properly understand end-user expectations and build the platform from the ground up while keeping in mind that the intended audience, even within a single organization, can be diverse and must be properly segmented and with specific and varying needs.

In this scenario, complex systems based on distributed intelligence will be increasingly designed and operated based on accurate data sharing and analysis techniques. But as one of the upper layers is showing, the "smart" functions of the platforms will gain more power by using the network and community effects, such that organizations' habits are changed while their dimensions of business are expanded.

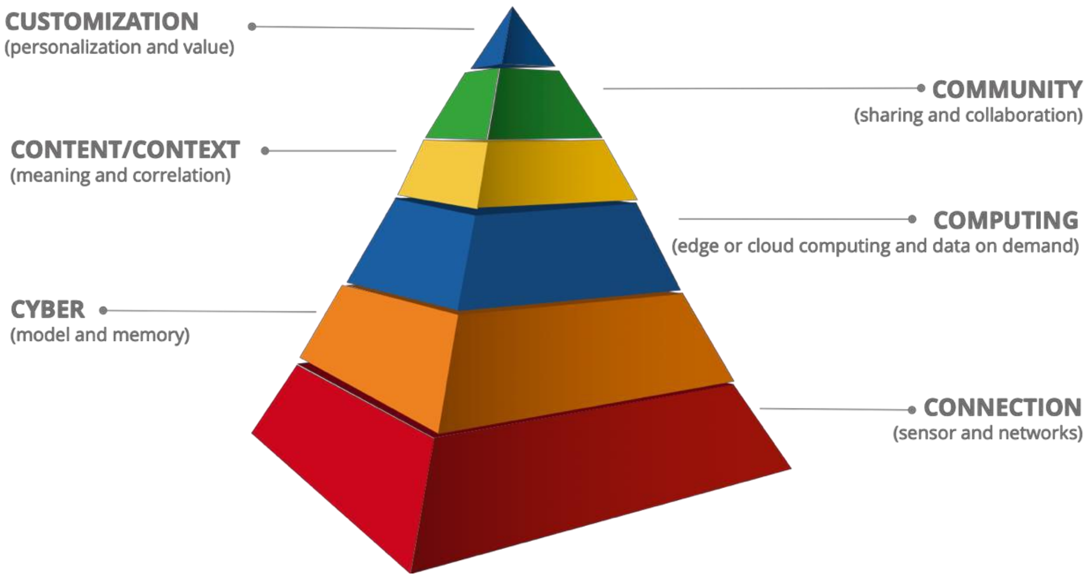

Figure 21. 6C Architectural Model

The aforementioned 6C Architecture principles have driven the design of the OPEN DEI RAF, developed around the main concept of Data Spaces in which data is shared (published and accessed), identifying three main different layers described in the following using a bottom-up reading approach:

- Field Level Data Spaces, includes the Smart World Services able to collect data and support the interaction with the IoT Systems (configuration, calibration, data acquisition, actuation, etc.), Automation and Smart Assets (robots, machinery, and related operations) and Human Systems (manual operations, supervision, and control, etc.).
- Edge Level Data Spaces, defines the typical edge operations from the data acquisition (from the logical perspective) to the data processing through the data brokering. The edge services will play a key role also for data analytics (i.e. validating and improving models for data analysis).
- Cloud Level Data Spaces, includes data storage, data integration and data intelligence operations on the cloud. The cloud services will process big data, deploy algorithms, integrate different source platforms and services, provide advanced services such as AI prediction and reasoning.

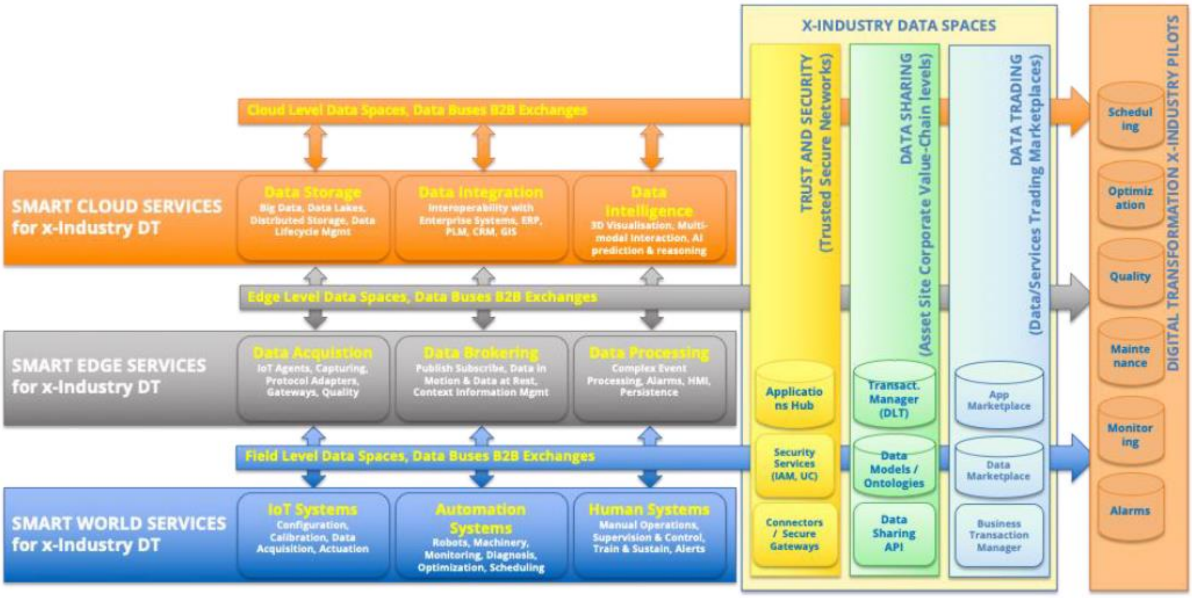

Figure 22. 6C Architecture overview

Furthermore, all these horizontal Data Spaces spines will feed the OPEN DEI Reference Architecture Framework a main orthogonal dimension, named X-Industry Data Spaces, characterized by following components:

- Trusted and Security, incorporating technical frameworks and infrastructures that complements the previous to support trusted and secure exchange, which embraces:
    - Applications Hub, an infrastructure which collects the recipes required for the provision of applications (e.g. deployment, configuration, and activation) in a manner that related data access/usage control policies can be enforced.
    - Security Services, a technical framework to support Identity Access Management, Usage Control, and other security services.
    - Connectors and Secure Gateways, a technical framework for trusted connection among involved parties.

- Data Sharing, incorporating technical frameworks and infrastructures for an effective and auditable data sharing, which more in details embraces:
    - Transaction Manager, a distributed ledger/blockchain infrastructure for logging selected data sharing transactions.
    - Data Models and Ontologies, to leverage common standard and information representations.
    - Data Sharing API, a technical framework for effective data sharing: a data-sharing API.
- Data Trading, incorporating technical frameworks and infrastructures for the trading (offering, monetization) of data, which embraces:
    - App Marketplace, enabling the offering of applications and application building blocks which can be integrated plug&play to enrich existing data spaces.
    - Data Marketplace, enabling the offerings around data resources with associated terms and conditions including data usage/access control policies as well as pricing schemas.
    - Business Support Functions, enabling data/applications usage accounting as well as implementing Clearing House, Payment and Billing functions.

Finally, all the mentioned layers serve the realization of Digital Transformation X-Industry Pilots, for enabling applications (sometimes sector-specific) for supporting business scenarios from experiments.

6.9 NIVA IACS Reference Architecture

The **Integrated Administration and Control System** (IACS) operated by the Member States forms the core of the digital infrastructure of the European Unions for the Common Agricultural Policy (CAP). At the same time, trends in digitalisation of agricultural businesses and administration, availability of digital data and their wide acceptability in the agricultural industry as well as the need for more evidence-based policy evaluation put new demands on the current IACS.

The European Commission has been promoting using satellite imagery for checks on crop types and crop areas that are the basis of farmer's claims for income support since 1990. This is now common practice in the whole EU. With the current CAP 2020-2030 planning period with National Strategic Plans the European Commission wants to gradually move to a performance approach, rewarding farmers for doing or avoiding activities which contribute to climate goals.

In the NIVA project[25] [NIVA], Paying Agencies from nine Member States joined efforts to harmonize/modernise the Integrated Administration and Control System (IACS) used by making efficient use of digital solutions and e-tools to reduce administrative burden and improve environmental performance.

Up to the NIVA project, there did not exist any IACS Reference Architecture that all Paying Agencies might follow. The only harmonization outcomes have been supported thanks to INSPIRE[26] and JRC[27]

[25] www.niva4cap.eu
[26] https://inspire.ec.europa.eu/
[27] https://ec.europa.eu/jrc/en

coordination of LPIS main components. Furthermore, DG Agri is promoting additional initiatives of data sharing capabilities of LPIS data through INSPIRE. However, there are other possibilities thanks to NIVA RA, APIs definition and Linked Open Data Technologies.

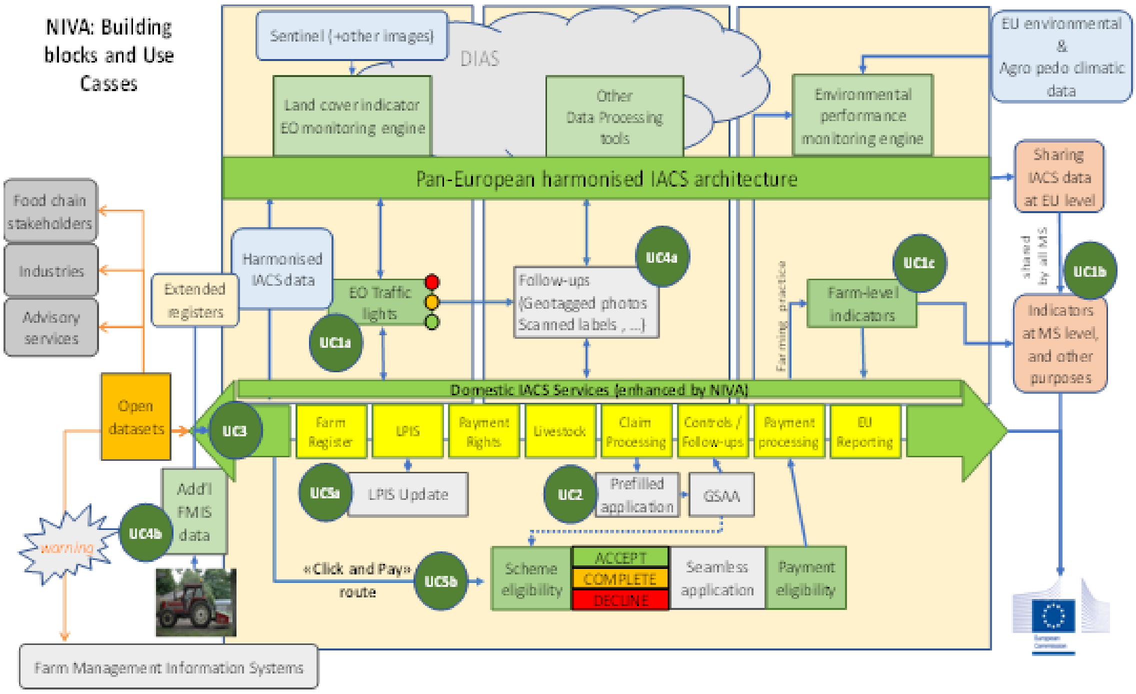

Figure 23. NIVA Building Blocks and Use Cases

Table 3. NIVA Use Cases

Use Case Group	UC ID	Use Case Title	LEAD MS
Monitoring	UC1a	Earth Observation Monitoring and Traffic Lights	Greece
	UC1b	Agro-environmental monitoring	France
	UC1c	Farmer Performance	Estonia
Pre-filled application	UC2	Prefilled application, GSAA/Land link	Lithuania
Farm Registry	UC3	Farm Registry	Spain
Self-Certification	UC4a	Geotagged photos	Ireland
	UC4b	Machine data in Geo-spatial 'on-line' aid application GSAA as added value data	The Netherlands
Seamless Claim	UC5a	Land Parcel Identification System LPIS update & change detection	Denmark
	UC5b	Scheme Eligibility and Payment-Eligibility: Click & Pay	Italy

7 Overview of questionnaire findings

In this section, we present the questionnaires that were given to, first, the DEMETER pilots and, second, to the developers. The pilot questionnaires were used in order to gauge the architecture changes as well as the usage of DEMETER enablers developed and issues with their integration. Additionally, they were used to check if there are any plans for the commercialization of data (similar to initiatives such as GAIA-X). The developer questionnaires focus mainly on the development of the enablers and whether they follow the principles of the DEMETER RA or some revision is required; they examine the data being used but to a lesser degree.

In the next two subsections, we present the questionnaires and summarize the findings from the answers submitted and the resulting actions that were taken in order, e.g., to address identified shortcomings.

7.1 Processed Pilot Questionnaires

To assess potential revisions to the DEMETER Reference Architecture and regarding the usage of enablers and data, the following questionnaire was prepared and distributed to the pilots for feedback about the architecture:

Reference Architecture Revision Questionnaire: input from Pilots

1) Which DEMETER Enablers did you use in your pilot and for which purpose? Did you get the functionality you needed for your pilot? Please elaborate and provide Gitlab link to the code as well.
2) Which DEMETER Enablers you plan to use in pilot round 2? For which purpose?
3) Was there any DEMETER Enabler that you wanted to use in pilot round 1, but eventually did not do so? Please explain the reasons.
4) Do you need additional DEMETER Enablers/functionality/features that is not provided by the current implementation nor foreseen in the initial RA design? Please explain.
5) Describe the overall experience in using the DEMETER Enablers in support of your pilot.
6) Have you detected any shortcomings, weaknesses, missing elements, required revisions regarding the initial RA design? Please elaborate.
7) Any other comment on the initial RA design/specification or any recommendation towards the RA revision, based on your pilot development/integration/deployment experience.
8) What kind of data have you use in your pilot? Please refer to their types, sources, formats and indicate if they public or privately owned. Please refer to both pilot rounds 1 and 2 (foreseen data usage).
9) Does you pilot require paying for any external private data? If so, please elaborate on the respective data types/sources/formats, as well as on the paying scheme and the terms of the lease/use of these data. Please refer to both pilot rounds 1 and 2 (foreseen data usage).
10) In your pilot do you collect/generate any data that data owners are interested to sell/lease to other stakeholders? Please elaborate on the status in pilot round 1 and refer also to the foreseen situation for pilot round 2.

To summarize the findings of the questionnaires as answered by the pilot partners, we come to the following conclusions and *also state what actions were taken to address the issues identified.*

First, in general, there were no issues with the reference architecture itself and, thus, no real comments regarding any architecture revisions. However, this might be due to the pilot partners only seeing the dashboard components of the architecture and to the fact that the full functionality of DEMETER has been available for only the last few months before the questionnaires were distributed, therefore it is understandable that there might be limited experience and exposure to the DEMETER RA. As the second round of DEMETER pilots is currently about to start, the pilot partner should be fully exposed to DEMETER tools and enablers in actual field conditions.

Second, regarding the enabler integration, most pilots reported the integration of a number of enablers, e.g. visualization and decision support from WP4 and data wrappers/translators to AIM from WP2 and using some other core enablers or attempting to do so for some core enablers. For example, some difficulties with the integration of some DEMETER enablers, such as BSE, were identified. This has since been addressed for the most part by creating a user manual that covers the installation and usage of some core enablers as well as live demos and workshops to help the pilots with the integration. This addresses comments in the pilot questionnaires such as "some live practical examples of WP3 tools integration will be important".

Third, no requests for new enablers, needed for the last round of pilots, have been made, but rather more information about what has been developed; this has been addressed by demonstrating how to use the DEH in order to discover the developed enablers and by getting developers to register their enablers with the DEH.

Fourth, regarding the usage of paid data and the sale/commercialization of generated data, this has not been done but some pilots report that they will examine the possibility of marketing the data they generate. For example, pilots 2.1 and 2.2 report that they "see partially commercial potential in the applications generated" and that "the data owner is interested in gain more actionable insights in the data, and therefore it might be the case that the data owner is interested in selling/ leasing the data." A few other pilots also report similarly that they would like to examine whether there is interest in their data and how to promote them. In general, regarding the usage of external data, for the most part, the pilots use open data (e.g., for meteorological data, or satellite data and Earth Observation data in general).

Therefore, the questionnaires were especially useful both in identifying issues with the integration of enablers to pilots, which have since been addressed and, additionally, to gauge that no major RA revisions or to core enablers are required and that pilots can work within the proposed architecture.

7.2 Processed Developer Questionnaires

The questionnaire given to developers had a different focus. Given that the developers were more aware of actual implementation issues relating to the enablers and how they were being used by the architecture, we put more emphasis on this questionnaire in order to discover if any major revisions to the DEMETER Reference Architecture are needed and regarding the need for the potential development and usage of new enablers. Thus, the following questionnaire was prepared and distributed to the developers of DEMETER enablers for feedback regarding the architecture:

Reference Architecture revision QUESTIONNAIRE (for WP2-3-4 developers):

1) Please record the DEMETER enablers you are responsible for or in the development of which you are involved. Please also record the WP/Task under which these enablers are being developed and provide the respective Gitlab links to the code as well.
2) Which DEMETER enablers did you develop and in which pilots are they being used? Did you deliver the functionality that was needed for the pilot(s) where these enablers are used or did you compromise compared to what you originally intended to develop?
   Please elaborate.
3) Have you used any enablers from other partners? (e.g., in order to develop your enablers)
4) Which additional DEMETER Enablers do you plan to develop (or are in development) for pilot round 2 and for which purpose? This could also include improvements to existing enablers, or the completion of enablers that you were planned for round 1 pilots, but have not been available on time.
5) Considering the DEMETER RA (Reference Architecture) and its components (e.g., BSE, DEH) and further considering its various views, i.e. high-level view, functional view, data view, process view, business view (please refer to deliverable D3.1 chapter 11 for details), are you fully in line with these views in the development of your enablers, did you diverse or extend them?
   Please elaborate identifying the specifics of RA revisions that reflect the current implementation of your enablers.
6) Considering the DEMETER requirements extracted for the RA, do you feel that some requirements have not been implemented as described in the architecture (please refer to deliverable D3.2 regarding the specified RA requirements)? Please identify any requirement that you believe is missing or is addressed differently.
7) Same question as above (Question number 6), but now regarding the specific requirements extracted for each technical workpackage's enablers (please refer to deliverables D2.1, D2.2, D3.2, D4.1 and D4.2 regarding the specified requirements).
8) While working on the implementation of your enablers, did you identify any element(s) not foreseen in the initial RA design? Please explain.
9) Describe the overall experience in using the DEMETER core infrastructure when developing your enablers.
10) Upon using your enabler(s) in the first round of pilot(s), has it been necessary to pay for any external / private data? Are your enablers based on the collection/generation of any data that is sold by external DEMETER providers? Are your enablers used to support the collection/generation of any data made available by data owners interested to sell/lease to other stakeholders?
11) Please record any other comment on the initial RA design/specification or any recommendation towards the RA revision, based on your enabler development/integration/deployment experiences.

In general, there were no issues with the reference architecture itself, so there were no significant requests for architecture revisions. As stated, the holistic and high-level approach does not change, the infrastructure and the main software modules and concepts remain the same without changes. However, there have been some small requests for changes to the low-level functionalities and some changes made during the implementation of some of the actual enablers of the architecture, which do not affect the DEMETER reference architecture, but represent the normal distribution of business logic functions that can change over time and fluidly as the needs shift slightly while the implementation is ongoing. One developer mentioned, regarding the usage of data and on the topic of being in line with the RA and its requirements, that getting closer to the GAIA-X paradigm would not require any major change to the architecture; rather DEMETER will need to clarify the business aspect of how data and enablers are used and contracted. Now, this is possible to be done with the current DEMETER RA, and, in fact, the business aspect is not clearly specified as we wanted to leave this up to the actual users and regulatory authorities (potentially) to be able to specify these and thus be able to customize the marketplace that will emerge for such enablers. So, to sum up, no changes to the RA are requested, only modifications to individual enablers.

Second, regarding the enablers themselves, each developer has listed the enablers that were developed and are (or will be) available to pilots via the Demeter Hub. These are summarized in broad categories later in this deliverable. As far as the further development of the enablers is concerned, all the developers state that they plan to maintain, update, improve and extend the enablers that they have already created and provided, with hardly any exceptions of providing brand new enablers. Therefore, any software (e.g., enabler) further developed will extend or be similar to those already developed.

Third, we asked whether third party enablers were used during a partner's enabler development process. For the most part, the enablers used from other partners (developers) were the core DEMETER enablers and particularly those provided by WP3 (the architecture tools and core architecture enablers). Especially, most answers mention the use of the DEH, BSE and ACS enablers to integrate all the enablers in a DEMETER enabled app. Some developers also commented on the lack of documentation by examples for the integrations of some core enablers, such as the BSE. As we mentioned before, this was also reported in the pilot questionnaires and this has since been addressed with extra documentation and workshops to demonstrate the integration and step-by-step usage of the core enablers (especially those related to WP3 and the architecture). There was no actual usage reported of creating an enabler by using any other enablers from other partners. We would like to point out though that this obviously does not include the DEMETER enabled apps as they are composed of enablers provided by several partners. This comment refers to individual enablers that could be created from existing ones, which is a feature provided and allowed by the DEMETER RA, even if it has not been used in the current implementations.

Fourth, regarding the usage of external data for which a payment is necessary, this has not been the case for any developer. Most report that they only used open-source datasets or data generated by sensors and software of their own resources and that no private data, requiring payment, was used up to this point.

Fifth, in the question regarding whether any requirements should be changed, all except one mentioned no issues with the requirements for the architecture. The exception is a partner who is uncertain about whether requirement TI9.24 Data fusion should be an individual enabler or under a more general data analytics and Knowledge Extraction Enabler. However, this comment does not pertain to the requirements for the RA.[28] Thus, to sum up, the requirements for the DEMETER RA are in line, according to the partners, and no changes are foreseen to the general structure of the RA.

Therefore, these developer questionnaires were useful both in identifying issues with the integration of enablers to pilots (same issue as with the pilot questionnaires which has since been addressed to a significant degree) and in determining that indeed no major RA revisions are required and that any changes should be limited to individual enablers; these changes to individual enablers are described in the sections that follow.

[28] These requirements are revisited and examined under D3.4 which is to be delivered chronological a month after this deliverable, so this comment will be examined within the overall revisions of specific tools and enablers in the architecture.

8 Main Concepts and Terminology

This section presents the main concepts and terminology of the DEMETER reference architecture, as revised since the original description in D3.1. Most of the key concepts have not changed, but there are changes in some of their components. This section is self-contained including all information presented in the equivalent section of D3.1, but updating and extending this information where needed.

DEMETER, as presented in Figure 24, is currently built around the following main concepts that enable the delivery of the project's objectives and targeted outcomes:

- The **DEMETER Stakeholders Open Collaboration Space (SOCS)**, focusing on **resolving the needs of the farmers** using a structured process that converts either an individual need or the most relevant/shared need from a set of previously identified needs to a **challenge**. A challenge is then resolved through a unique **co-creation process**, in which farmers, service advisors and providers can select together the most appropriate set of tools, devices, components, data sources, etc., taking into consideration the existing ones already deployed at the farms as well as the farmer-defined improvement goals. This process goes through the DEMETER Enabler Hub to register and discover available components. The SOCS also includes a wide range of features that, together, deliver the knowledge sharing and improvement process, structuring the **human-in-the-loop dimension of DEMETER**. The SOCS is strongly inspired by the EIP Agri Social Spaces and Operational Groups, operating as a set of defined activities for multiple actors implemented through physical meetings, workshops, hackathons, etc., and supported by a dedicated online platform. The DEMETER multi-actor approach is addressed by WP7 and all related aspects are elaborated upon in detail in WP7 deliverables, e.g., deliverables D7.1 or D7.3 (foreseen by April 2021).
- The **DEMETER Agricultural Interoperability Space (AIS)**, which focuses on **delivering** a full set of interoperability mechanisms to **develop**, **validate** and then **deploy** the solution. DEMETER does not define completely new interoperability mechanisms but instead uses (and extends) a wide range of pre-existing mechanisms at sensor, data, and service levels. This is described in more details in the WP2 deliverables, e.g., in D2.1 and the forthcoming D2.3. Moreover, AIS is supported by the DEMETER **Brokerage Service Environment (BSE)**, which facilitates the deployment of a DEMETER enabled application by providing information regarding the endpoints offered by the various DEMETER enhanced entities (e.g., endpoints for getting data, for processing information in offered enablers) which have been discovered through the DEH and are to be consumed. The core components of the BSE are the following: the Access Control Server (ACS) that supports the authentication and the authorization of the DEMETER enhanced entities (DEEs), Brokerage Server (BS) that realizes the DEE registration, discovery, and the respective provisioning functionality and the Service Registry (SR) that is used to store user and service-related meta data in a persistent manner. For more details on the AIS, the BSE and the ACS, please refer to deliverable D3.2 and the forthcoming D3.4.
- The **DEMETER Enabler HUB (DEH)**, which centralises the full description of all the components, devices, services, data sources, platforms, etc. that are accessible for exploitation and ultimately for deployment. The DEH provides, on the one side, the harmonised description that enables each component to be used in the co-creation mechanism, and on the other side its uptake in different deployments through the full set of

DEMETER enabled interoperability mechanisms. The DEMETER Enabler HUB includes the **mechanisms** that ensure interoperability not only with standardized solutions, but also with dominant solutions introduced by other initiatives: such initiatives include IOF2020, ADAPT, DATABIO, or SmartAgriHubs, as well as the more recent GAIA-X initiative and is compliant with the recent European strategy regarding Data and relevant Data Spaces.[29]

In this respect, the **core of the DEH** handles the registration and discovery of DEMETER enhanced entities as described above. The **DEH client** offers runtime facilities (connecting via the Docker host) when running the actual DEMETER enabled apps which allows keeping track of the state of the various DEMETER enablers and DEMETER enhanced entities during the execution of the app. This could potentially offer facilities to address certain runtime issues such as notifying the rest of the components when a particular enabler is not working up to specs. For more details about how the DEH client and the rest of these components of the DEH interoperate, please refer to deliverables D3.2 and the forthcoming D3.4. The DEH is supported by the DEMETER **Brokerage Service Environment (BSE)**, which facilitates the deployment of a DEMETER enabled application by providing information regarding the endpoints offered by the various DEMETER enabled entities (e.g., endpoints for getting data, for processing information in offered enablers) which have already been discovered and consumed through the DEH. This way, the offered enablers have all the necessary information to execute the application. This would also facilitate the connection with the DEMETER core enablers and includes in fact a couple of these, such as the DEMETER Access Control Server (ACS) which provided part of the security and authentication facilities.

- The **DEMETER Dashboard** is the sole entry point to the DEMETER ecosystem for all DEMETER Stakeholders, enabling them to access SOCS and AIS. The Dashboard also offers them user-friendly interfaces to access, understand and control data related to their personal accounts, to perform basic administration tasks over their DEMETER accounts, get an overview about the usage of their data (e.g., field data or even perhaps some personal data) by external stakeholders, and to perform other related tasks.

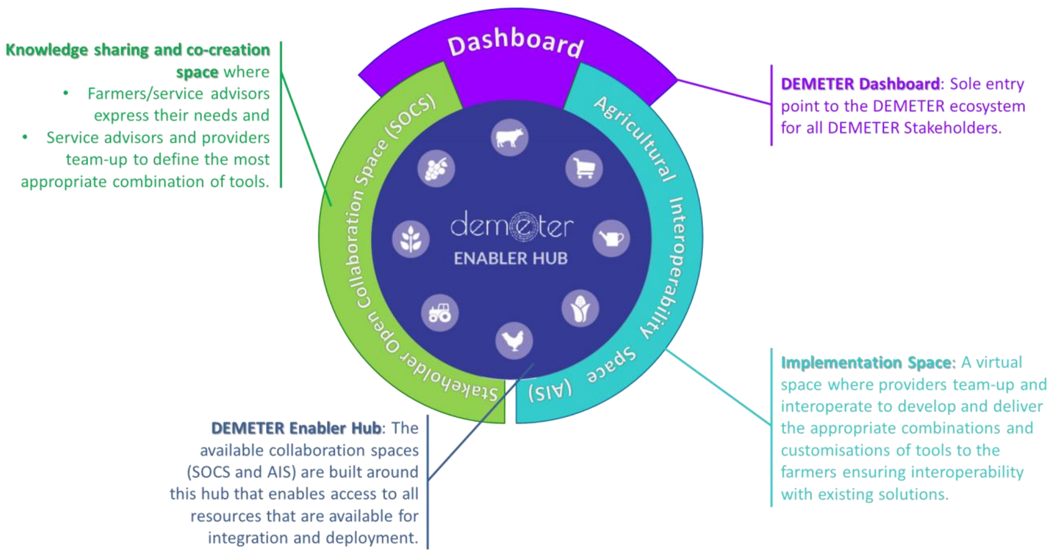

Figure 24. An updated overview of the main DEMETER concepts

[29] These are described in the State of the Art section in this deliverable.

A high-level overview of the main DEMETER components and concepts (i.e., DEH, SOCS, AIS, Dashboard), which were just described, is presented in Figure 24. The key benefits are that it connects a human-focused interaction space on the left with the actual digital implementation space on the right. This ensures the fact that DEMETER remains fully human-centric and human-driven – delivering digital enablers that are fully aligned to the needs expressed by the farmers and based on the knowledge and wisdom captured through structured mechanisms.

An alternative view of the main DEMETER concepts is provided in Figure 25. As highlighted in this diagram, all communication with external third parties is based on the DEMETER Agriculture Information Model (AIM), a common semantic data model used for information exchange across the DEMETER ecosystem. Moreover, the notion of the DEMETER-enhanced Entity (DEE) is that a service, application, platform, or thing is being wrapped with DEMETER enabler functionalities to act as a DEMETER consumer and/or producer. Many of these DEEs interoperate with each other to form an application solution. The respective concepts are further elaborated upon in the rest of this section.

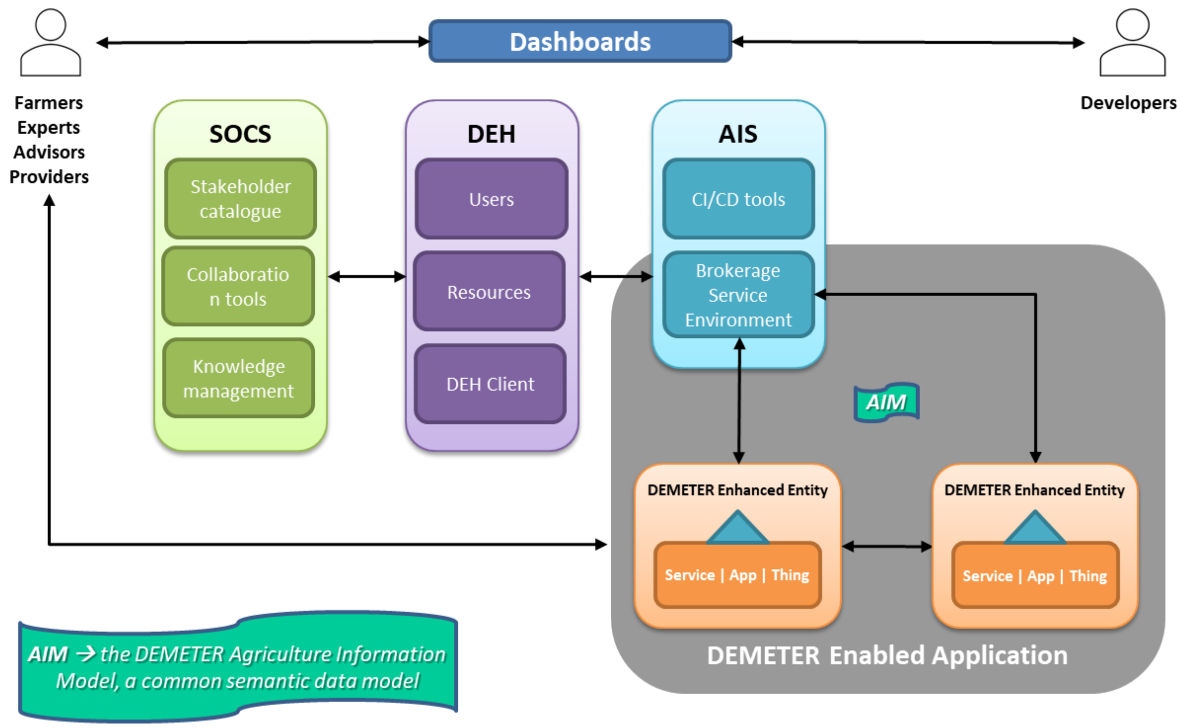

Figure 25. An alternative view of the main DEMETER concepts

As already mentioned, all stakeholders access DEMETER through the dashboard which connects them to the DEMETER facilities. Depending on whether a user connects through AIS or SOCS and depending on the type of usage that the user aims for (e.g., collaboration with other stakeholders, an indication of own needs, resource consumption, application development based on DEMETER resources/enablers, etc.), the dashboard serves a different application and provides different workspaces. To this end, the dashboard exposes several views suitable for the usage intended. The view presented depends of course on the user and the targeted space.

As already discussed, the *DEMETER Enabler Hub* acts as a point of reference for the interested developers and stakeholders in order to register their offered capabilities and resources and act as ***DEMETER Providers***. These offerings are semantically described and are escorted by meta-data, which include (among others) the security and data usage policies applicable, or Quality of Service metrics. ***DEMETER Consumers*** can browse the *DEMETER Enabler Hub* to discover suitable capabilities and resources matching their requirements and specified criteria. The Hub verifies the identities of the consumers and the providers and provides the support necessary for the establishment of a direct secure communication channel among them. The Enablers made available via the *DEMETER Enabler Hub* are either services developed by the project or resources offered by external stakeholders, i.e., by third-party service providers, or by platform providers. These enablers are then available for consumption and usage in DEMETER enabled apps and their deployment and runtime monitoring is facilitated by tools offered by the DEMETER cloud.

There are some more concepts that need to be introduced herewith before we proceed with the description of the DEMETER Reference Architecture design. Any platform, thing, service, or application that makes itself available via the DEMETER Enabler Hub, or consumes resources available in the Hub, or both, is represented by a **DEMETER-enhanced Entity** (Figure 26). More specifically, an application can consume DEMETER resources (thus acting as and implementing the DEMETER Consumer), while a service and a platform can both consume or provide resources (implementing the DEMETER Consumer and/or Provider) and finally a thing (i.e., a physical device/asset, such as a sensor or an actuator) can only be made available for consumption (implementing the DEMETER Provider). To allow for full-scale secure interoperability and communications, there are a few specific DEMETER enablers that are mandatory and need to be available at each DEMETER-enhanced Entity. These are the **DEMETER Core Enablers** that are encapsulated, along with the DEMETER Provider and Consumer in the **DEMETER Enhancing Service**. The Entities communicate with the DEMETER Enabler Hub and the facilities offered by it. All DEMETER-enabled platforms and individual things/resources are registered in the **DEMETER Registry**, along with access rights/policies.

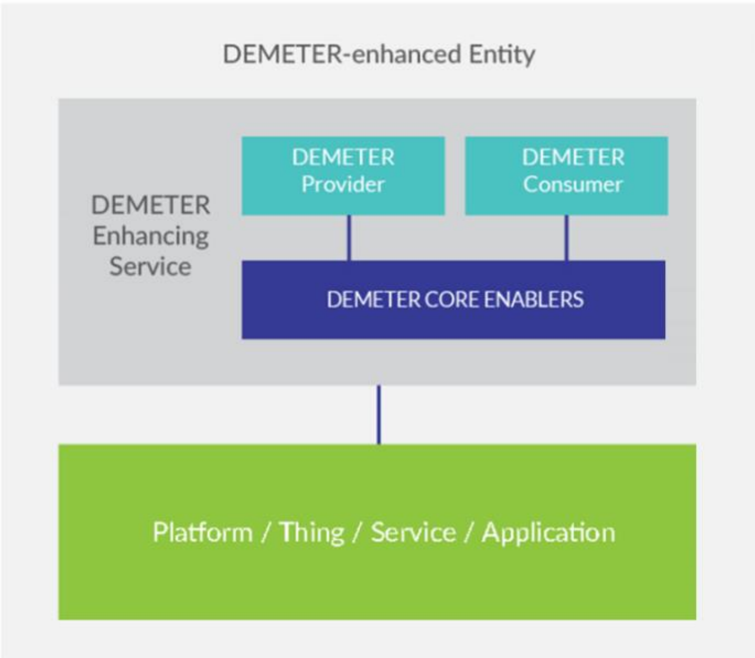

Figure 26. Necessary components of a DEMETER-enhanced entity

More information about how all these components relate are presented in the following section which details the updated DEMETER Reference Architecture. The various instantiations of the DEMETER-enhanced entities are presented in detail in the following section, which, initially, elaborates on the high-level view of the DEMETER Reference Architecture. Furthermore, the section presents the other views (functional, data, process, etc.) of the RA as revised since the delivery of D3.1.

9 Revised DEMETER Reference Architecture

This section presents the revised DEMETER Reference Architecture as it has been evolved given the experience from the initial deployment of the various tools and enablers developed by DEMETER for the first round of DEMETER pilots. It has also been influenced by some of the development reported in the State of the Art section earlier in this deliverable. The changes since the initial RA presented in D3.1 are incremental, but we give here the full updated architecture so that this section can be self-contained and the reader does not have to refer to D3.1.

To this end, this section presents how the main concepts of the DEMETER architecture presented in the previous section interact with each other in the Reference Architecture. The latter is presented here through several viewpoints. Firstly, we give a high-level view of the whole architecture including an instantiation example and describe various instantiations of the DEMETER Entities (in subsection 9.1). Then the functional viewpoint is presented (in subsection 9.2) where the DEMETER systems' main components are described; these include a description of the DEMETER Enabler Hub (DEH), as well as the core (mandatory) and the advanced (optional) enablers offered for the creation of DEMETER entities using the tools offered by DEMETER. Emphasis is given to the evolution of the hub and its tools as these have had the most significant evolution since D3.1. Subsequently, in subsection 9.3 the process view of the RA is presented, and it is described how the components interoperate to deliver their basic functionalities; these are detailed by also providing activity and sequence diagrams for the registration and then the discovery and usage of DEMETER Enablers. Subsequently, the data view is elaborated upon in subsection 9.4, which highlights the data flows and which components are needed to manage the main data processes, such as storage architecture, data retrieval, processing, storage and security management of the data exchanged by DEMETER components and enablers. Next, the deployment viewpoint of the RA is introduced in subsection 9.5. This deals with the runtime operations and presents the topology of software components on the physical layer as well as the connections of these components to each other when applications are deployed. Finally, in subsection 9.6, the business viewpoint of the architecture is discussed, which guides the development of the application components and supports the decision-making process of the stakeholders involved.

9.1 High-Level View

DEMETER proposes an overarching approach that integrates heterogeneous technologies, platforms and systems, while supporting fluid data exchange across the entire agri-food chain, addressing scalability and governance of data ownership. In this way, it offers a way for the integration of already deployed smart farming [SMART] and platforms, which could employ several different communication, sensing and data processing technologies.

As described in the previous section, these goals are delivered through the Agricultural Interoperability Space. The proposed approach enables existing Agriculture Knowledge Information Systems (AKISs) to continue their operation, but also allows those systems to both make available and consume data from other cooperating systems. Additionally, newer technologies and services can be exposed and included in updated applications that may be of interest to the cooperating AKISs. This is more realistic and viable in terms of usability, market adoption, and sustainability. Furthermore, another goal is to facilitate the exchange and interoperability of data, from various sources and in different formats potentially, which is needed to create advanced applications. To realize this approach, the following core objectives need to be fulfilled by the proposed solution:

- Allow existing AKISs to offer their data to and consume data from their counterparts, providing also the means to incentivize AKISs for sharing data by ensuring data integrity and valorisation, giving them also the chance to make some profit, by supporting the appropriate business models.
- Supporting privacy and data governance to incentivize the sharing of data by the providers, thus being in line with newer initiatives that promote the creation of common data spaces (and markets) for such data; although DEMETER aims to take this further by also allowing a common space not only for data but also for services and anything else that would be required to create advance agricultural applications.
- Supporting interoperability between various data formats that would enable the integration of existing systems, sensors and services.
- Extensive use of virtualization containers for services should be made to ensure rapid deployment, portability and scaling once required.

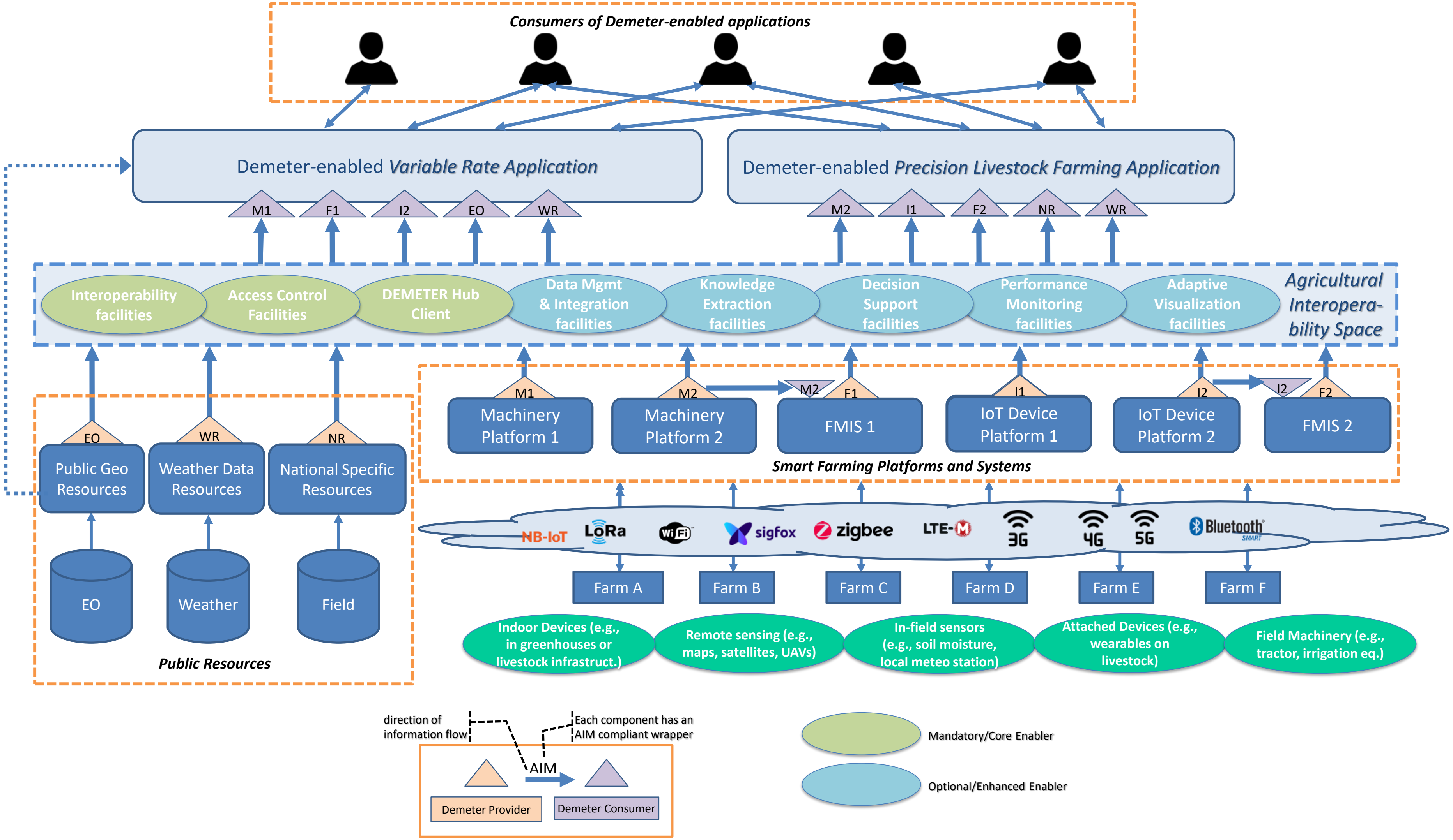

Figure 27. High-level view of DEMETER Reference Architecture instantiation example

The proposed architecture (Figure 27) consists of services available from DEMETER Providers and to DEMETER Consumers, and is loosely based on the architecture model introduced by the Industrial Data Space (IDS)[30], then further specified by the International Data Space Association (IDSA)[31], which is the continuation of IDS [IDS]. This model is also consistent in general with more recent initiatives such as GAIA-X. However, extending the original IDSA architecture, DEMETER Provider and DEMETER Consumer services further extend their applications by supporting AKISs to also expose and consume data. Rapid deployment and decommissioning are highly beneficial for survey services that might not require a continuous feed from a particular AKIS. Such a service would deploy and start a DEMETER Consumer service for that particular AKIS, gather necessary information, and then stop the service. The service is then packaged into a lightweight container along with all the software necessary to support self-contained deployment of the service (runtime environment, libraries for supported communication protocols, encryption techniques, etc.).

As data interoperability is of critical importance, the proposed solution provides the necessary data translation mechanisms combining the use of a semantic data model (Agriculture Information Model — AIM) developed by DEMETER, along with the respective data translation/management/inference mechanisms adopting widespread standardised solutions such as NGSI-LD[32] [INDS], Saref4Agri[33], ADAPT[34], etc. In order to enable interoperability of heterogeneous data handling approaches, the DEMETER provider-consumer services, deployed on various AKISs, translate and exchange data based on the AIM common data format with the use of lightweight data wrappers/translators. For this conversion to be feasible, each AKIS needs to provide the specifications of the utilized data model and semantics, or it should parse returning content in the AIM format. The AIM is not built ab initio but incorporates and extends existing ontologies and vocabularies already available for this domain.

To elaborate further upon this crucial topic, AIM was created by incorporating concepts and entities from some of the best-known ontologies, some with general concepts such as people, time, GPS coordinates, sensor data etc. and some with concepts of the agri-domain. These include FIWARE, Saref4Agri, ADAPT, INSPIRE, FOODIE, the AGROVOC vocabulary and EO standards. There are also plans which are currently in progress to further extend AIM by including concepts from other ontologies, e.g., FOODON. For more details about how AIM is being developed and regarding its interoperability with other existing ontologies, please refer to deliverables D2.1 and the forthcoming D2.4.

DEMETER provider-consumer services maintain the necessary mechanisms for satisfying data security and privacy concerns. DEMETER can support several different ways of sharing data and processing services and the security and data governance features of the Reference Architecture need to support them.

First, they need to be trusted to be deployed and hosted by the AKIS on their own cyber-premises (i.e., hosting environments) following the principle that moving processing capabilities is easier than

[30] http://www.industrialdataspace.org/
[31] https://www.internationaldataspaces.org/
[32] ETSI. Context Information Management (CIM); NGSI-LD API. Available online: https://www.etsi.org/deliver/etsi_gs/CIM/001_099/009/01.01.01_60/gs_CIM009v010101p.pdf
[33] ETSI. SmartM2M; Extension to SAREF; Part 6: Smart Agriculture and Food Chain Domain. Available online: https://www.etsi.org/deliver/etsi_ts/103400_103499/10341006/01.01.01_60/ts_10341006v010101p.pdf
[34] ADAPT - Agricultural Data Application Programming Toolkit, Homepage URL: https://adaptframework.org/

moving data itself. This also maintains an inherent data privacy protection feature as the owner of the data maintains the control/decision of which data are allowed to be shared with other entities. The services need to provide privacy and security functionalities, including user authentication and access authorization. Once a DEMETER-enabled application is implemented, the final version at a production level can be discovered by consumers (e.g., Farmers, Agronomists, Cooperatives, etc.) through the DEMETER Dashboard, which is also used by these stakeholders to provide their feedback regarding the perceived experience and added value.

However, in order to be compliant with newer initiatives such as GAIA-X or the drive towards European data spaces (e.g., for agri-data and processing services), the RA also supports each of the components being situated in different locations. For example, the provider of data maintains an endpoint from which the data can be obtained/streamed from. In this case, security and being able to maintain ownership and control of one's data is of paramount importance. The DEMETER RA can maintain control by putting in place policies about how data is accessed and for where this data would be accessible from, e.g., the owner could put policies regarding which specific users are excluded or specifying that the users of specific regions can access this data etc. The DEMETER Enabler Hub (described later in this section) can enable such policies. Note that in order for the data to be consumed (after all security and governance concerns have been addressed), both the provider and consumer of data need to download the appropriate data wrapper services (which could be provided by a third party through the hub) which would allow data to be translated to AIM and then to the format required by the processing service, thus ensuring interoperability.

For simplicity, Figure 27 presents only some of the platforms that can be integrated in the DEMETER Reference Architecture, thus representing a specific instantiation of the architecture deployed to serve the needs of one pilot site for example. However, in addition to the integrated platforms, the DEMETER enablers are made available and can be used by the interested parties (e.g., data/knowledge facilities), as well as any other 3rd Party resource registered. Thus, all registered resources are made available to the developers through the DEMETER Enabler Hub, presented in the next subsection of this deliverable report; these are annotated with rich metadata that describe the capabilities (or constraints) of these resources thus guiding the deployment of DEMETER apps based on the adopted technologies as well as information regarding ownership of resources that are available and the restrictions that their locations might impose during this process.

As already mentioned in Section 8, each platform, thing, service or application is represented by a DEMETER-enhanced Entity and either makes itself available via the DEMETER Enabler Hub, or consumes resources available in the Hub, or both. Thus, there are various instantiations of the DEMETER-enhanced entity that are listed hereafter:

- **DEMETER-enhanced Resource**: This entity contains the resource (platform, thing, service) that registers its capabilities to the DEMETER Enabler Hub and makes them available to interested parties. It is worth mentioning that a DEMETER-enabled Resource can make use of other Enablers registered in the DEMETER Enabler Hub to enhance its features.
- **DEMETER-enabled Service**: A DEMETER-enabled Service is a 3rd Party service that is provided by a stakeholder external to the DEMETER project, which is integrated to the DEMETER ecosystem. It can both register its Service Logic to the DEMETER Enabler Hub, thus making it discoverable by interested parties, as well as discover other DEMETER Enablers via the DEMETER Enabler Hub and directly consume their exposed interfaces without any interoperability implications.

- **DEMETER-enabled Application**: The "Application Logic and User Interfaces" are DEMETER ignorant and are provided by an application provider external to DEMETER. The DEMETER-enabled application can communicate with the DEMETER eco-system and browse its Enabler Hub to discover available resources that are compatible with and registered in DEMETER. End-users directly access the user interfaces provided by these applications. Furthermore, users can consume functionality exposed by the DEMETER-enabled Resources (or resources in general, including data) only through these applications.

The following figure (Figure 28) illustrates where these entities are positioned in the DEMETER ecosystem and how they interact with stakeholders, with the DEMETER Enabler Hub and with each other. The human users (stakeholders) can have direct access to the DEMETER Dashboard, in order to use SOCS or AIS facilities, as well as to any DEMETER-enabled application. The interaction of the various entities with the DEMETER Enabler Hub is required primarily in the registration and discovery processes (indicated via the dashed lines), so that these are made available in the DEMETER Enabler Hub and are discoverable by interested parties. Once the interested DEMETER consumer discovers the enablers and other resources it aims to use, these are packed for delivery along with the necessary facilities that support this development and integration process; these deployment and runtime facilities are provided by the hub. It should be highlighted that in general the DEMETER Enabler Hub does not hold any resources or processing services, but just information on who provides the registered components and data, the terms of usage, information about, e.g., the types of data or processing, the region where the data come from, policies regarding access set by the providers etc. So packaging in this case means sending the information required to find the endpoint from which registered components and data can be consumed and also to provide appropriate translation services to/from AIM so that the various components can maintain the necessary interoperability; these translators/data wrappers are also discoverable through the DEMETER Enabler Hub. Finally, please notice that the DEMETER-enabled application can directly interact with the DEMETER-enabled services or DEMETER-enhanced resources it aims to consume, once these are discovered in the hub. The same is true for the DEMETER-enabled service that consumes DEMETER-enhanced resources.

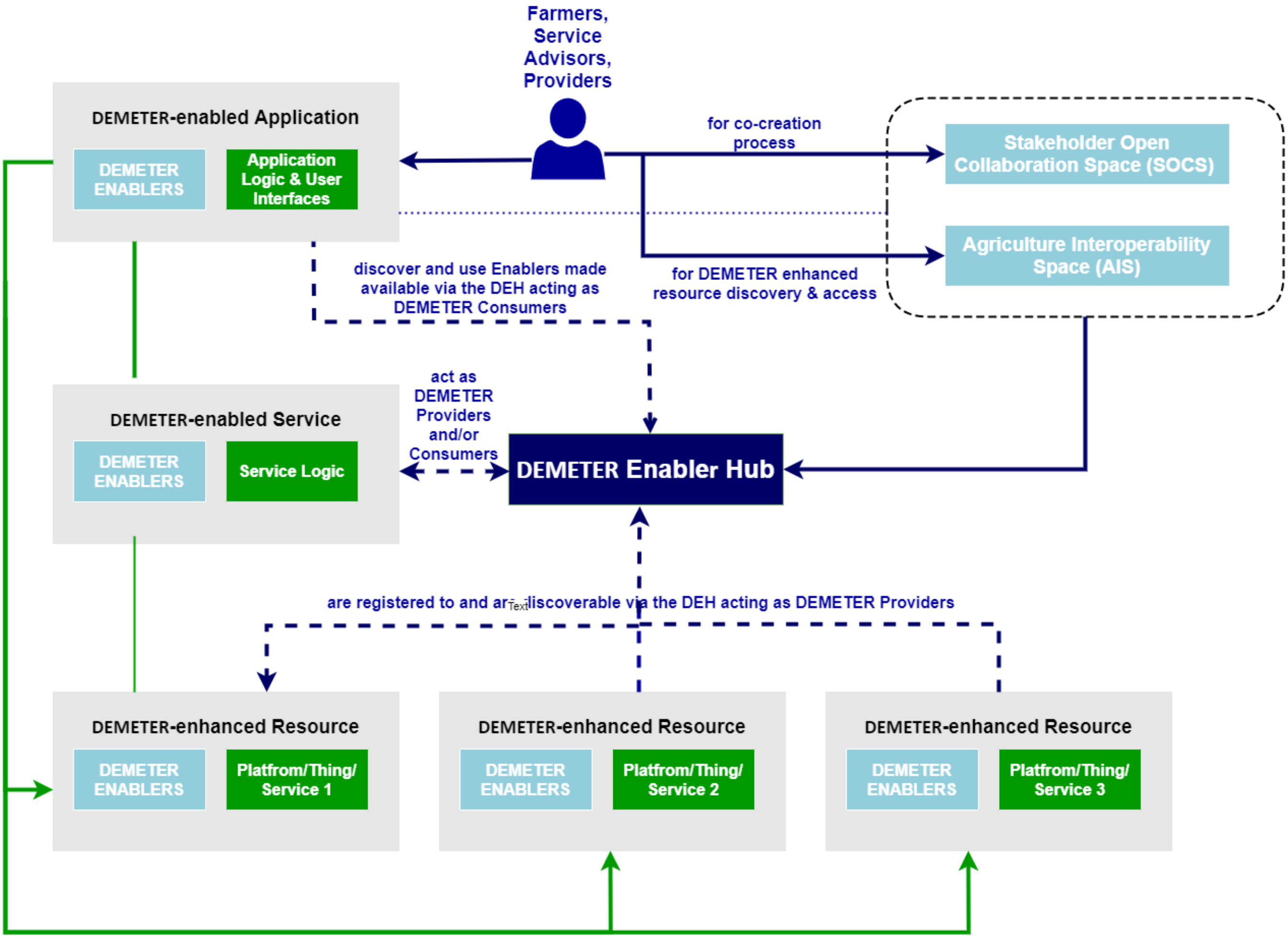

Figure 28. Positioning and interoperation of entities (i.e., applications, services, resources) enhanced/enabled and/or made available via DEMETER

9.2 Functional View

In order to implement the high-level view of the architecture and to implement the objectives and vision of it, DEMETER needs to provide several facilities/modules that interact with each other, with the various stakeholders as well as with a wealth of existing devices, platforms, systems and data sources. The main functional blocks of the DEMETER ecosystem that constitute the **functional view** of its reference architecture are the following: Demeter Enabler Hub, Stakeholder Open Collaboration Space, Agricultural Interoperability Space, Dashboard, DEMETER Core Enablers and DEMETER Advanced Enablers. Before we describe these functional components, we need to link them to the high-level view described in the previous section. According to this view, it is necessary to create appropriate DEMETER compliant wrappers in order to use the available (public) data resources and the external devices (things in general) and systems that we want to include in DEMETER enabled applications. On top of these resources sits the communication infrastructure responsible for handling any communication between DEMETER and these external resources. These resources are DEMETER agnostic in the sense that they do not need to comply with the DEMETER AIM and models in general. However, to be integrated into a DEMETER enabled application, they need to be paired with the aforementioned data wrapper/translator, which translates their data format to/from the DEMETER AIM model. The respective facilities that deliver this are wrapped in the so-called DEMETER Provider, depicted by triangles in Figure 27 (please refer to the previous subsection). These facilities are of course provided by DEMETER in support of all pilots, but in general, for other domains, they are developed and offered through DEMETER by 3rd Party developers and stakeholders, who can access DEMETER in order to develop and offer these via AIS.

In order to support this creation process of appropriate wrappers for the external resources (e.g., platforms, things, services, applications), DEMETER's facilities support the development process and ensure semantic interoperability always based on the DEMETER AIM model. To ensure that these objectives are met, *DEMETER provides interoperability mappings for various dominant ontologies* (see deliverables D2.1 and the forthcoming D2.3). Furthermore, the AIM ontology has been published on ontology discovery sites, such as agroportal[35], to ensure that both the ontology and relevant concepts are easy to discover by any interested third party. Finally, DEMETER has been developing several data wrappers for data used in the DEMETER pilots and tools that enable the translation to/from AIM; the data of the pilots cover a range of data usable in the agri-domain and the wrapper are made available as part of the DEMETER software and tools which would further facilitate any developer to take these and modify them to any other type of related data.

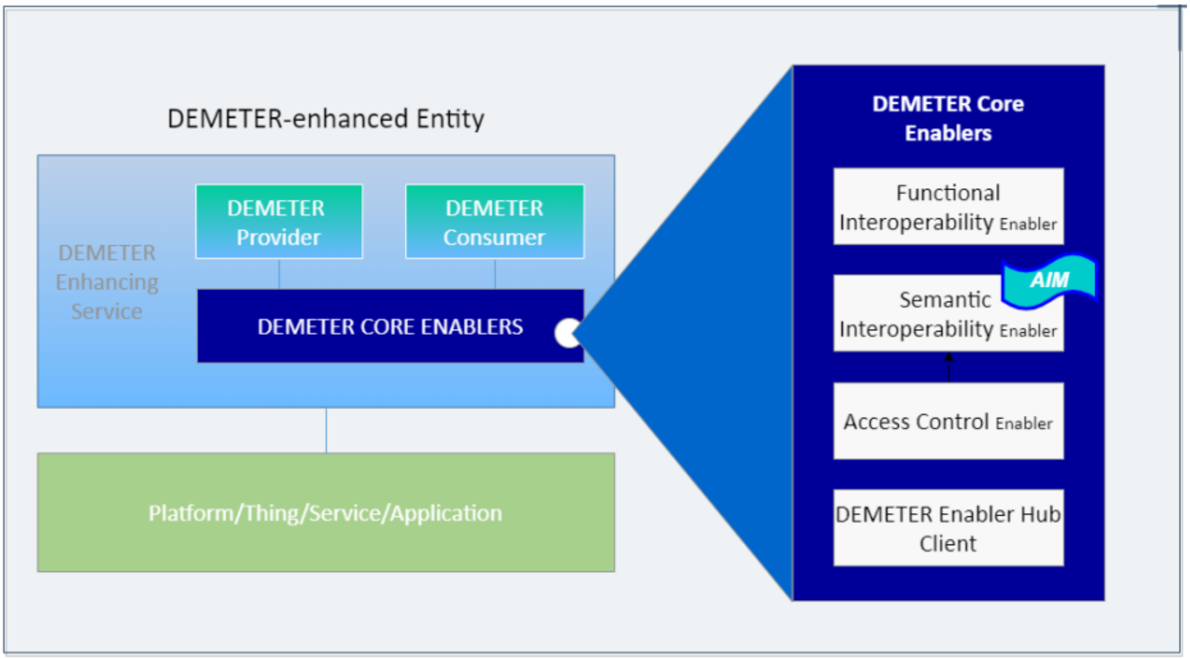

Figure 29. Functional view of DEMETER enhanced Entities with the included DEMETER Core Enablers

In addition to the interoperability tools, DEMETER also offers a set of **Core Enablers** needed for creating any DEMETER application. These are listed in Figure 29, which presents the architecture of a DEMETER-enhanced Entity that is made compliant with DEMETER (and thus able to register with the DEMETER Enabler Hub). As previously discussed, on top of the existing resources, e.g., platforms, devices, services or applications, it is necessary to create a DEMETER wrapper that allows the resource to interoperate with other DEMETER Entities. In order to facilitate this creation, DEMETER offers a list of core enablers. These enablers are mandatory for any interested stakeholder that

35 http://agroportal.lirmm.fr/ontologies

wishes to expose or share its own resources, and provide support for: semantic & functional interoperability, so that any communication complies with the DEMETER AIM model, access control, e.g., to prevent access to unauthorized entities, while they also include a Client for the DEMETER Enabler Hub, for any information that needs to be communicated with DEH's runtime facilities.

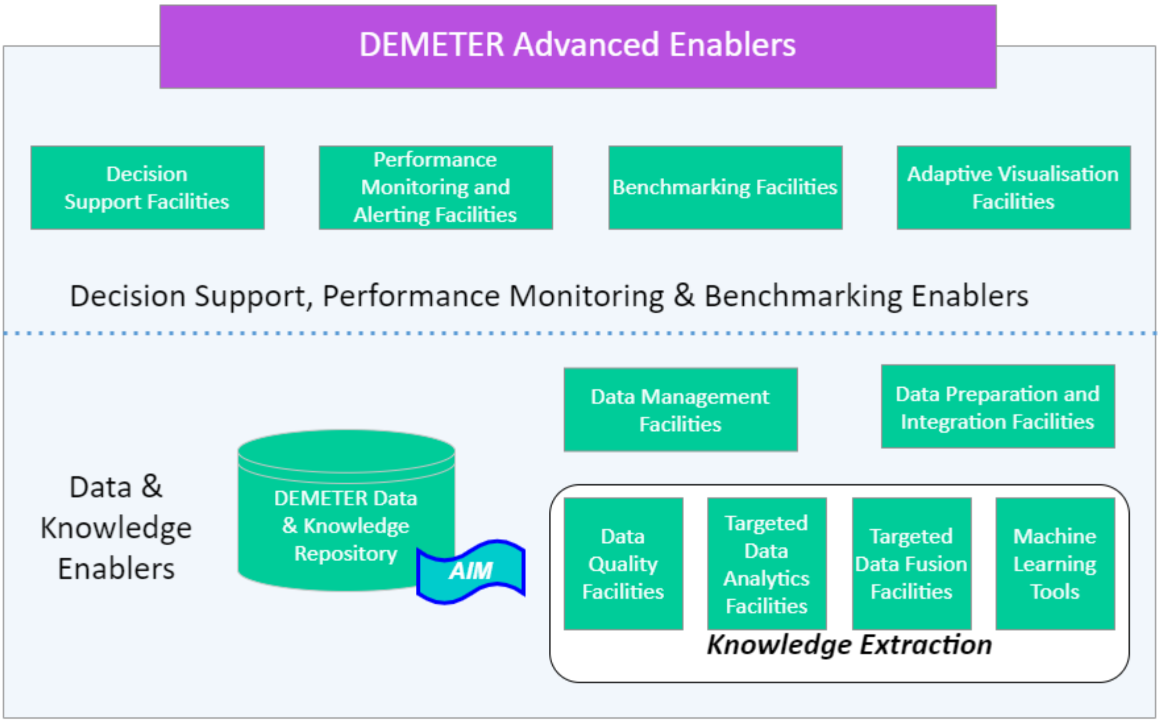

Figure 30. Advanced Enablers offered by DEMETER

DEMETER also offers another type of enablers: **Advanced Enablers** that are optional and are discoverable and accessible through the DEMETER Enabler Hub. They are depicted in Figure 30 and fall under several distinct categories.

First, the *Data & Knowledge Enablers* are responsible for Collecting and Curating data from the various sources that the DEMETER developers and stakeholders have been registered for. To elaborate, the Data Preparation and Integration enablers curate, prepare, integrate and link the data obtained, while the Knowledge Extraction enablers handle matters related to data quality assessment, fusion of data collected from heterogeneous sources, targeted data analytics applicable to specific pilots and machine learning. The knowledge extraction facilities are either generic (to be used across multiple pilots) or are developed to serve the needs of specific pilots. Furthermore, Data Management (including data storage and selection) is also supported exploiting the DEH facilities. More specifically, the advanced enablers supporting the handling of Data and Knowledge are listed below:

- 2.B.1 Data management
    - 2.B.1a Data storage
    - 2.B.1b Data selection
    - 2.B.1c Data management
- 2.B.2 Data Preparation & Integration
    - 2.B.2.a Data Preparation

- 2.B.2.b Data Integration
- 2.C.1 Data Quality
  - 2.C.1a Data Quality Assessment Service (CSV, JSON, shapefile)
  - 2.C.1b Data Quality Assessment Service (AIM, JSON-LD)
  - 2.C.1c Data Assertions for Machine Learning Pipelines
- 2.C.2 Targeted Data Fusion
  - 2.C.2a Fusion of Rice & Maize filed Imagery
  - 2.C.2b Fusion of Weather information
  - 2.C.2c Fusion of Fruit Fly Imagery
- 2.C.3 Targeted Data Analytics
  - 2.C.3a Data analytics for optimal rice irrigation
  - 2.C.3b Data analytics for optimal maize irrigation
  - 2.C.3c Data analytics for optimal fertilizer usage (for arable crops)
  - 2.C.3d Data analytics for weather forecast
  - 2.C.3e Data analytics for optimal pesticide usage
  - 2.C.3f Data analytics for crop irrigation
  - 2.C.3g Data analytics for olive phenology prediction
  - 2.C.3h Data analytics for Fruit Fly recognition & counting
  - 2.C.3i General Approach for Pattern Extraction with Computer Vision in crop fields
- 2.C.4 Machine Learning Tools
  - 2.C.4a Labelled datasets for training
  - 2.C.4b Model Management
  - 2.C.4c AIM-Compliant Serving

More details on the functionality of these enablers will be provided in deliverables D2.3 and D2.4, while their usage across the pilots is elaborated upon in Section 11 that aims to present the instantiations of the revised Reference Architecture for the 20 DEMETER pilots.

Second, the *Decision Support, Performance Monitoring and Benchmarking Enablers* provide to the DEMETER developers and stakeholders the availability to choose the Decision Support (DS) mechanisms they are interested in (among the set of DS that DEMETER implements) and that fit the specific application being developed; of course, any developer has the option to use her own DS system instead of the offered ones. In addition, it also provides Performance, Monitoring and Alerting facilities[36] as well as Benchmarking facilities, in order to monitor, at runtime, the performance of DEMETER entities, such as the aforementioned decision support algorithms. Finally, visualisation enablers complete this class of DS related enablers: these are instrumental in conveying the information and actions taken automatically (or needed) to the final users of the DEMETER applications, such as the farmers. More specifically, the advanced enablers supporting Decision Support, Performance Monitoring and Benchmarking are classified in 9 areas (A, B, …, I) and are listed below:

- Area A
  - 4.A.1 Plant Yield Estimation
  - 4.A.2 Plant Phenology Estimation

[36] This ties in with other tools offered by the DEMETER Enabler Hub, such as the runtime facilities, and which are described later in this section.

  - 4.A.3 Plant Stress Detection
  - 4.A.4 Detect Crop Type
  - 4.A.5 Estimate Beehive
- Area B
  - 4.B.1 Moisture Estimation
  - 4.B.2 Salinity Estimation
  - 4.B.3 Irrigation Requirements Estimation
  - 4.B.4 Plant Water Status Estimation
- Area C
  - 4.C.1 Nitrogen Balance Model
  - 4.C.2 Nutrient Monitor
- Area D
  - 4.D.1 Emission
  - 4.D.2 Field Operation
  - 4.D.3 Variable Rate
- Area E
  - 4.E.1 Pest Estimation with Sterile Fruit Flies
  - 4.E.2 Estimate temperature-related pest events
- Area F
  - 4.F.1 Estimate Milk Production
  - 4.F.2 Poultry Feeding
- Area G
  - 4.G.1 Estimate Animal Welfare Condition
  - 4.G.2 Poultry Well Being
- Area H
  - 4.H.1 Traceability
  - 4.H.2 Transport Condition
  - 4.H.3 Field Book and FaST
- Area I
  - 4.I.0 Indicator Engine for Benchmarking Purpose
  - 4.I.1 Generic Farm Comparison
  - 4.I.2 Neighbour Benchmarking
  - 4.I.3 Technology Benchmarking

More details on the functionality of these enablers will be provided in deliverables D4.3 and D4.4, while their usage across the pilots is elaborated upon in Section 11 exposing the instantiations of the revised Reference Architecture for the 20 DEMETER pilots.

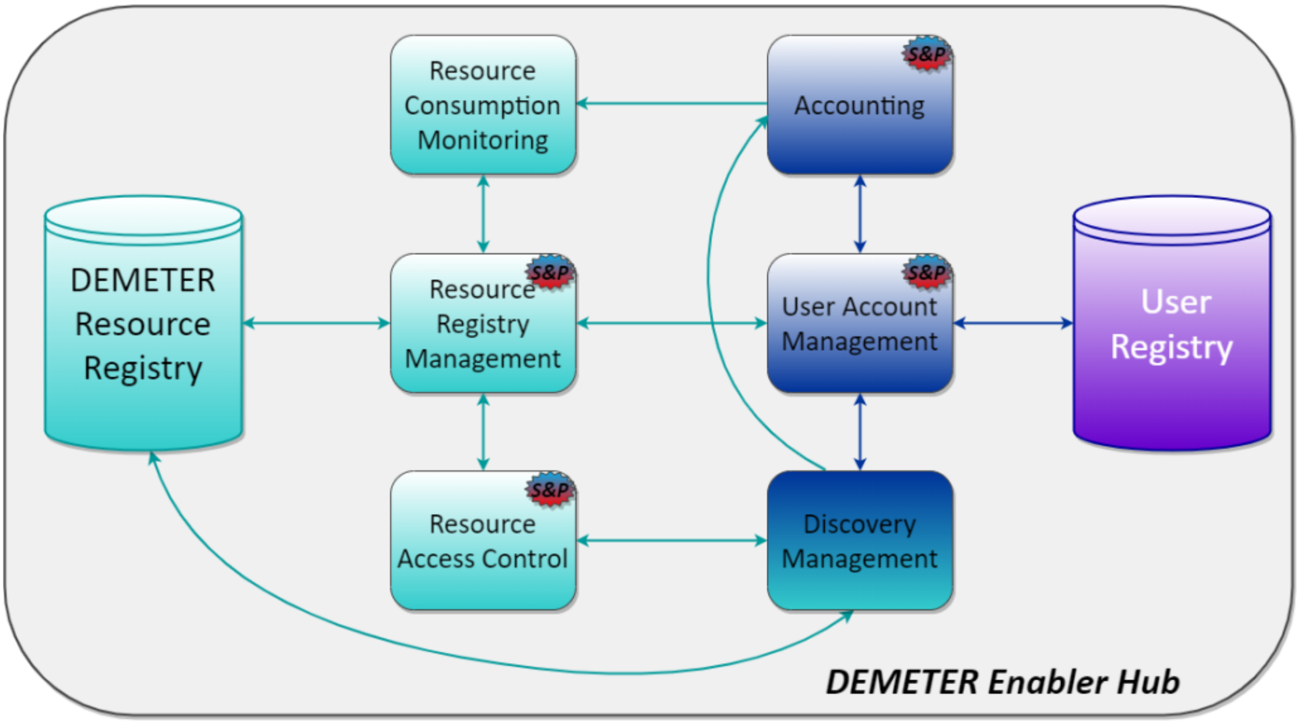

Figure 31. Internal Management Components and Registries of the DEMETER Enabler Hub (DEH)

So far, we have described the components of the DEMETER enabler hub that deal with the creation of the DEMETER entities and the entities themselves. The registration and management of these entities is the task of the **DEH management facilities** component. The internal subcomponents of this are presented in Figure 31. Users first need to register with the User Account Management, which updates the user registry DB before they can consume DEMETER resources or get apps and services, or register a new DEMETER enhanced entity or resource that they wish to offer through the hub. To accomplish the latter, they interact with the Resource Registry Management module that updates the DEMETER Resource Registry with the data for the new entity. Subsequently, the resource access control module is contacted by the resource registry management with the information regarding the entity owner's preferences for the submitted entity, including what access rights and policies are to be enforced. In this way the user can limit which users can discover the new entity and in which way it may be used, or restrict usage to ownership only, thus enabling and facilitating the governance of the provider's data as per her stated policies in the hub.

Subsequently, when a user wishes to discover DEMETER enhanced entities, the Resource Registry Management module queries the Discovery Management module, which in turn retrieves the permissions on what entities to display from the access control component; afterwards, depending on the rights provided by the access control, it queries the resource registry in order to get the entities to which the current user has access (rights) to use. Should an entity then be contracted, the accounting component is informed so that the appropriate compensation for using the entity is provided. All these processes regarding how the DEH modules interoperate are detailed in the following subsection, which elaborates on the *process view* of the DEMETER Reference Architecture.

While in our DEMETER pilots the usage of such facilities is not foreseen, there is also a placeholder for an accounting component that can be implemented to handle any kind of transaction, e.g., regarding how to pay for data and services offered through the hub. The RA includes this component (even if this has not been implemented or planned for usage) in order to facilitate any kind of transactions and be compliant with the newest initiatives which promote the sharing (e.g., selling) of data and services to interested parties.

Finally, there is additional functionality used by several of the hub components in this ecosystem, which focuses on the privacy and security requirements that need to be addressed.

For example, there are sensitive data (e.g., billing data) being handled by the user and resource registry modules, or by the accounting component that need to be protected. In Figure 31, the respective facilities are depicted as “S&P” (i.e., Security and Privacy) modules within the appropriate components of the management facilities. All these concerns are being addressed by tools developed in T2.4 (Data Protection, Privacy, Traceability and Governance Management) and T3.4 (Connectivity and Security Framework).

Once the required modules are discovered in the DEH and are selected by the interested stakeholders, the **Brokerage Service Environment (BSE)** takes over to facilitate the deployment of the selected enablers, as well as the deployment of the DEMETER enabled applications, in case these have been built based on DEMETER discoverable enhanced entities contracted through DEH. Essentially the BSE aims to link together the various enablers composing each application: once a complete app is composed or consumed through the hub, the BSE is responsible for providing information regarding the endpoints (e.g., by offering a URL or URI where enablers can be contacted and data obtained) from which data and services can be consumed (if used in online mode) or downloaded if they are meant to be consumed locally by the consumer, meaning that data and tools will be run at the consumer’s workstation.

Furthermore, the runtime facilities of the DEMETER Enabler Hub are offered through the **DEH client**, whose task is to monitor the execution of the enablers and which can receive data back from the application and the individual entities these are composed of, in order to gauge whether the various entities operate according to their specifications. To accomplish this and in view that most components are implemented and executed using docker-compose, the DEH client links to docker and get this data regarding processor and memory usage in order to gauge the execution (and health) of each enabler. They will also offer facilities that can receive ratings back and then update the information available in the registry for each resource available through it. These facilities have been developed and are currently being tested. They are detailed in deliverable D3.2 and furthermore in the forthcoming deliverable D3.4.

9.3 Process View

The **process view** deals with the dynamic aspects of a system, describes the system processes and their interactions, and focuses on the run time behaviour of the system. The process view is produced for people designing the entire system and then integrating the subsystems or the system into a system of systems. This view shows tasks and processes that the system has, interfaces to the outside world and/or between components within the system, the messages sent and received, and how performance, availability, fault-tolerance, and integrity are being addressed.

In DEMETER, for the Reference Architecture, we identified two processes that are related to DEEs and DEMETER enablers:

1. DEMETER DEE Registration
2. DEMETER Enabler Discovery and Usage

For these two high-level processes, we have created their corresponding high-level Activity and Sequence diagrams. These diagrams are presented in the following subsections.

9.3.1 DEMETER Service registration

9.3.1.1 Activity diagram

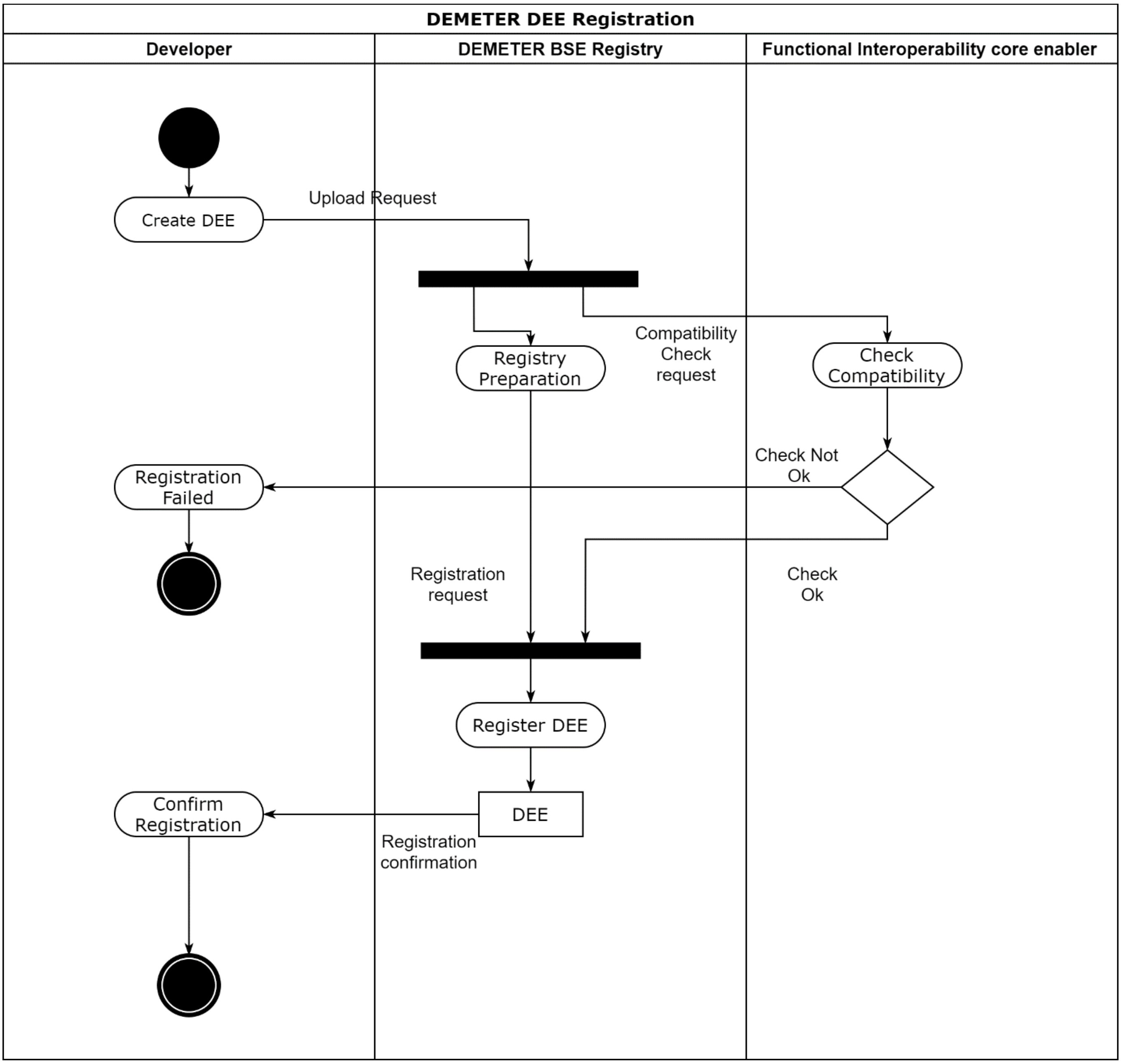

Figure 32. DEMETER Enhanced Entity Registration Activity Diagram

The diagram in Figure 32 illustrates the three parties/roles that are involved in this process/activity:

- ***Developer***, the development teams that make use of DEMETER Enablers to create their own DEMETER service.
- ***DEMETER BSE Registry*** in the Brokerage Service Environment module, where DEMETER DEEs are registered during runtime.
- ***Functional Interoperability core enabler*** that includes the compatibility checker module functionality and is used to validate the compatibility of a service before it is registered in the registry. For more details on this, please refer to Deliverable 3.4.

The Developer implements a DEMETER service and issues a request for it to get registered to the BSE Registry. DEMETER backend services (e.g., BSE with its Registry and the FI core enabler) prepare the service and request a compatibility check to assess whether the service can be registered or not.

9.3.1.2 Sequence diagram

The diagram in Figure 33 depicts the sequence in the interaction between the three different systems from the moment a developer creates a DEMETER service until it gets notified that this resource has been registered to DEMETER's BSE Registry.

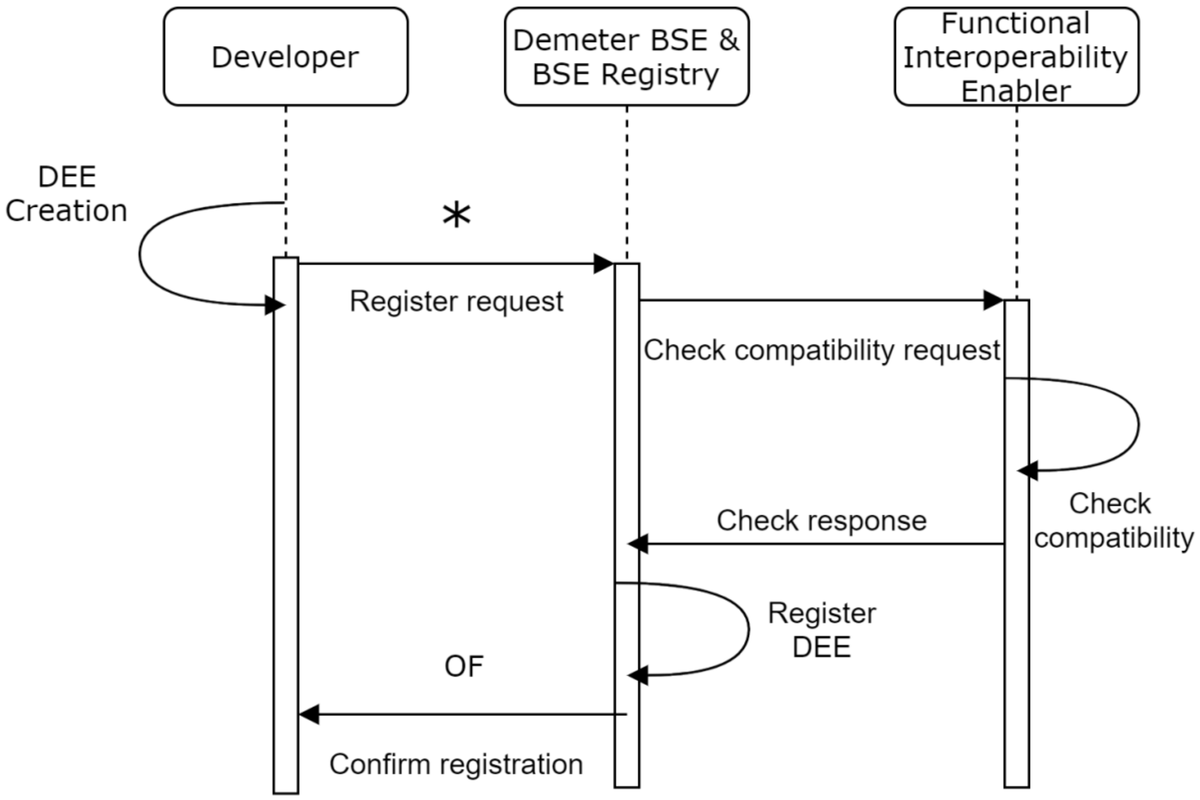

Figure 33. DEMETER Enhanced Entity Registration Sequence Diagram

9.3.2 DEMETER Enabler Discovery and Usage

9.3.2.1 Activity diagram

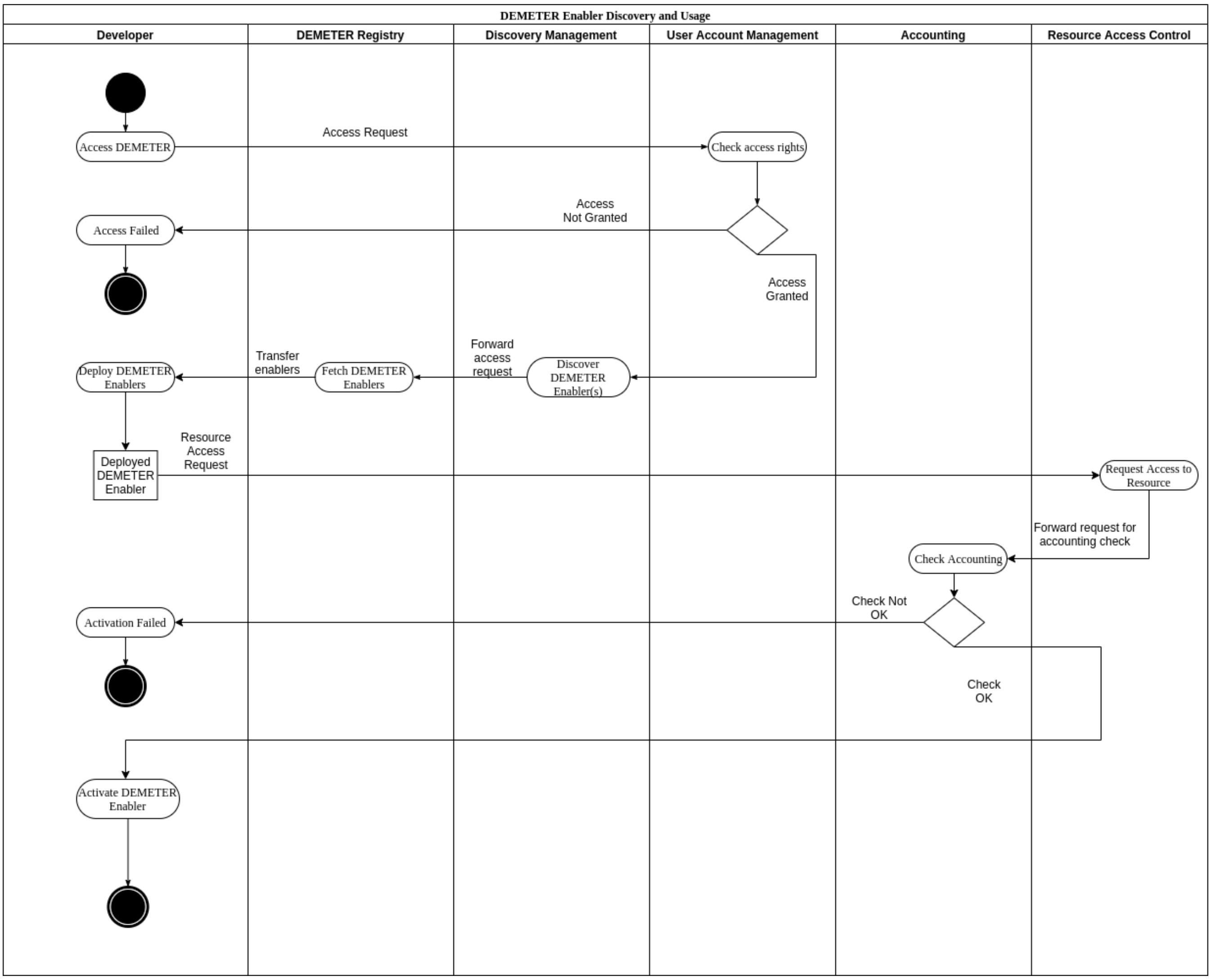

Figure 34. DEMETER Enabler Discovery and Usage Activity Diagram

The diagram in Figure 34 illustrates the six “systems” that are involved in this process/activity:

- Developer, the development teams that create their own DEMETER Enablers.
- DEMETER Hub Enabler Registry, where DEMETER Enablers are registered.
- Discovery Management, which offers the enabler’s discovery service.
- User Account Management, which provides all the user account related services, granting different access rights to different user roles.
- Accounting, which includes functionality for (monetary) transactions between actors.
- Resource Access Control, which controls users’ access to specific resources (services, devices, etc)

The Developer accesses the DEMETER dashboard and searches for Enablers via the Discovery Management module, whenever they are authorised to. Enablers are fetched to the Developer’s premises from the Registry and then a resource access request is issued to be checked and validated by the Resource access control system and the Accounting system. If the user has indeed permission to access that resource, the DEMETER Enabler is activated providing access to that particular resource.

9.3.2.2 Sequence diagram

The diagram in Figure 35 depicts the sequence in the interaction between the six different systems from the moment a developer accesses the DEMETER dashboard to discover Enablers up to the moment that the developer gets access to a DEMETER enabled resource.

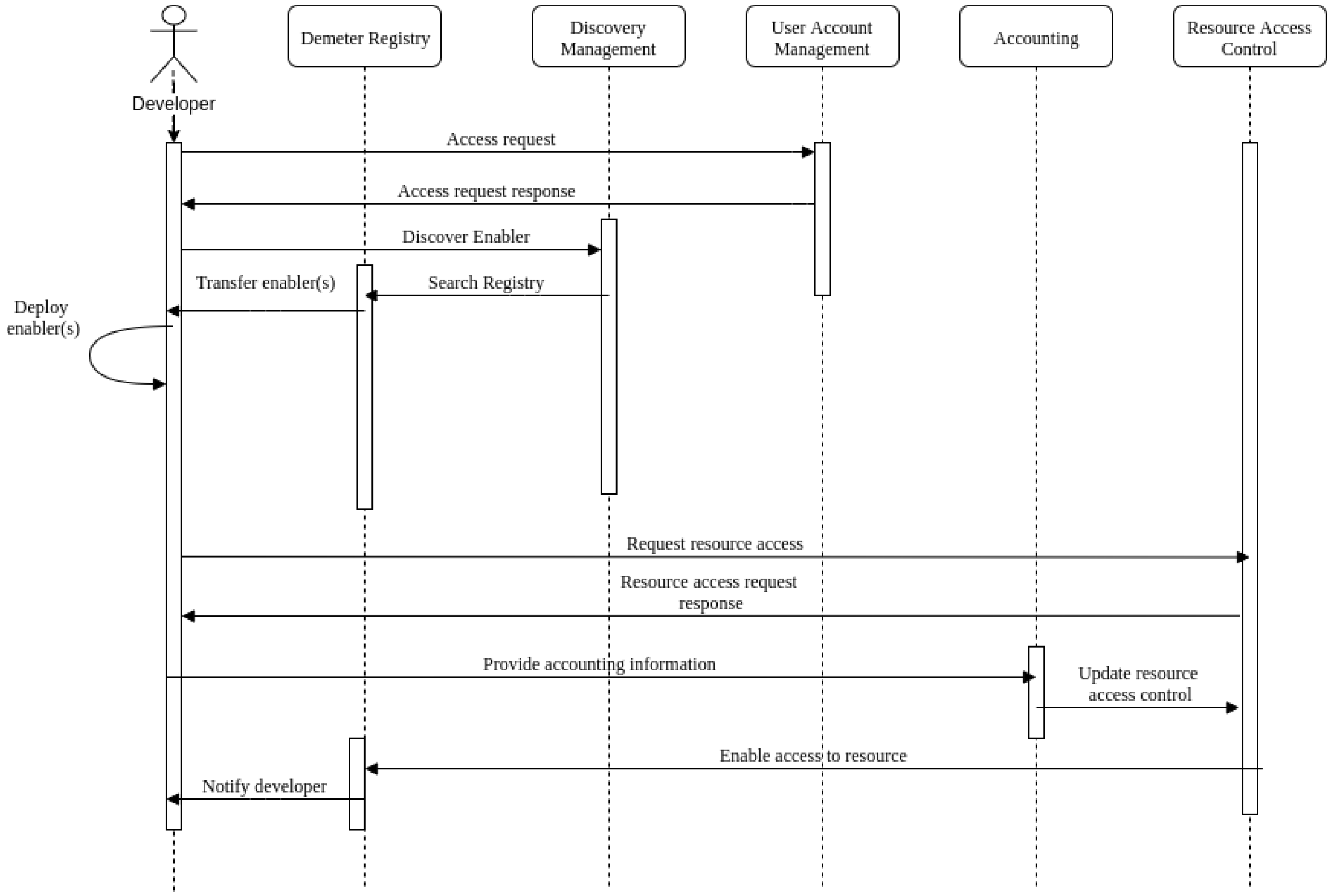

Figure 35. DEMETER Enabler Discovery and Usage Sequence Diagram

9.4 Data View

This section aims to report the updated and final version of D3.1 regarding the data view representation of DEMETER Architecture. It provides the grounding information related to the main changes brought by technical partners to align this view with the DEMETER Reference Architecture (RA) with respect to the first version of this deliverable (D3.1). Basically, this view is about data storage architecture, data retrieval, processing and security management. The view highlights the data flows and which components are needed to support and manage the main processes, such as archiving and processing. There were no major deviations from the criteria used to define the methodology that inspired this view; however, improvements and enrichments were made with respect to the identification of components, such as data spaces, which take part in the data management in the DEMETER solution. Based on more mature awareness made at a technical level in the DEMETER consortium, the main DEMETER software modules, who took part in the data management process, remain the same, but with a renewed and clear positioning within the architecture of DEMETER enablers, with a better technical contextualization, thus considerably approaching the gap between a diagram defined in the first iteration of the deliverable or D3.1 and the relative real technical context of the project, reached in this second iteration of the deliverable or D3.3.

The renewed definitions of the main DEMETER data archives now appear clearer, while the main elements are identified as follows:

- **DEMETER Data & Resource Repository**
- **DEMETER User Registry**
- **DEMETER BSE Registry**

The need also appears clearly in this second iteration of the Reference Architecture deliverable, as it is necessary to connect these modules to the real DEMETER technologies in this data view. In order to clarify why this analysis is made before describing thoroughly these components, it is fair to consider that these decisions have not been made instantly, but all decisions have been formulated after many technical meetings among WP2 WP3 and WP4 members, who established that DEMETER data relating to users, things, applications, platforms, devices should have their representation in the aforementioned data stores. These DEMETER modules are linked to real DEMETER technologies, such as the **BSE**, the **DEH**, and finally the **ACS**. As mentioned at the beginning of this section, representing the main DEMETER technologies is valuable, as they are used to deal with the management, security and processing of data coming from DEMETER data providers.

The **DEMETER Data & Resource Repository** or **DEH Resource Repository** addresses the problem of the physical representation of the DEMETER resource information model, normalizing the information flow coming from the DEMETER data providers using a formal definition of the DEMETER resources. Once normalized, this information is easily interpretable within the context of the DEMETER main software modules, through the use of a data management API layer. This data management API layer is the outcome of technical WPs, i.e., WP2 and WP3. It is therefore undoubtable that, compared to the first version of this deliverable (D3.1), this repository and its APIs will neither support the semantic validation of a resource, nor the saving of semantically correct instances from the point of view of the AIM model (defined within WP2), simply offering data space and tools as a resource repository. The DEH represents the DEMETER marketplace, where a DEMETER stakeholder can discover all the resources offered by the data providers who will take part in the project.

The technology that supports the DEH database is based on the NoSQL paradigm, better optimized for reading data, as well as for the representation of a flexible data model. The real innovation here is constituted by the data management APIs and by technologies that allow the dynamic modelling of an entity: this means that, if in the future the formal representation of the information model will have to change, this will not represent a problem for the DEH. Furthermore, an important aspect that needs to be highlighted is that the full interoperability and flexibility of the DEH technology is suitable for future integrations outside DEMETER with other technologies in the agri-space. The internalization of resources from other platforms such as GAIA-X[37] could be well supported, and also the exposure to the DEMETER resources data consumption is made possible, as long as third-party applications/services are compliant with the guidelines and the security protocols implemented in DEMETER via the ACS module.

The DEMETER User Registry or **ACS User Repository**, offered by the ACS module, supports GDPR compliant storing and securing users' personal data, credentials, user permissions and other aspects of personal data. This database is also flexible, in the sense that it allows an extension of user data based on a dynamic JSON[38] template. The services or APIs exposed by this component enable the injection of new data after a client service has been suitably verified and validated by security controls, such as authentication and authorization modules. It is no coincidence that this user data store is subjected to stringent security measures, given the important value of the data it manages. In terms of technologies, a regular open source relational database is used (such as MySQL[39]), therefore being adaptable to many application contexts.

The DEMETER BSE Registry, or simply BSE Registry, is the last software module of the DEMETER software infrastructure, being one of the most significant modules in the data view. Providing a common interface both in the data model and in the APIs, it allows the addition of metadata to describe DEMETER services. Any consumer, be it another DEMETER core module or a third-party service provider/consumer, has to communicate with this database or with its services to find out services and/or data. Any interested data producer is required to register their services in this store, offering the application logic of their services to third parties or DEMETER consumers from an as-a-service perspective.

Considering the data store itself (only data container or the technologies that enable data persistence), it is also fundamental to consider the API frameworks able to support and interoperate with these technologies. In fact, it allows operations such as data reading and writing, while it holds the business logic of single services and the overall functionality of the technology they implement when considered as a whole. With the aim to contextualize these frameworks with the DEMETER enablers/modules identifying them in the macro functional block of competence, it should be highlighted that BSE and DEH represent the data management system and therefore the real heart of the data management software block, while the ACS APIs frame this block representing a vertical solution, allowing data secure exchange and secure communication between data management services APIs.

The diagram in Figure 36 below is revised and improved with respect to its initial version in Deliverable D3.1. It brings together all above concepts, i.e., entities, information and their interactions within DEMETER processes, in order to structure the data flows between them.

[37] https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html
[38] https://www.json.org/json-en.html
[39] https://www.mysql.com/

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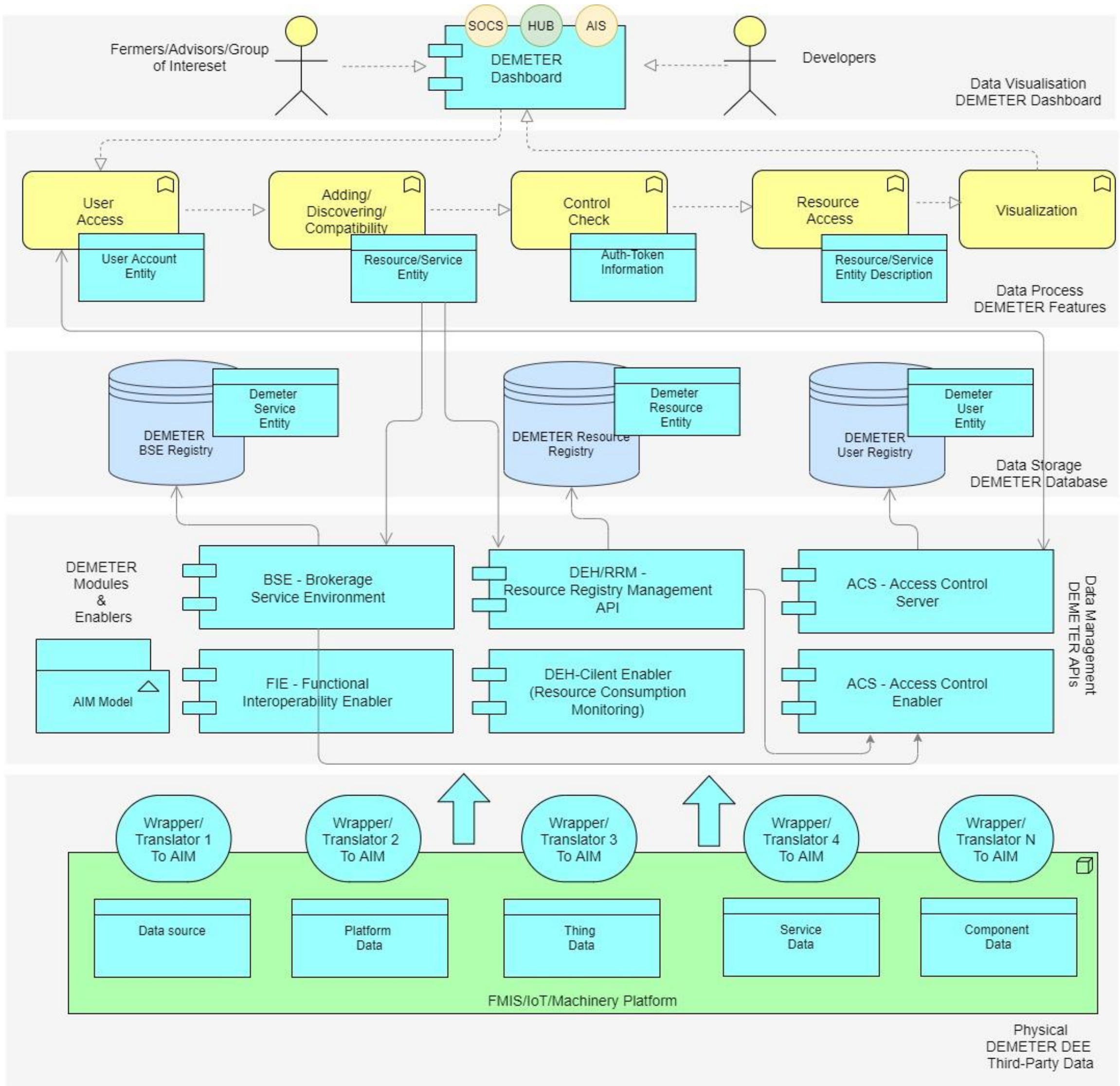

Figure 36. DEMETER Main Data Flows (Second Iteration D3.3)

Any third-party resources or DEMETER-Enhanced Entities (e.g., thing, platform, service, component), which can feed DEMETER with its own data, communicates with DEMETER data management APIs for data acquisition. Specific wrappers/translators on the physical layer on the data providers side, deals with translating the raw data that are not compliant and not aligned with the DEMETER AIM model. This allows support for data interoperability by combining the use of a semantic data model (AIM) with the respective data translation/management mechanisms, even in case other standardized solutions are used by the DEMETER stakeholders.

To enable full interoperability between heterogeneous data modelling/semantic approaches, DEMETER provides the necessary structures to support data transformation and data exchange according to the AIM format. The translated and semantically aligned data can then be used as services. The BSE and DEH modules represent the data management block that allows for data injection from heterogeneous data sources into DEMETER. The data management APIs are integrated with the ACS service, to enable the usage of data security policies. The ACS is highly significant in potential integrations with other platforms or infrastructures that intend to exchange data with DEMETER representing the starting point of interaction with the DEMETER infrastructure, paving the way for possible and future DEMETER platform integration and potential collaborations with other research projects as well in a secure manner. Once the injected data is securely stored inside the DEMETER database, the data can be used by the other DEMETER enablers (e.g., advanced enablers) through APIs usage. This information can be provided across the DEMETER architectural layers by making use of the APIs. So, e.g. for the visualization enabler and dashboard, corresponding information can be provided if the end-user needs to discover new resources available within DEMETER. The data are processed internally through specific operators, interfacing the dashboard view (UI) with the backend components of DEH (services layer) or Resource Registry Management APIs. The data are encapsulated as a DEH resource, and the metadata of each service, object, application, platform are made available through the BSE APIs. These BSE APIs are then used to feed all business processes and satisfy all use case scenarios defined in the project.

Finally, ACS Access Control and DEH-Client core enablers represent software facilities that should be used at the Pilot side: the first one allows the secure communication of data, while the second one enables gathering of resource consumption metrics and reports back the data to DEH. The ACS Control enabler provides the libraries to interact with the Access Control Server module and to encrypt the data when this data is transmitted over an insecure communication channel. Additionally, the DEH Client provides a client interface for the DEH and resource monitoring at Pilot environments basing its logic on extracting consumption metrics from Docker containers.

9.5 Deployment View

The **Deployment view** depicts the system from a system engineer's point of view. It is concerned with the topology of software components on the physical layer as well as the physical connections between these components.

In DEMETER we identified the nodes that will be present upon the run-time of and the execution of the entire system along with the components that participate, both internal and external ones. In the DEMETER's deployment diagram in Figure 37, the locations where the several software artefacts reside are depicted. It is also demonstrated that the interconnections between the participating nodes are internet-based.

DEMETER's reference platform includes the Dashboard which provides the user interface to the users and the developers and exposes the functionality of the other software artefacts included in the reference platform, SOCS and Enabler HUB.

FMIS/IoT/Machinery platforms can connect with the AIS to register and get access to DEMETER Enhanced Entities while, by utilizing their already deployed DEMETER Enablers (in containers), they provide access to their resources (services, apps, devices) and communicate among each other directly via the internet.

Since the last version of the Reference Architecture deliverable, the Deployment view has changed. Considering the needs of the various stakeholders in DEMETER, an update was necessary to better capture cases where Agricultural Interoperability Space contained modules are deployed on pilot premises. Also, in the updated version of the Deployment view, DEMETER Enhanced Entities (DEEs) and modules such as the Brokerage Service Environment (BSE), Access Control Server (ACS), and Functional Interoperability core enabler (FI) are included and placed in relation to the rest of the modules.

As depicted in Figure 37, AIS is capable of including cases where part of its functionality and modules are deployed on pilot premises.

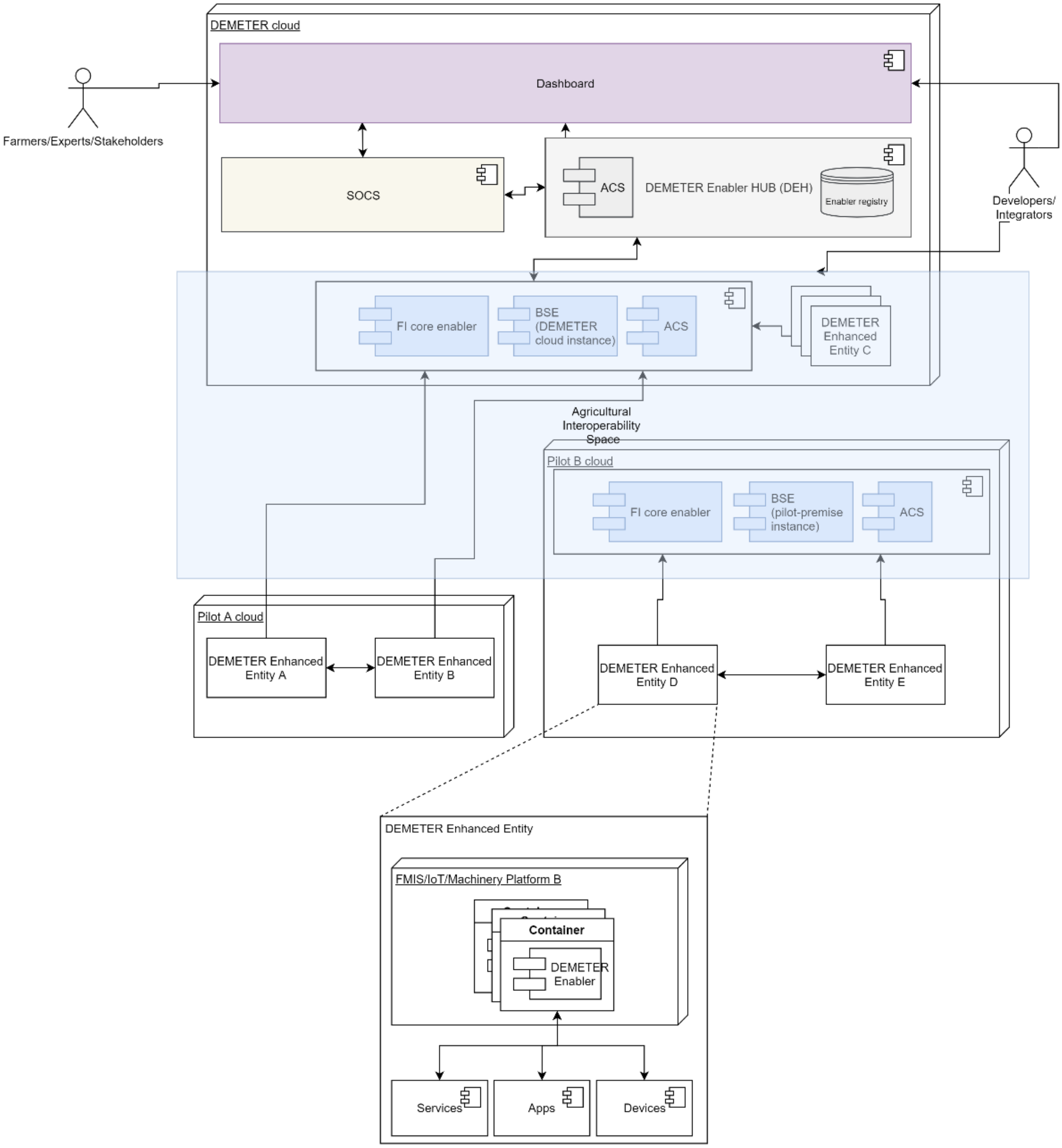

Figure 37. DEMETER Deployment diagram (Second Iteration D3.3)

9.6 Business View

The process view follows the incremental approach by identifying in this second iteration (D3.3), changes and alignments with respect to the first version (D3.1). This view has been heavily revised and enriched compared to its initial version, referring perfectly to the definition model on which it is based. In fact, from the point of view of the methodological approach that influenced the design of the view itself, there are no critical changes to underline. The logic used to conceive the DEMETER solution is still valid considering the business processes point of view. The model used and based on business process management continues to consider fundamental aspects such as users, data, functions and processes as the main inputs for the definition of any use case in DEMETER. The correlations between these aspects contribute to the definition of this view considering the business processes that it manages, serving as the enabling factors of the architecture.

This version of the Reference Architecture also takes into account the fact that the iterations between DEMETER stakeholders and processes will undergo changes over time, considering a whole series of dominant factors, such as sudden changes in the context, applications and technological scenarios in continuous evolution. Technologies and hence solutions could change and consequently affect this vision. The previous version of this view has been enriched with a few more elements, but the basis of the processes remains practically the same. The views proposed in Figure 38 present aggregated business processes extracted from the DoA and consolidated through the requirements depicting the real process vision of the DEMETER reference architecture.

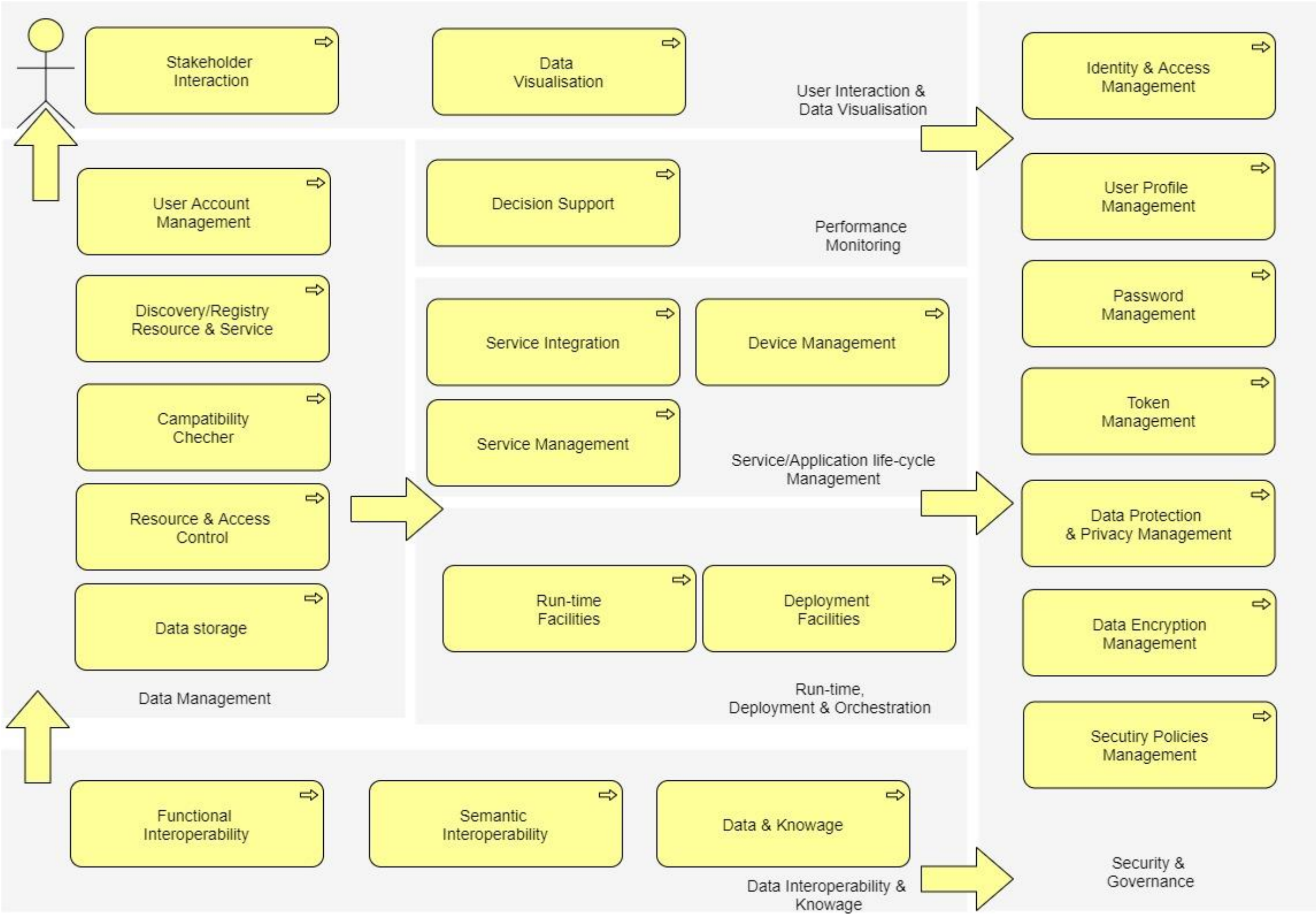

Figure 38. DEMETER Business Processes in the Reference Architecture (Second Iteration D3.3)

Only the changes compared to the first version in D3.1 are reported and described in detail below. The aggregated view of **Discovery, Provisioning & Resource Management** has been merged into **Data Management**, as it was considered better to contextualize and identify the business functions that have the greatest impact on the data (both collected and processed) by making them flow into a container or group of processes closest to DEMETER's business vision. Furthermore, it was decided to enrich the group of processes of the **Security & Governance** aggregated view, sometimes changing the name of the process itself to better contextualize the group in the DEMETER context. The new processes in this aggregated group turn out to be: **Password Management**, **Token Management**, **Data Protection & Privacy** and finally **Data Encryption**.

Finally, the aggregated view of Communication & Networking processes was integrated and better contextualized in the **Security & Governance** view as its processes were to be considered related to the encryption of data in the communication between services and therefore included in the Data Encryption Management group.

10 Revised Interfaces between main architecture components

The DEMETER Architecture is designed based upon the following pillars: interoperability, integration, adaptability, modularity, analytics, and decision support system. In general terms, modularity and adaptability is supported by exploiting the Microservices Architecture patterns and scalability is implemented to support both a cloud-based and on-premises approach.

The main software modules that support the visualization of all DEMETER results are further detailed in this document and grouped into two main layers: presentation and business layer. The first layer contains the modules that expose user interfaces such as ACS, DEH, BSE and SOCS, while the latter contains the main DEMETER core enablers such as Functional and Semantic Interoperability enablers, DEH-Client for resource consumption monitoring, and security-related facilities such as Access Control Enabler.

This section presents the main interfaces of the DEMETER-based systems, highlighting the differences, the updates between D3.3 and D3.1. Having a complete view of the main system interfaces allow addressing the concerns of various DEMETER stakeholders, mainly business and technical partners that, on one hand, want to create a system that is technologically capable of demonstrating the execution of the DEMETER pilots but, on the other hand, want to provide solid foundations for integration with other existing systems, important projects in the Agri-food domain or relevant initiatives, such as GAIA-X. The main interfaces between the main architectural layers are designed based on these assumptions, that is to provide an overall view that is closer to reality and the application context in which this view is located.

The DEMETER main interface view is designed using an iterative development process, dealing with the design and implementation of a high-level structure based on the first project outcomes. It is the result of assembling a certain number of modules in some well-chosen forms to satisfy the main systems functionality requirements. First, almost all modules contain interfaces or APIs that are able to communicate with other DEMETER systems. Therefore, when the software modules become interoperable by exposing standard APIs and sharing the DEMETER AIM information model, then they are able to communicate with other systems/services via remote interface or, via a web interface, with humans. Within the DEMETER information network, these modules are more mature and able to integrate perfectly, even in a changing and dynamic environment, using these interfaces designed and implemented for this purpose. Furthermore, proceeding with the integration by the DEMETER pilots, it becomes clear that DEMETER main modules are truly scalable, instead of being simply centralized or cloud based. The information is exchanged between them, without the explicit need to use centrally stored data. Furthermore, management processes and decision making are controlled using defined interfaces. Finally, the complete adoption of these interfaces by the pilots is going to optimize the response time of developers (eg for required adjustments). These modules will thus be able to extend their field of action within different infrastructures, even if they are not centralized in the cloud but rather locally deployed in the pilot infrastructures. Since the DEMETER infrastructure layers represent essential software modules and technologies for the technical demonstration in each Pilot, the dynamics of these processes will be accelerated, and also the adoption of their main interfaces.

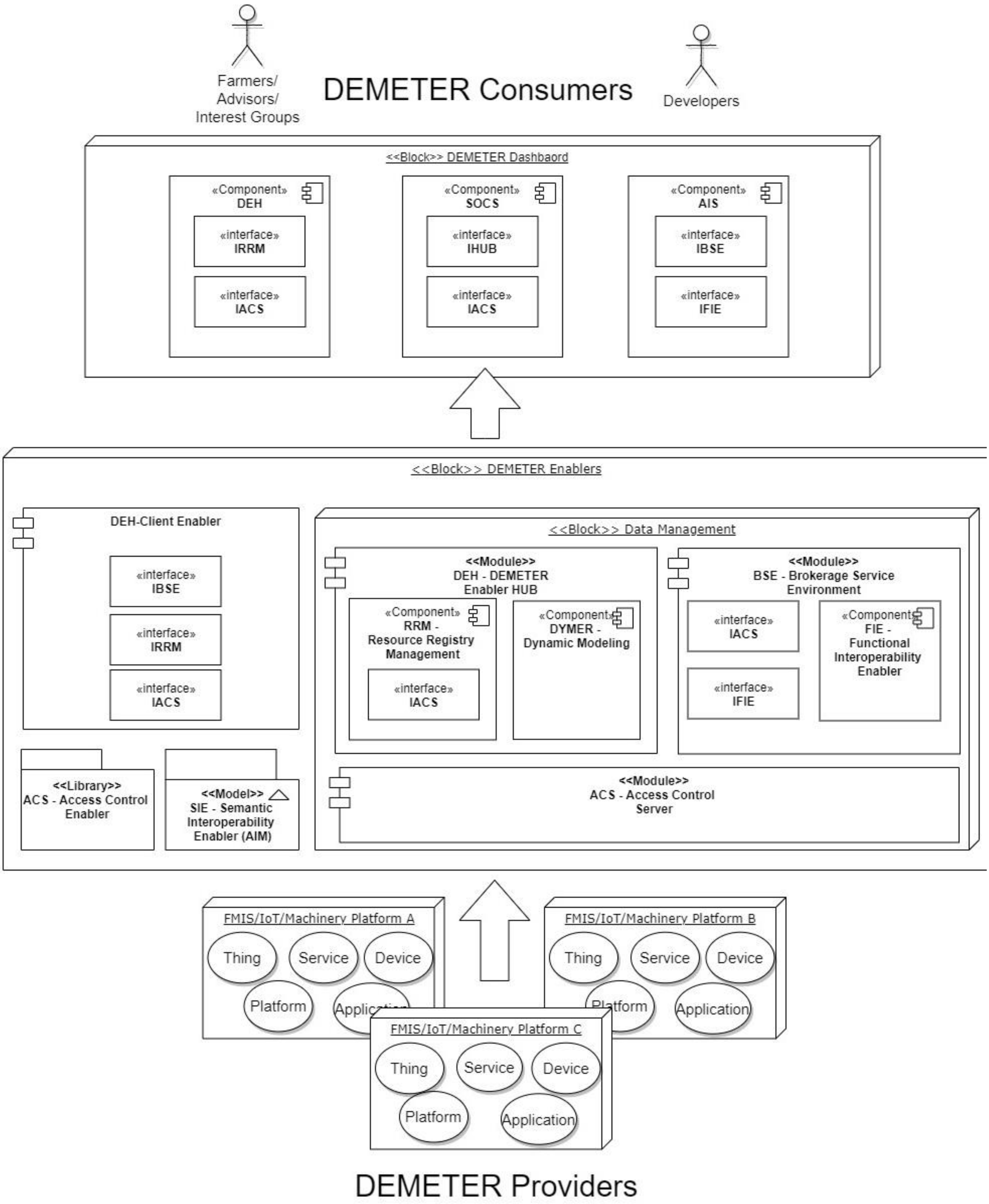

Figure 39. Main Interfaces between DEMETER's main component blocks (Second Iteration D3.3)

Compared to Deliverable 3.1, this view contains a greater refinement. The main blocks or architecture layers have been consolidated, as well as the modules inside them. The main interfaces between the blocks before and between the modules have been refined and better modelled. The proposed view in the image above (Figure 39) shows the changes made so far using the iterative approach. It provides a clearer perspective, especially regarding the main interfaces of the system.

Mainly the changes to this view involved some refinement on the real modules and more contextualized blocks, as opposed to a more high-level approach occurred in D3.1, which had considered more the functional aspects of the architecture and less the technical ones, the latter being much more mature at this stage. It is worth emphasizing that deviations or misalignments with D3.1 are to be considered minimal, demonstrating that the DEMETER architecture has been designed correctly, considering the blocks that would actually take part in the business and logic processes. However, since the solution is more mature, the macro-blocks defined in this iteration represent and constitute the final solution.

The Dashboard block is the highest level of the DEMETER architecture, which implements the interfaces that interact with the main backend software modules. DEMETER main software modules are represented by: SOCS DEH and BSE; in addition to those already described, the Dashboard block will also support the DSS visualisation dashboards, as part of WP4 activities and more precisely of T4.3. It is important to add this detail, as the output of the T4.3, or framework on the DSS visualization, represents another component that will contribute to the whole DEMETER visualization solution, managing the visualization of the DSS pilots.

The implementation and instantiation of the main interfaces will enable a set of operations: these include the co-creation process via SOCS, the discovery of new DEMETER entities via DEH and the possibility for developers to assemble new components through the AIS application. The Dashboard enabler also supports the visualization of data in user interfaces or web GUIs, enabling a full range of standard data formats in web-based applications. The Dashboard UI (e.g., User interface) has the dual objective of conforming to backend services formats, but also to provide the necessary data to the web interfaces in a useful format for web interoperability. In addition, each visualisation dashboard exposed via DEH or SOCS has specific web user interfaces to perform a specific task, as was already extensively described in D3.1.

The DEMETER core enablers will essentially provide support to all DEMETER Stakeholders to produce or consume data, providing a set of necessary APIs to support basic operations like data acquisition, data retrieval, data management and storing. The business logic functions, contained in the enablers and exposed through APIs REST framework, cover most of the functional and non-functional requirements defined at the beginning of the DEMETER project. Obviously, these business functions will be further refined, improved, and enriched over time, until the end of the project, ensuring continuous integration and continuous delivery. By adopting this method, in addition to cover the project milestones which in each case support at most two releases of these enablers, continuous releases of new versions will be envisaged (reasonably until the conclusion of Pilot Round 2) which will meet the changing business needs, covering requirements dissatisfied or mitigating incorrect behaviour of the individual software blocks. Some DEMETER enablers (core enablers, Semantic Interoperability enabler, Functional Interoperability enabler, Access Control enabler, DEH-Client) need to be adopted by all DEMETER Pilots and, more generally, by third-party data providers who intend to share and exchange data with DEMETER. The mandatory nature of these enablers translates into on-premises installation or use through the cloud in perspective of SaaS (Software as a Service) solution. The integration of data and sharing of service resources like components, things, services, devices, platforms, or applications (so that consumers can discover new resources according to their business needs) will only be possible through the main DEMETER enablers interfaces. The main interfaces in this block are represented by the DEH Resource Registry Management APIs, DEH Client, BSE, ACS, ACS Enabler or ACS client library, FIE or Functional Interoperability Enabler. The DEH, BSE and ACS modules use REST interfaces to interact with each other, while a component like SPE is just a library that requires to be added within the source code in order to be integrated. The core block communicates with the data providers via the DM or Data Management framework APIs; the latter consist mainly of API frameworks of DEH, ACS and BSE allowing interconnection through its interfaces with the more sophisticated DEMETER enablers. Thee enablers are represented by data analytics components or DEMETER advanced Enablers currently under development in WP2/4 WPs (more details on the functionality of these enablers will be provided in deliverables D4.3 and D4.4). The rest of the DEMETER's advanced enablers also use these APIs, to primarily discover DEMETER enabled resources or simply to use core services as in the case of the BSE interface.

11 Mapping of the related State-of-the-Art approaches to the revised DEMETER Reference Architecture

This section presents details on how the evolved state of the art related initiatives can map to the revised DEMETER Reference Architecture.

11.1 European Strategy for Data

DEMETER is compliant with this data strategy as will be discussed in more detail in the rest of this section and, in particular, in the next two subsections, which cover respectively GAIA-X and the common EU Data Space. To sum up, the DEMETER Enabler Hub can be used to register any enabler, including those that just provide data from sensors, or processed data from data analytics enablers and this allows DEMETER Research Architecture to be compliance with the European strategy for data and the related initiatives currently in progress.

11.2 GAIA-X

Figure 40 shows the combined GAIA-X/IDS reference architecture extended with the corresponding DEMETER elements for the DEMETER Interoperability Data Space and the DEMETER Data spaces with the supporting elements of Federated Identity, Federated Catalogue – and supporting Agricultural Vocabulary and Agricultural Information Model, (AIM).

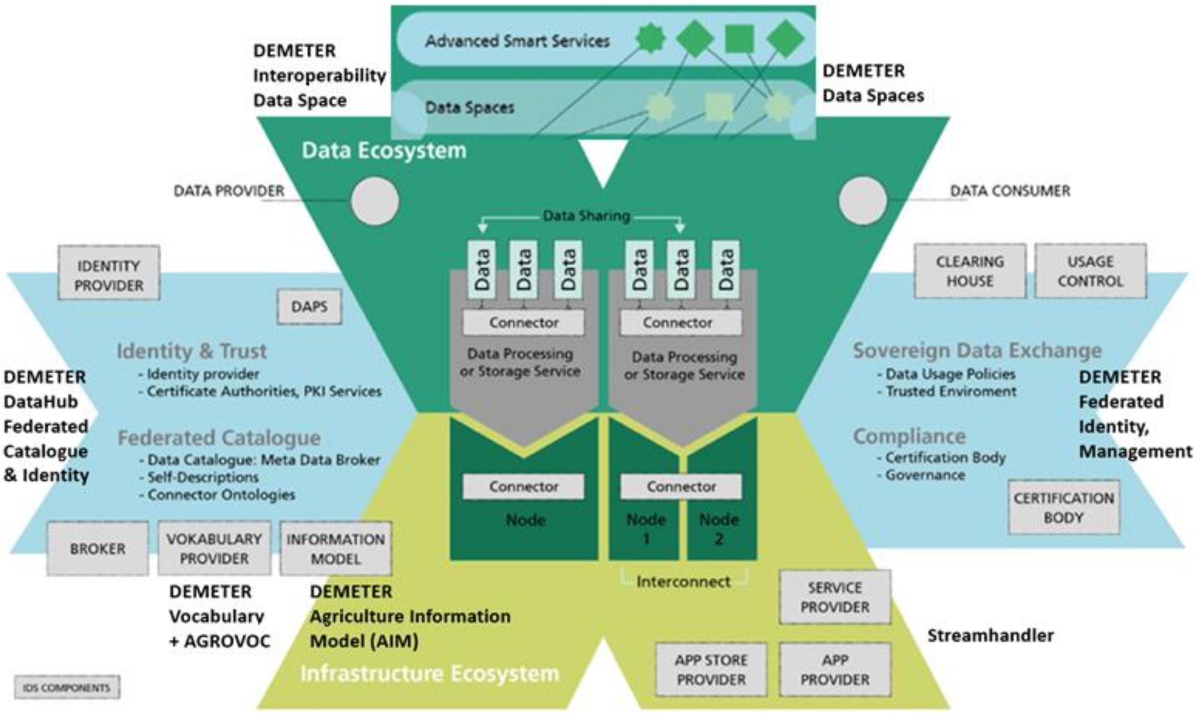

Figure 40. GAIA-X with IDS elements and relationship to DEMETER technologies

The combined architecture of GAIA-X and IDS, as depicted in Figure 40, supports and enables data spaces and builds advanced smart services in industry verticals. GAIA-X focuses on sovereign cloud services and cloud infrastructure, while IDS focuses on data and data sovereignty. The interaction of

GAIA- X and IDS has three main tasks: self-sovereign data storage, trustworthy data usage and interoperable data exchange. This way, GAIA-X is developed per the European Data Strategy and supports smart data applications and innovations across industry sectors. For this purpose, GAIA-X and IDS complement each other to ensure cloud and data sovereignty for end-to-end data value chains in federated ecosystems. The four Federation services are also corresponding to various IDS concepts: A key element is the GAIA-X Federated Catalogue, which uses the IDS Broker, Vocabulary Provider, and Information Model. The Federation Service of Sovereign Data Exchange is represented by the IDS Clearing House and Usage Control concept. Further, the GAIA-X Federation services of Identity & Trust and Certification can take advantage of the IDS Identity Provider and IDS Certification Body.

The DEMETER Architecture with the DEMETER Provider and Consumer approach follows the same pattern as the GAIA-X/IDS architecture and is, in principle, compliant with this approach – with additional extensions.

11.3 Common European Agricultural Data Space

While there is no final vision for the common European Agricultural Data Space, we look to Figure 5 and Figure 6 and the information that has been circulated so far about the Common EU Agricultural Data Space in order to check that the DEMETER RA is compliant and could be used to implement the key concepts of this initiative.

First, comparing the DEMETER high-level and functional views, we immediately notice that DEMETER, as designed, can include all the sources of agri-data mentioned and in fact can make them interoperable through the DEMETER AIM provided that the appropriate data wrappers/translators are developed. Furthermore, most of the actors (farmers, app providers and developers and advisors) are included in our high-level view (see Figure 27). The dealers and contractors could be represented in the DEMETER view by the advisors and app providers, who also double as contractors putting together enablers and data in order to provide a final DEMETER enabled complete application.

Looking at the view provided in Figure 27, it can easily be observed that DEMETER is also compliant with this vision provided that the following mappings are made.

First, regarding the functional view of the RA, the service platforms/solutions correspond to the app layer in DEMETER; the data sharing infrastructure corresponds to the Interoperability space and the enablers provided and accessible through it and the DEMETER hub; the cloud/edge infrastructure is also present in the DEMETER RA and finally the devices sit at the bottom of the architecture in the DEMETER RA as well. Therefore, overall, DEMETER is highly compliant with the general architectures required for the common EU Agri-data space.

Second, the essential trust services of the architecture are mostly implemented in DEMETER by the DEMETER Enabler Hub (DEH). The registration and discovery of enablers (data, services, apps etc.) which are key parts of the DEMETER hub, correspond to the Clearing House of the Agri-data space vision, as also assisted by the remaining modules of the DEH (e.g., accounting, discovery control, compatibility). To elaborate further, the DEH provides functionalities for compatibility checking which loosely corresponds to the certification requirements envisaged, the dynamic trust management corresponds to features of the DEH such as the Resource Access Control changing the Discovery Management process.

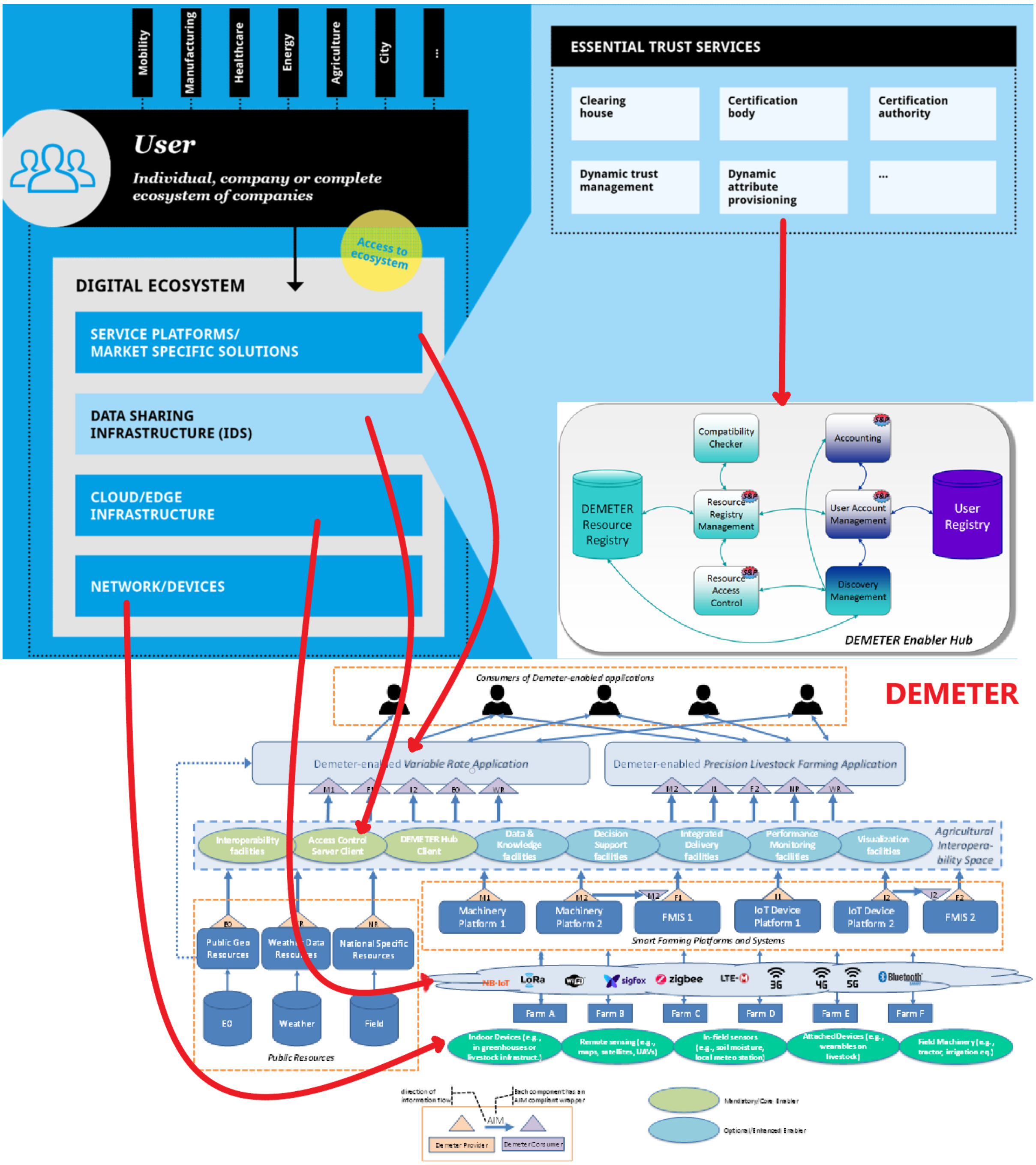

Figure 41. Mapping of the DEMETER RA to the IDSA view for implementing the common European Agri Space

Thus, the DEH can be used to register any enabler (data from sensors, or processed data, analytics and decision support services and visualization) which can then be contracted as needed and this allows DEMETER Research Architecture to be compliance with both the European strategy for data and specifically with the common European Agri Data Space as currently envisioned.

11.4 The AI4EU approach

AI4EU project [AI4EU] aims at the creation of an environment that allows developing AI based solutions, providing tools and infrastructure to do so. Additionally, it is expected to offer a catalogue of already developed solutions as well as a platform to foster cooperation and community creation.

When analysing in parallel both AI4EU and DEMETER reference architectures, we can see some similarities (and different approaches). Both architectures (in their latest version) include some components surrounded and linked, which are used to point at some of those similarities. Both architectures include catalogues (green boxes) where each platform stores and offers different solutions developed (AI4EU also aims at offering datasets). Besides, we included the external public resources in a green box as they might be added in the platform through a component developed for the DEMETER ecosystem.

Although the matching between the orange boxes linked in both architectures might not be direct, they highlight the way that some functionalities have been addressed in both ecosystems. While in DEMETER there is a set of mandatory enablers that have to be considered by any development to be carried out in DEMETER (to ensure interoperability, security, and component offering), AI4EU has designed some layers to address some of those issues, such as the security or the search layer. Nevertheless, DEMETER also provides components to perform search over the enablers in the ecosystem and to manage the identities of the users.

Another important aspect to compare in both architectures is the infrastructure resource offering (surrounded by blue boxes). In the DEMETER project the infrastructure is provided by the end-user (pilots), offering more flexibility, and allowing the end-user to choose (and provide) the infrastructure that better fits its needs. AI4EU project provides instead technical infrastructure resources (provided by AI4EU consortium partners) for the development and execution of the solutions in the ecosystem. Additionally, those components might be exported and run as docker images.

As we can see in the architecture comparison, one of the main differences in the creation of the ACUMOS platform in the AI4EU project, providing an environment for the development of AI-based solutions, facilitates the integration of these solutions thanks to the use of that common environment. In contrast, DEMETER does not provide that resource, but that lack of a common development platform might increase the flexibility of the solutions generated in the project, easing a fine-grained deployment in the pilot infrastructure (however that might affect the generalization of the solutions developed).

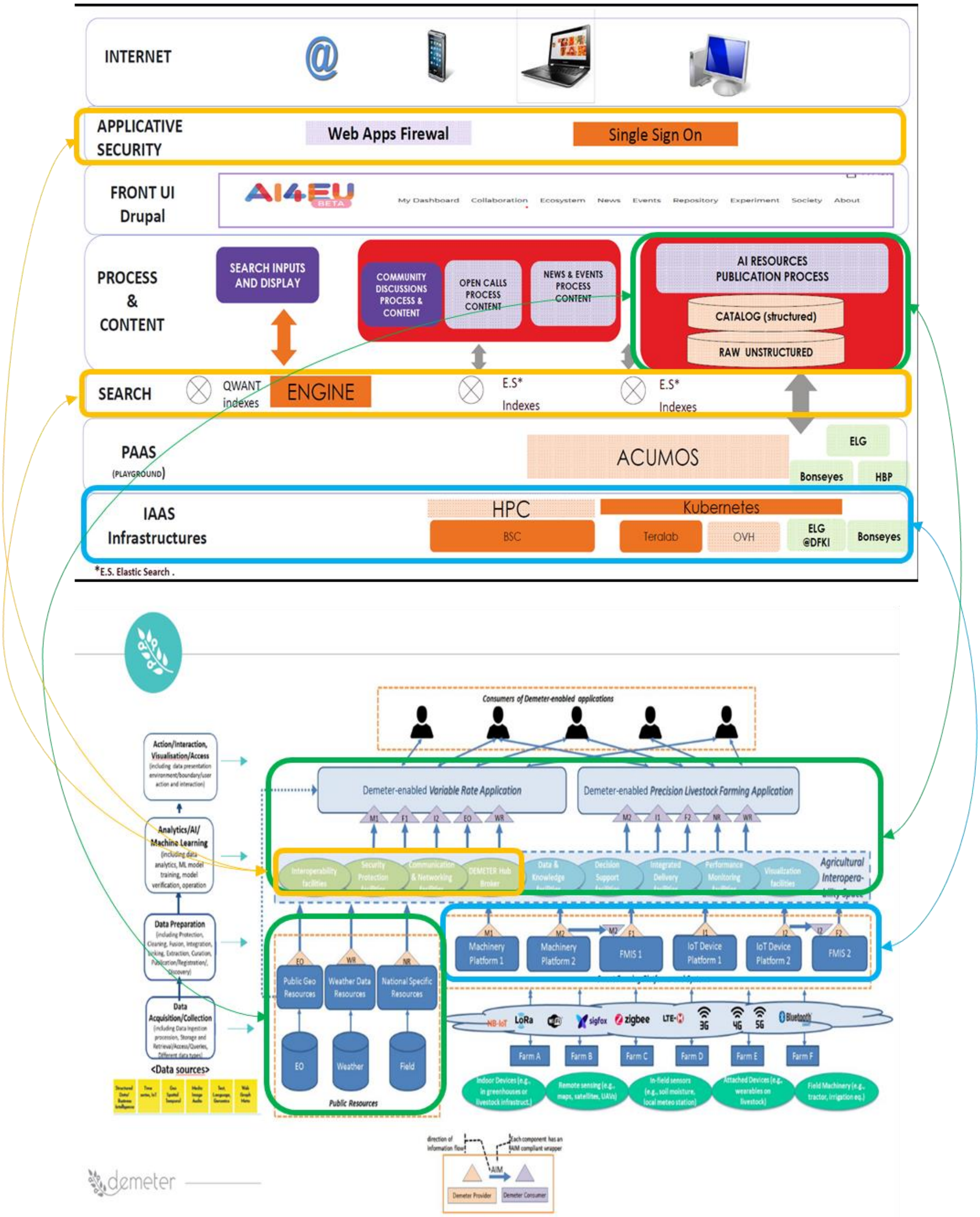

Figure 42. AI4EU (top) and DEMETER (bottom) infrastructures similarities

11.5 DataBench - Big Data and AI Pipeline Framework - related to BDVA and DAIRO models

The figure below illustrates how the DEMETER reference architecture maps directly to the Big Data and AI pipeline steps. There is a clear mapping of DEMETER RA blocks to the four main DataBench layers, as the Data Acquisition & Collection functionality of DataBench is handled by the lower layers of the DEMETER RA, the Data Preparation layer functionality of DataBench is handled by AIM and the DEMETER Data Management facilities, the Analytics/AI/ML layer of DataBench is mapped to the DEMETER Knowledge and Decision support facilities and, finally, the Action/Interaction/Visualization/Access layer functionality of DataBench is handled by the DEMETER BSE, as well as the Visualization & Performance monitoring facilities. These mappings are presented in the following figure:

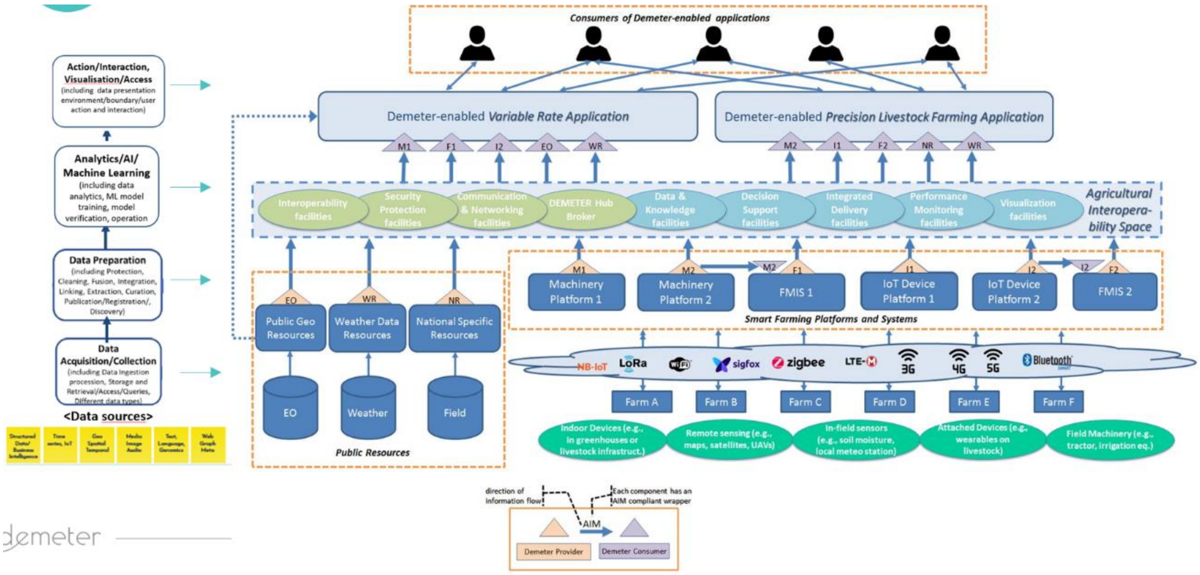

Figure 43. Mapping of the Big Data and AI pipeline steps to the revised DEMETER reference architecture

11.6 Minimal Interoperability Mechanisms (MIMs) – OASC – Synchronicity - dRural

The following figure shows the mapping of the three core MIMS mechanisms to related elements in the DEMETER architecture.

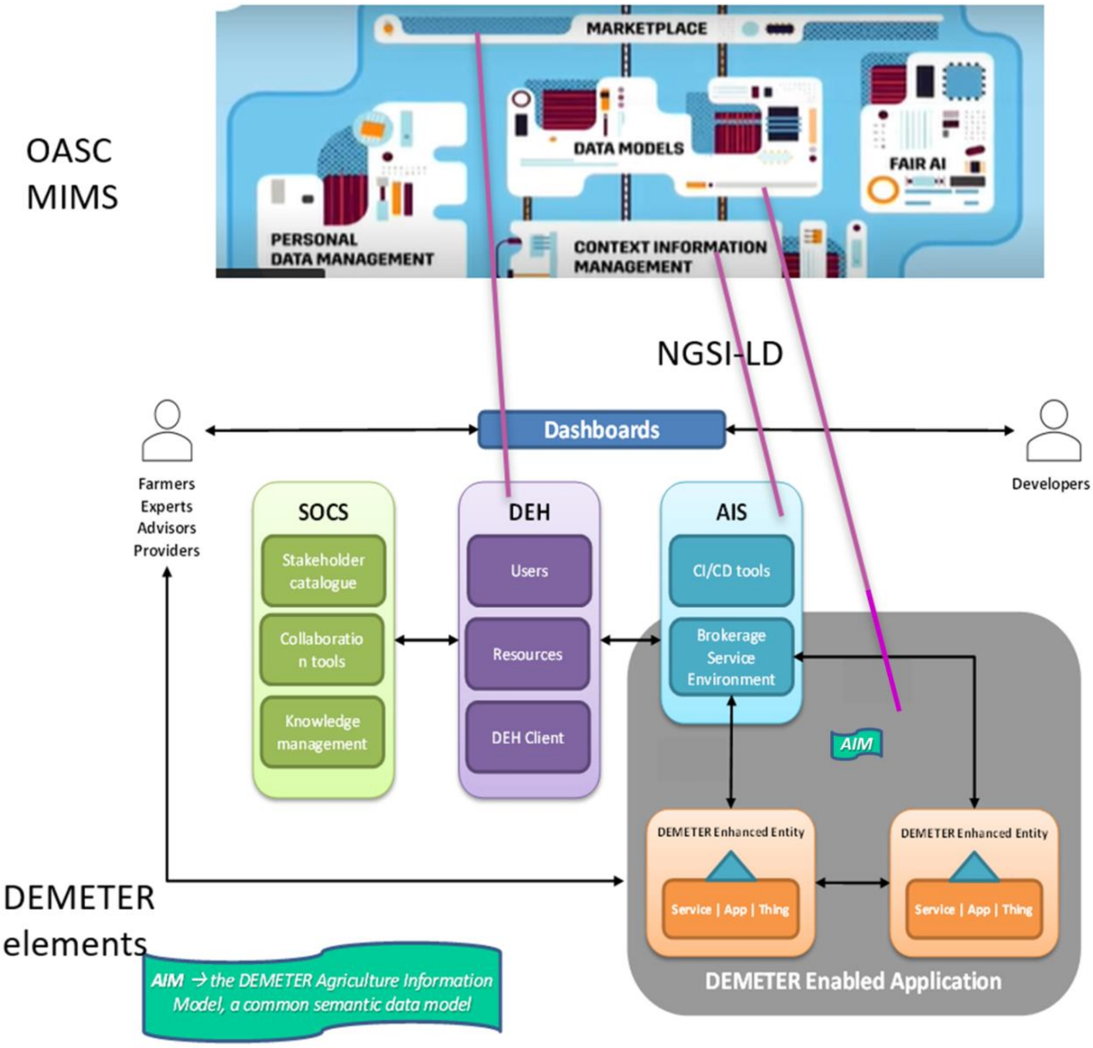

Figure 44. Mappings between OASC MIMS mechanisms and DEMETER elements

Table 4 describes the related DEMETER architecture elements for the mapping to OASC MIMS mechanisms. There is a common approach with the use semantic technologies with the NGSI-LD ETSI standard and potential use of implementations of this, such as the FIWARE Context Information Management technologies. Similarly, the Shared Data Model approach is aligned also with the modelling approach connected to the use of NGSI-LD also in DEMETER. Both approaches also support a marketplace ecosystem. There are variations in the implementations for this, but also a set of similarities which could be explored.

Table 4. Mappings between DEMETER elements and MIMS areas

Interoperability Point	**DEMETER**	**OASC MIMS**
Context Information Management API	AIS – Agriculture Interoperability Space with NGSI-LD support	OASC Context Information Management MIM

Shared Data Models	AIM – Agriculture Information Model	OASC Data Models MIM
Marketplace API	DEH – Digital Enabler Hub + Brokerage Service Environment (BSE) - with Access Control Server (ACS)	OASC Ecosystem Transactions Management MIM

Other MIMS proposed areas like Personal Data Management and Fair AI have not been focused on in DEMETER, but there might be synergies with these areas in the future. Some elements of personal data protection might also be relevant for farmer's data protection, and also Fair AI is relevant in the context of the Machine Learning based decision enablers and components within DEMETER.

11.7 CEF Digital: Connecting Europe Facility

CEF provides 3 Building Blocks that are aligned with DEMETER Architectural Framework: Context Broker, Big Data Test Infrastructure (BDTI) and eArchiving.

DEMETER bases semantic data interoperability on the AIM model, the management of context information and data translation mechanisms to standardised solutions such as NGSI-LD, Saref4Agri, etc. Context management is performed using the Context Broker from FIWARE as in CEF.

CEF Big Data Test Infrastructure offers a catalogue of datasets and open-source analytical software tools. Similarly, the DEH of DEMETER offers a catalogue of resources (including the aforementioned) but specifically for the agri-food domain and use cases. Besides, CEF provides a Big Data platform for IT practitioners to experiment with pre-built data analytics tools. In the same way, the DEMETER RA follows the principles defined by BDVA and NIST [NIST] architectures to provide Big Data analysis.

Finally, CEF eArchiving provides a secure infrastructure (based on Public Key Infrastructure (PKI)) to reserve, migrate, reuse and share data securely, according to European standards. Analogously, for data sharing and service federation, the DEMETER Architectural Framework covers security at all levels, by means of the Data Security & Privacy core enabler which provides functionality for authentication, authorisation, traceability, and confidentiality.

11.8 OpenDEI – Reference Architecture for Platform Interoperability within and across sectors

In the figure below a mapping of the OPEN DEI Reference Architecture Framework to the layers of the revised DEMETER Reference Architecture is illustrated. As seen, the impact of DEMETER RA on the OPEN DEI RAF is evidently strong.

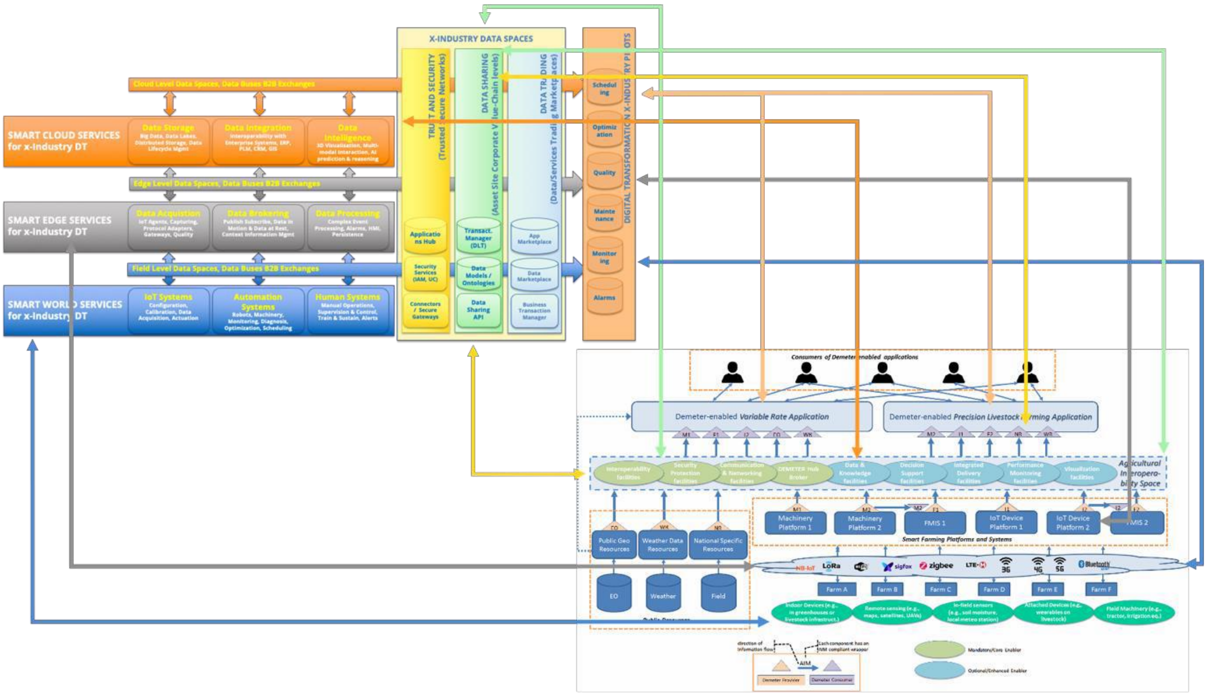

Figure 45. OPEN DEI RAF vs. the revised DEMETER Reference Architecture

Table 5. Mapping of OPEN DEI RAF to elements of the revised DEMETER Reference Architecture

OPEN DEI RAF	DEMETER Digital Platform
Smart World Services	“Indoor Devices”, “Remote Sensing”, “In-field sensors”, “Attached Devices”, “Field Machinery”, “FMIS”
Smart Edge Services	“Smart Farming Platforms and Systems” southbound agents (i.e. Lora, Sigfox, Zigbee, Bluetooth, 4G, 5G, etc.), and “Machinery Platforms”
Smart Cloud Services	“Decision Support facilities”, Integrated Delivery facilities”, “Performance Monitoring facilities”, “Visualization facilities”
X-Industry Data Spaces	“Public Resources” (for EO, Weather, Field information), “Data and Knowledge facilities”, “Security Protection facilities”
X-Industry Data Buses	“Interoperability facilities”, “DEMETER Hub Broker”, “Agricultural Interoperability Space”
Digital Transformation X-Industry Pilots	“Demeter-enabled Variable Rate Applications” and “Demeter-enabled Precision Livestock Farming Applications”

11.9 NIVA IACS Reference Architecture

NIVA project aims to provide SW components to test interoperability and data sharing capabilities between IACS and farmers through Farm Management Systems (FMS), Machinery, Field Books, Geo-tagged images, etc. where the Farm Registry Interface and Common Reference Data Model becomes essential. This Farm Registry Data Model has clear links with AIM adopted in DEMETER, as seen in figure below. Common harmonization efforts between DEMETER & NIVA are foreseen to explore how to better harmonize FMS interfaces with fewer efforts of investment from FMS providers, opening a wider market to EU ICT companies.

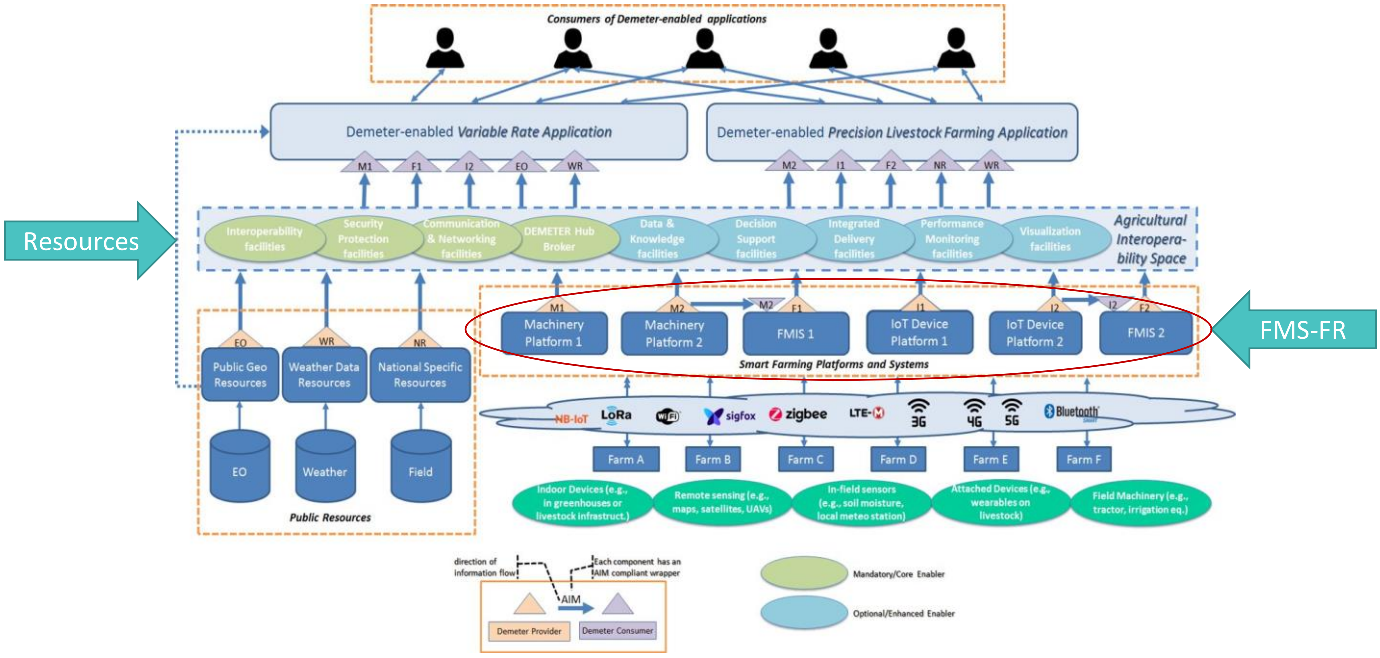

Figure 46. Mapping of NIVA to the revised DEMETER Reference Architecture

12 Revised Architecture Instantiations for the DEMETER Pilots

This section describes the instantiation diagram of the Revised DEMETER Reference Architecture presented in section 9 for each of the 20 pilots of DEMETER, illustrating the stakeholders, technologies, solutions and DEMETER enablers/tools used by each pilot. As many of the components of each instantiation are used by all pilots (i.e., mandatory, core enablers offered by DEMETER), it has been decided not to list them explicitly in the diagrams. These components are represented in the diagrams as the green ovals of the Agricultural Interoperability Space layer and will not be explicitly listed, unless there is a very specific requirement to be addressed (e.g., support for a given data encryption algorithm).

For each of the architecture instantiations presented in this section the specific RA elements used by the pilots are identified and recorded for all element categories below:

1. Pilot stakeholders/application end users;
2. Pilot applications;
3. Pilot-specific or optional DEMETER enablers that are required for the development of the pilot application (included in the diagrams as the blue oval shapes);
4. All existing platforms/systems/services to be engaged in the pilot. In case standardized data-models/semantics are used it should be recorded as a comment at the bottom of the diagram. If nothing is mentioned, it is assumed that vendor-specific data formats are used;
5. External (can be public or open) platforms/repositories used by the apps;
6. All networking/communication protocols to be used in the pilot;
7. The farms to be engaged in the pilots;
8. All HW, equipment, devices, machinery, etc. to be used in the farms.

The following subsections present the revised architecture instances for each of the DEMETER pilots.

12.1 Pilot 1.1 & 1.2: Water Savings in Irrigated Crops & Smart Energy Management in Irrigated and Arable Crops

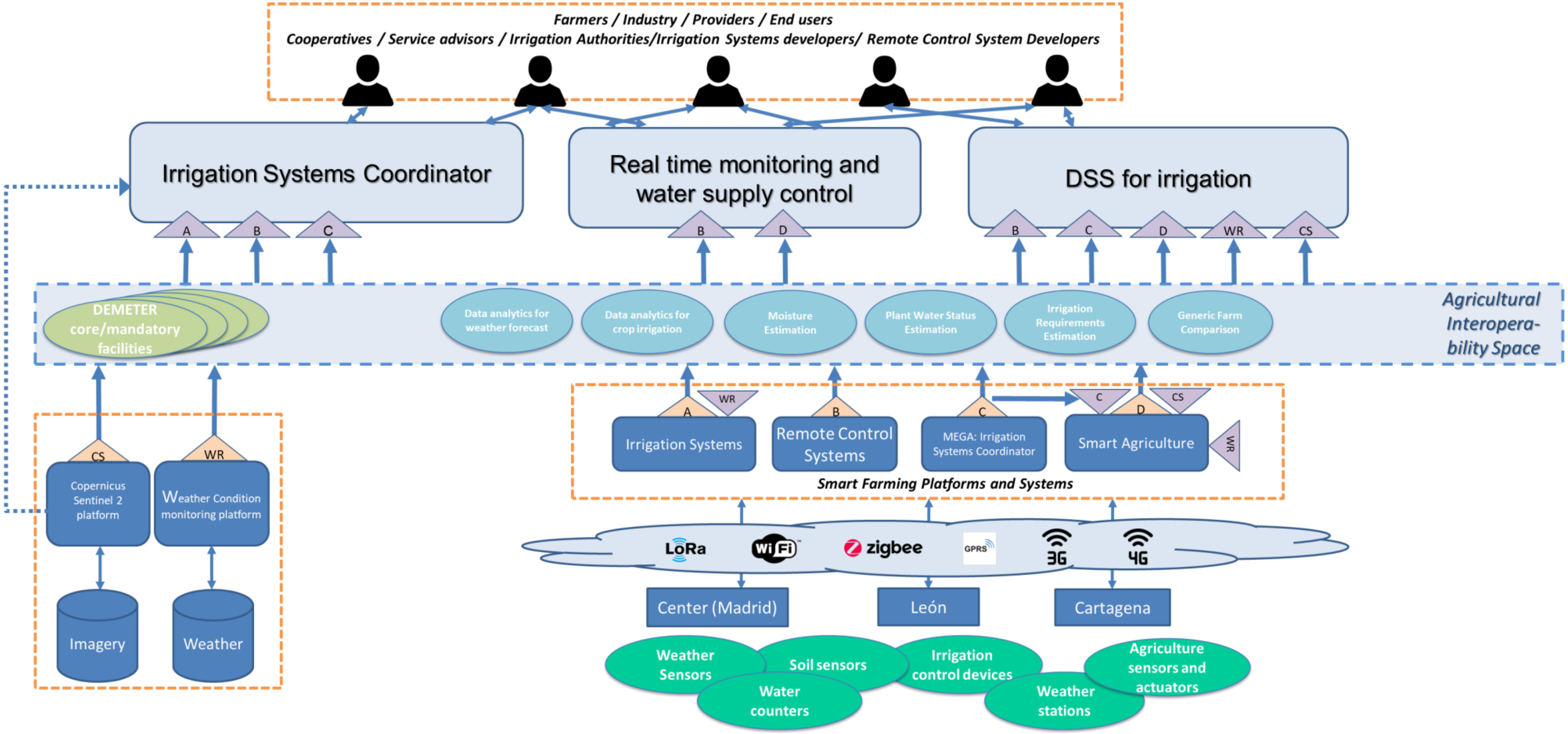

Figure 47. Pilots 1.1 & 1.2– DEMETER Revised Reference Architecture instantiation

12.2 Pilot 1.3: Smart Irrigation Service in Rice & Maize Cultivation

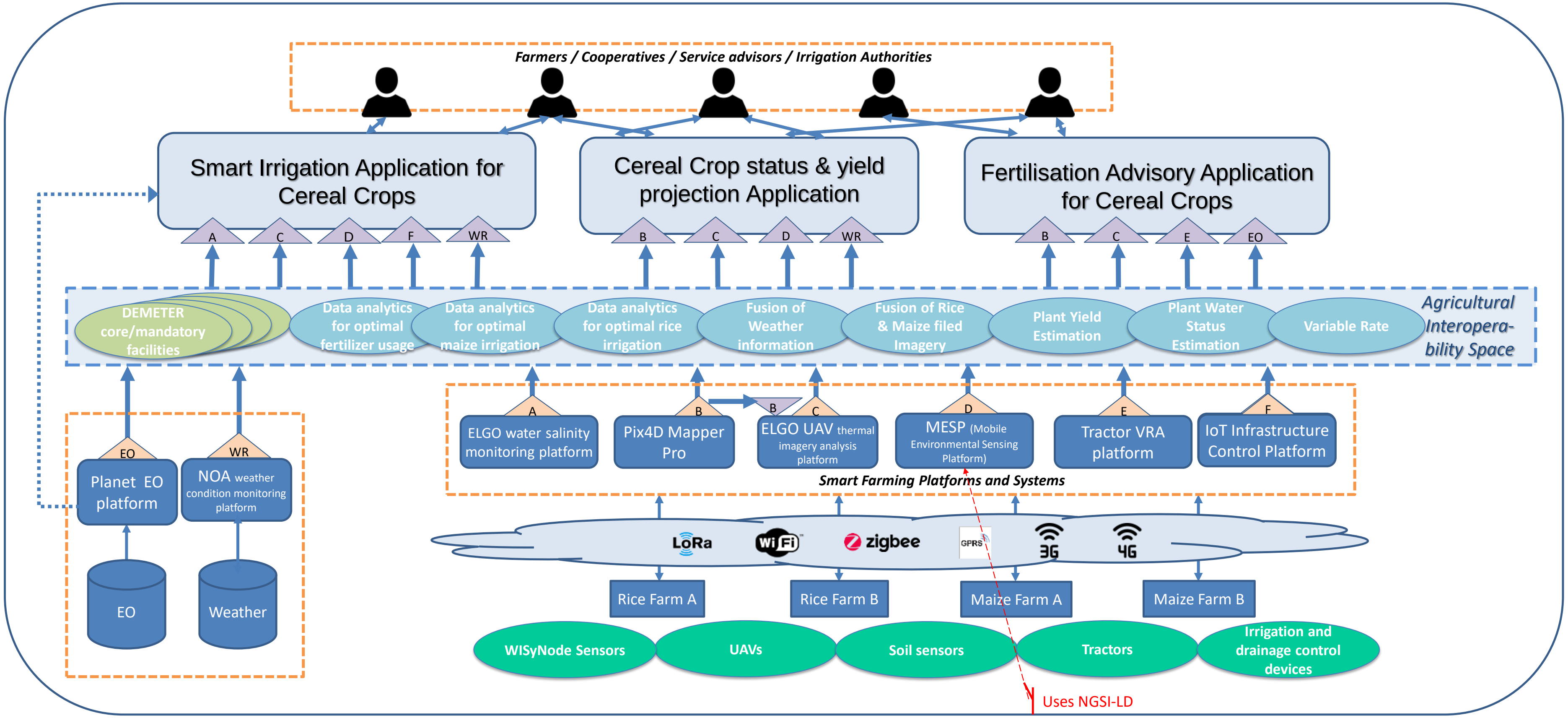

Figure 48. Pilot 1.3 – DEMETER Revised Reference Architecture instantiation

12.3 Pilot 1.4: IoT Corn Management & Decision Support Platform

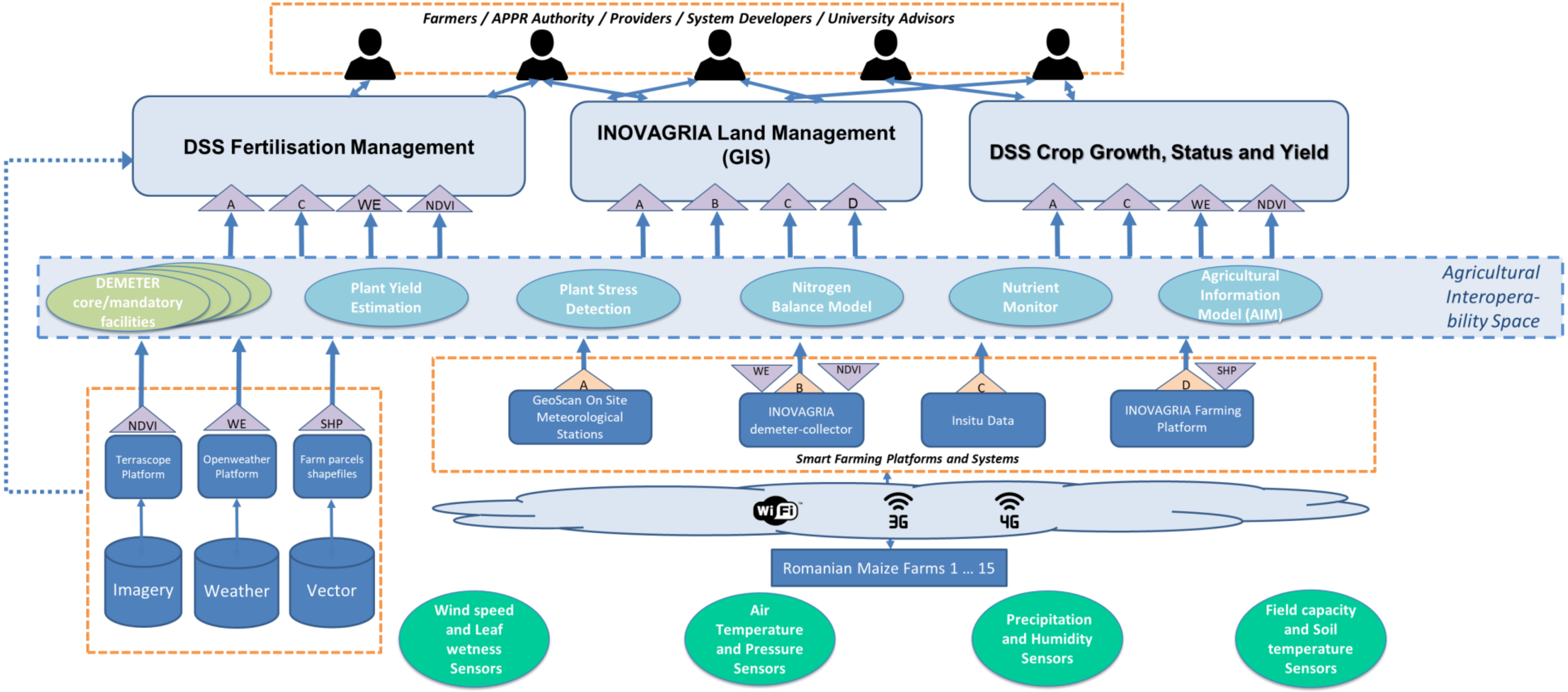

Figure 49. Pilot 1.4 – DEMETER Revised Reference Architecture instantiation

12.4 Pilot 2.1: In-Service Condition Monitoring of Agricultural Machinery

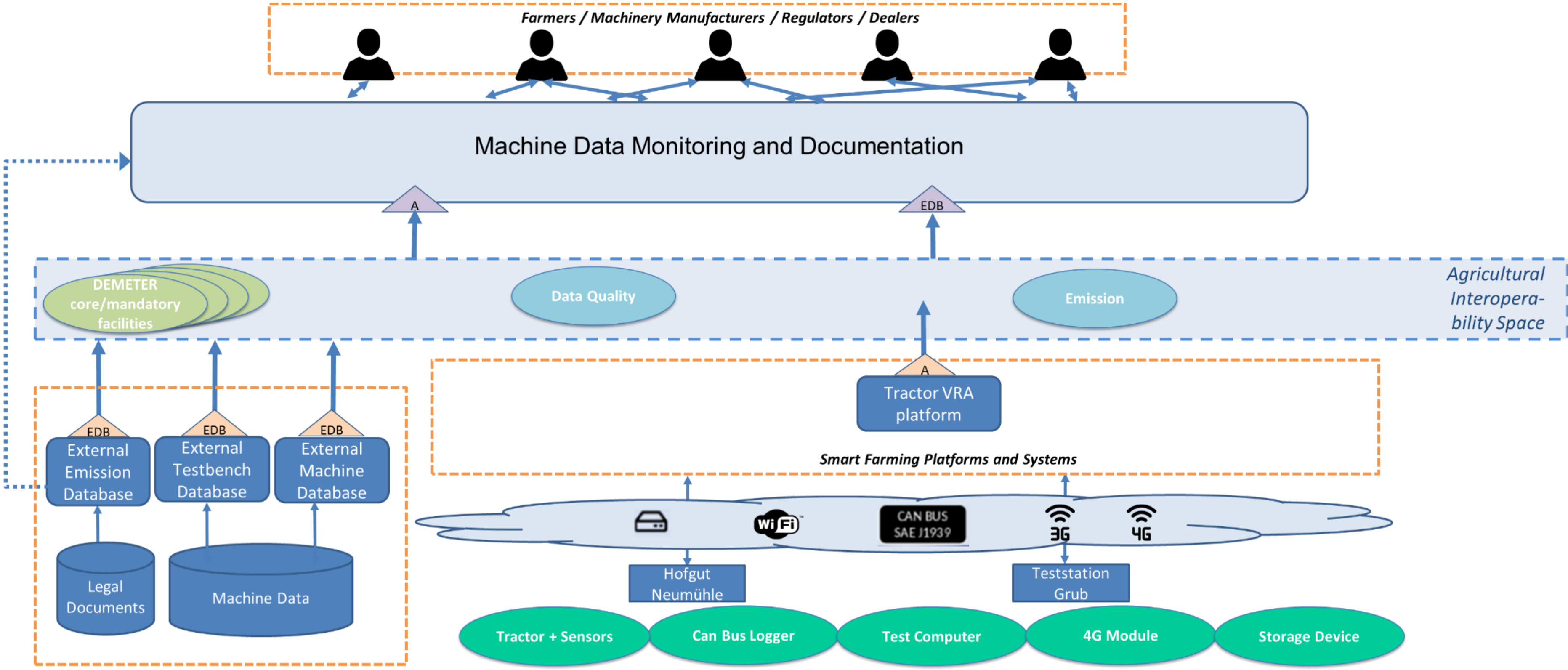

Figure 50. Pilot 2.1 – DEMETER Revised Reference Architecture instantiation

12.5 Pilot 2.2: Automated Documentation of Arable Crop Farming Processes

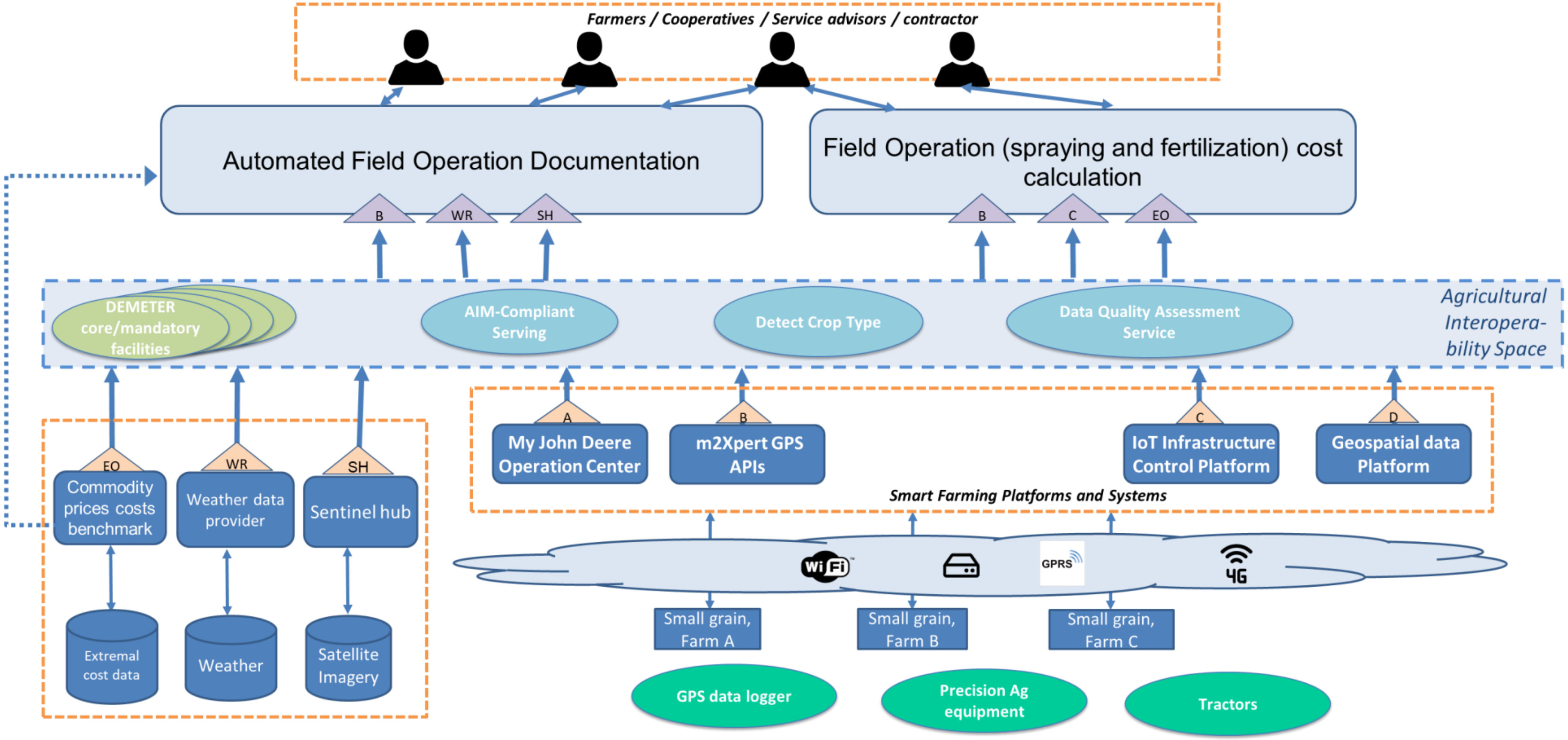

Figure 51. Pilot 2.2 – DEMETER Revised Reference Architecture instantiation

12.6 Pilot 2.3: Data Brokerage Service and Decision Support System for Farm Management

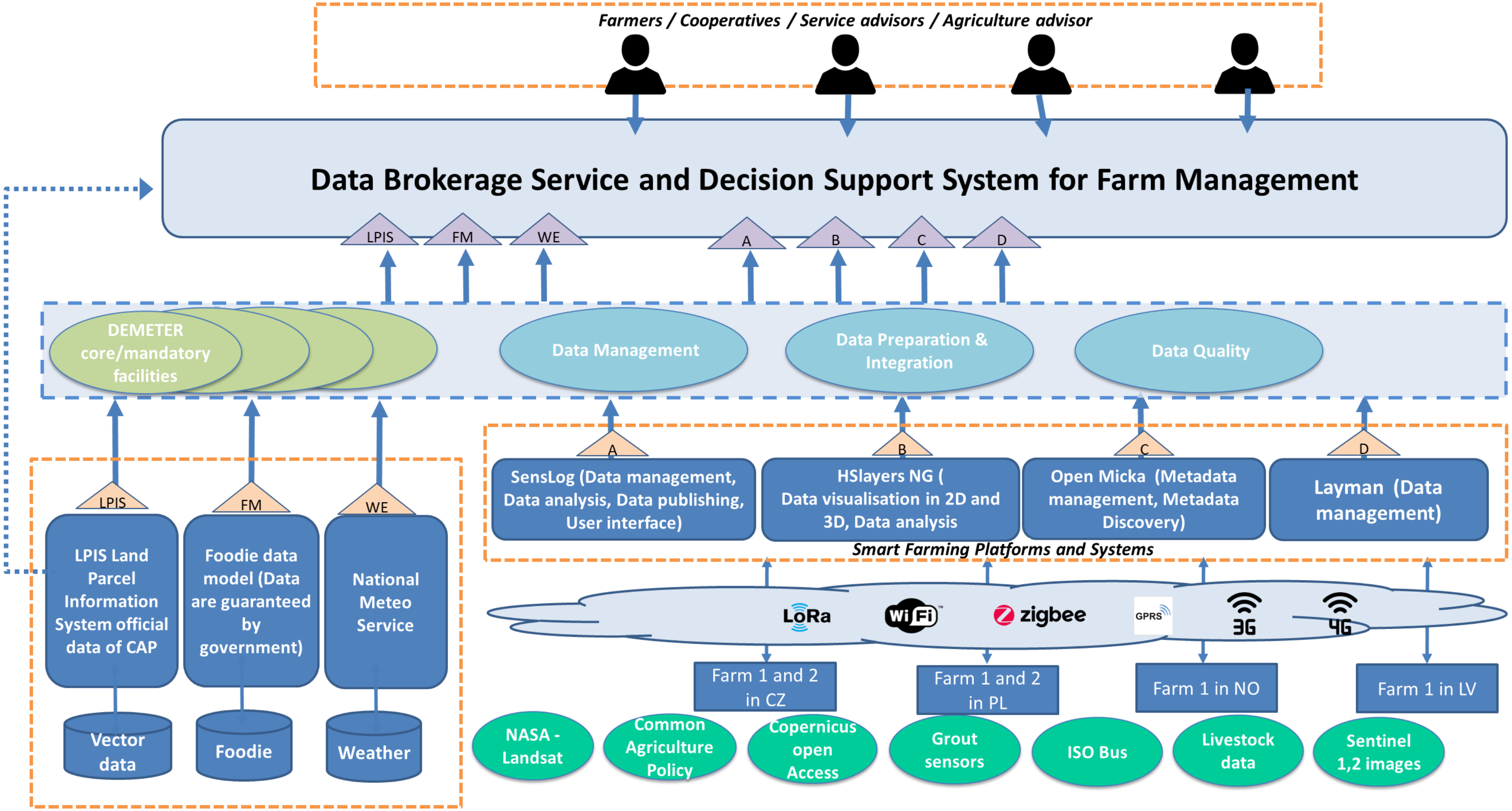

Figure 52. Pilot 2.3 – DEMETER Revised Reference Architecture instantiation

12.7 Pilot 2.4: Benchmarking at Farm Level Decision Support System

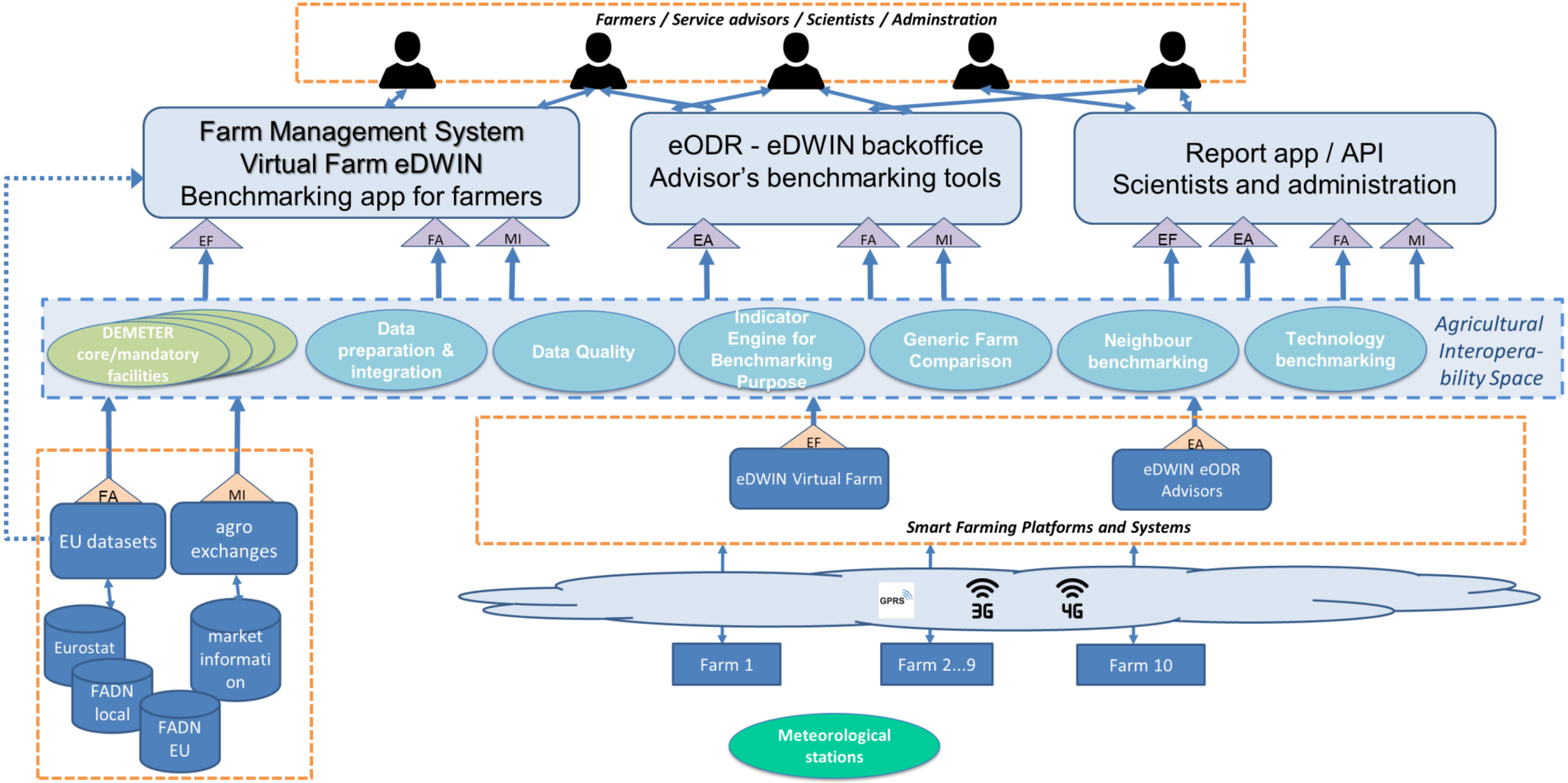

Figure 53. Pilot 2.4 – DEMETER Revised Reference Architecture instantiation

12.8 Pilot 3.1: Decision Support System to Support Olive Growers

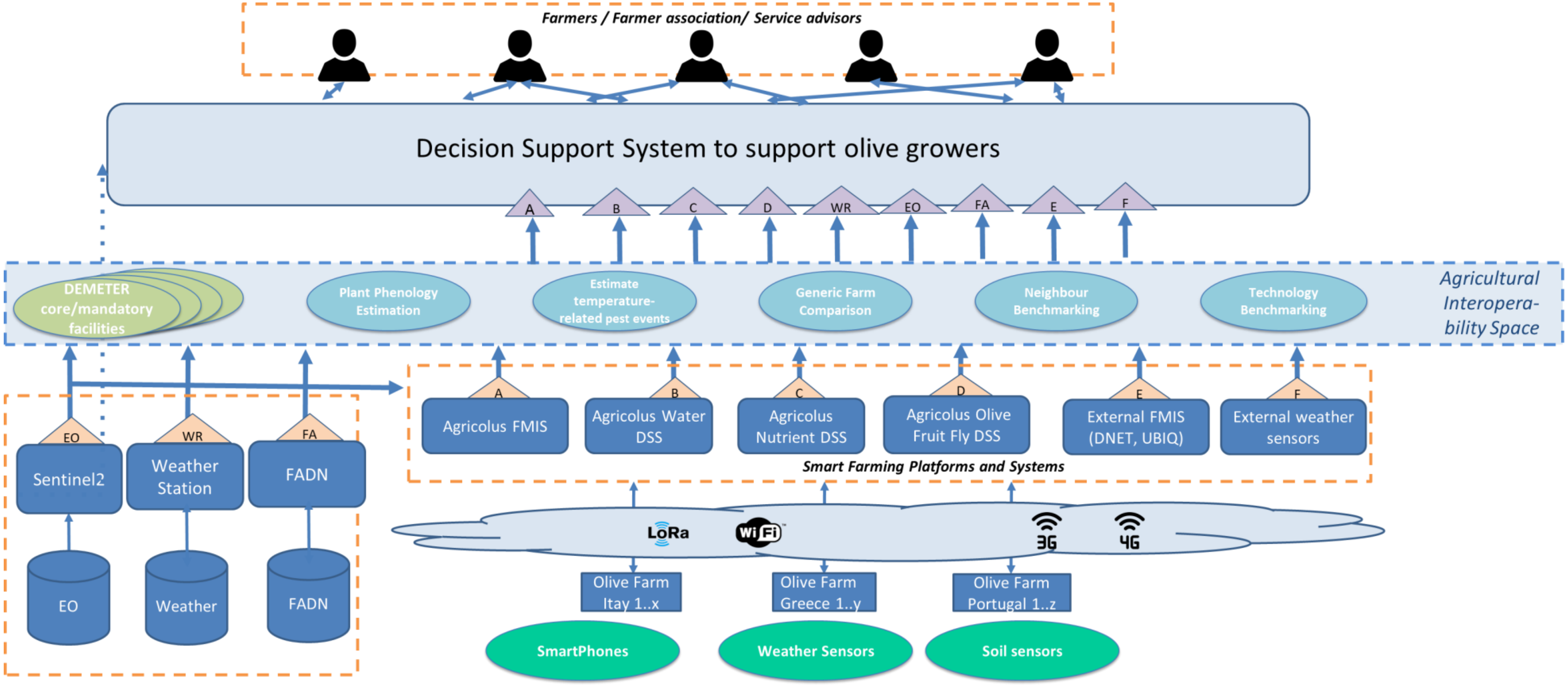

Figure 54. Pilot 3.1 – DEMETER Revised Reference Architecture instantiation

12.9 Pilot 3.2: Precision Farming for Mediterranean Woody Crops

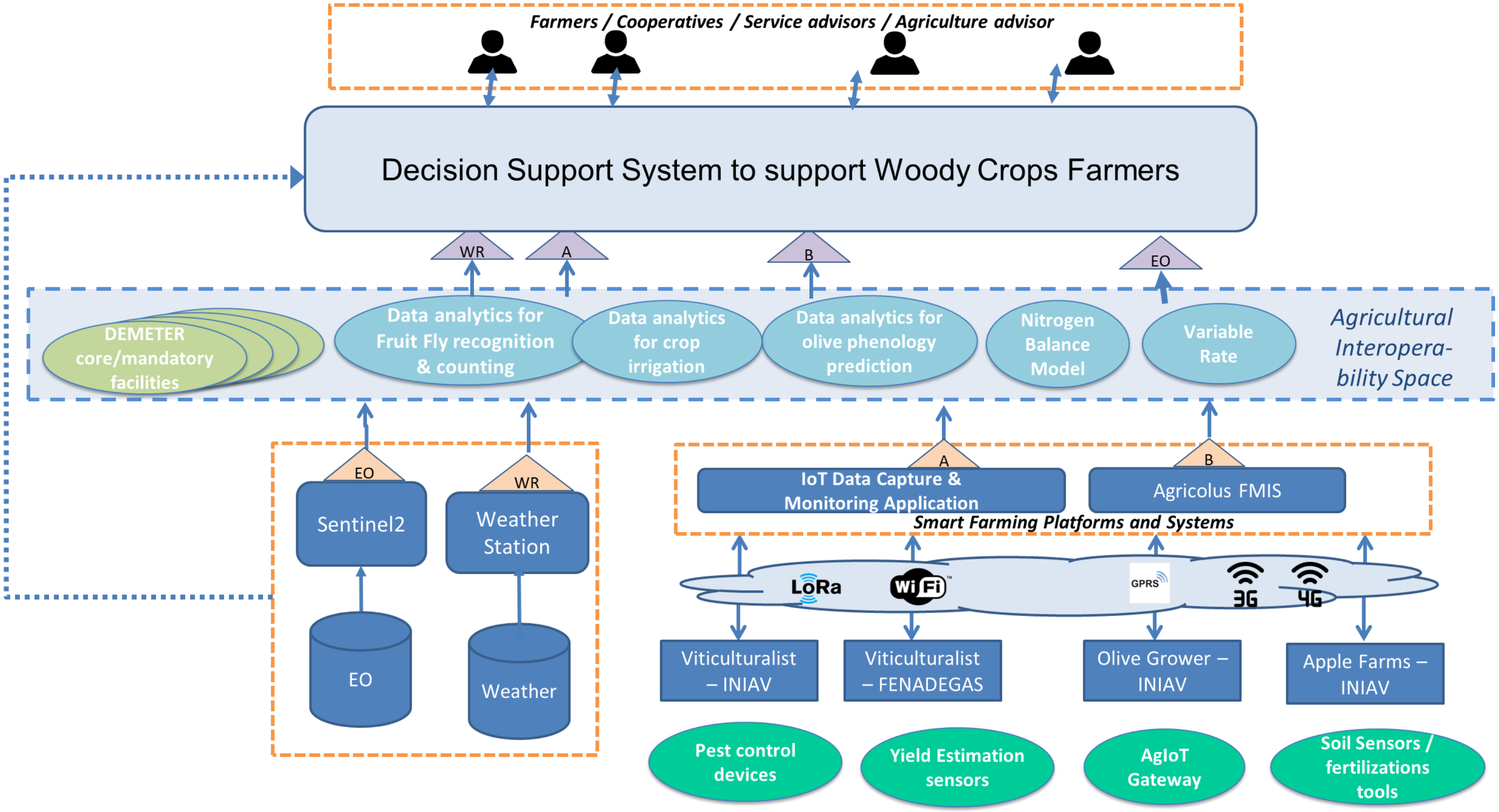

Figure 55. Pilot 3.2 – DEMETER Revised Reference Architecture instantiation

12.10 Pilot 3.3: Pest Management Control on Fruit Fly

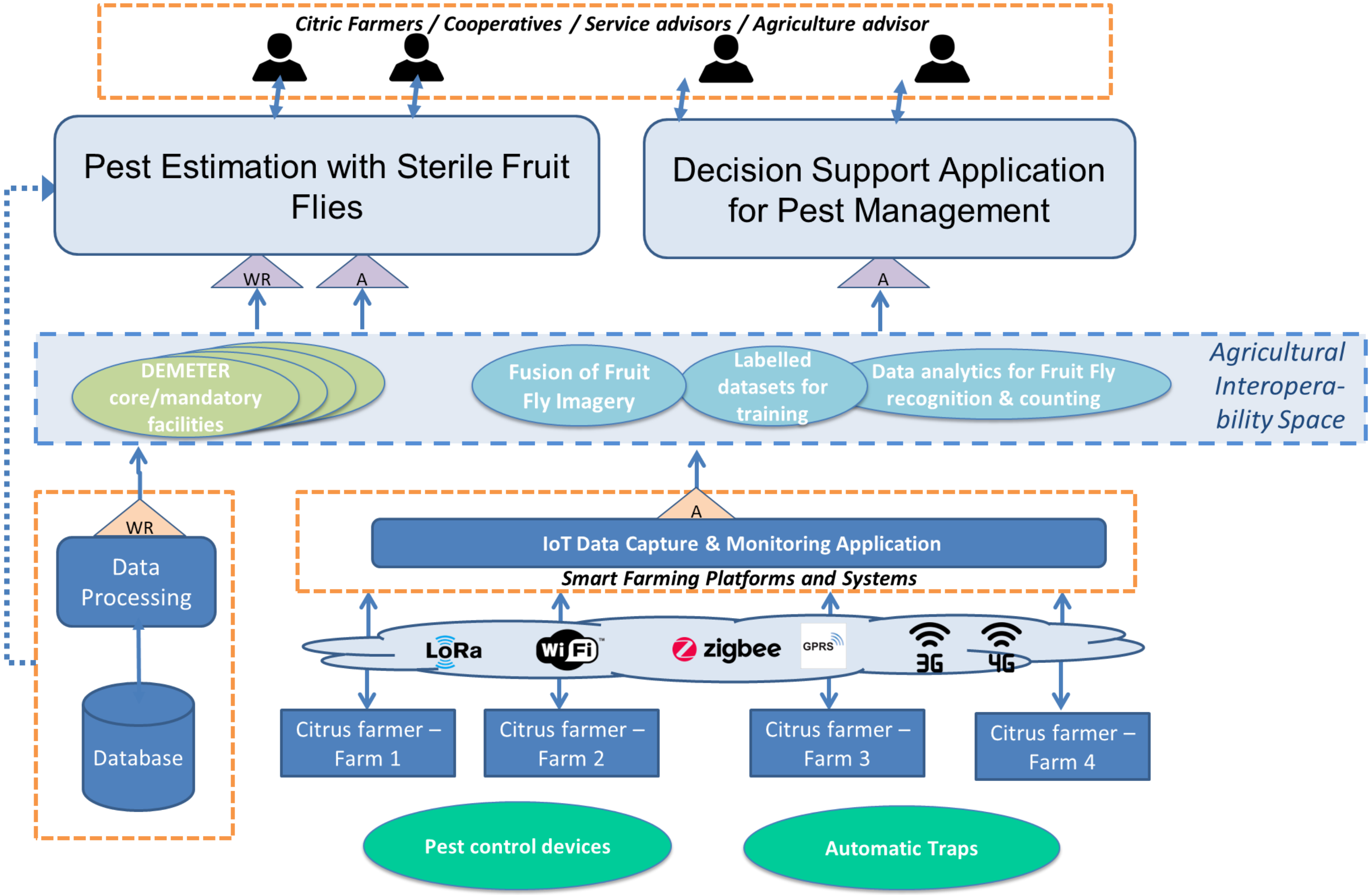

Figure 56. Pilot 3.3 – DEMETER Revised Reference Architecture instantiation

12.11 Pilot 3.4: Open Platform for Improved Crop Monitoring in Potato Farms

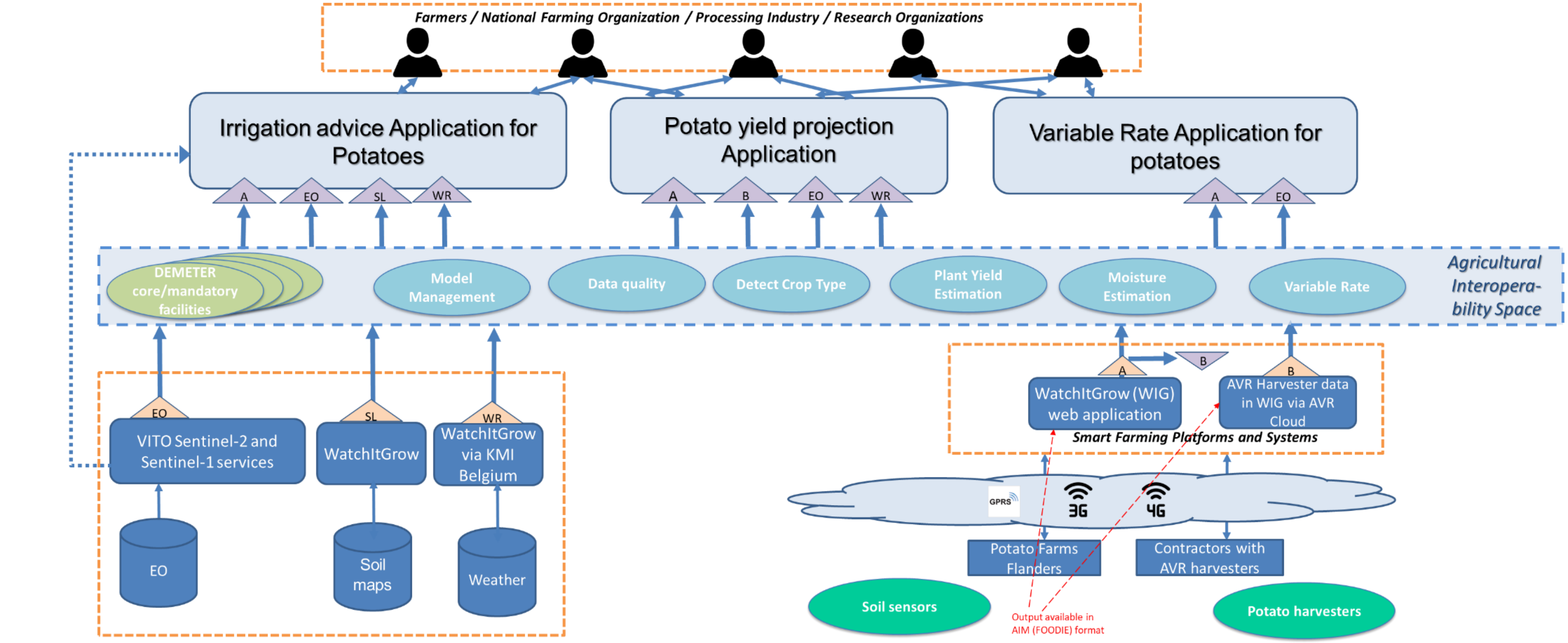

Figure 57. Pilot 3.4 – DEMETER Revised Reference Architecture instantiation

12.12 Pilot 4.1: Dairy Farmers Dashboard for the Entire Milk and Meat Production Value Chain

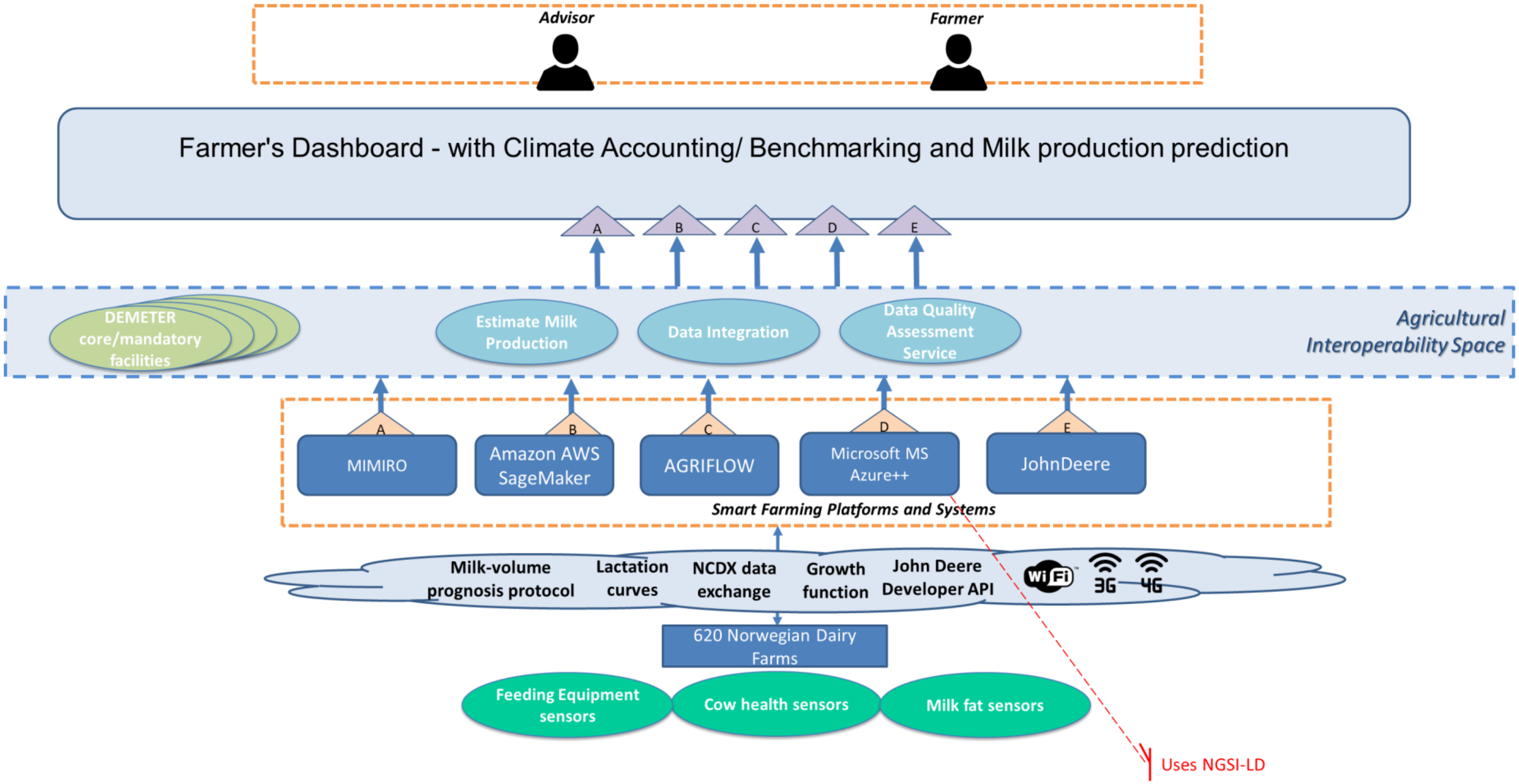

Figure 58. Pilot 4.1 – DEMETER Revised Reference Architecture instantiation

12.13 Pilot 4.2: Consumer Awareness: Milk Quality and Animal Welfare Tracking

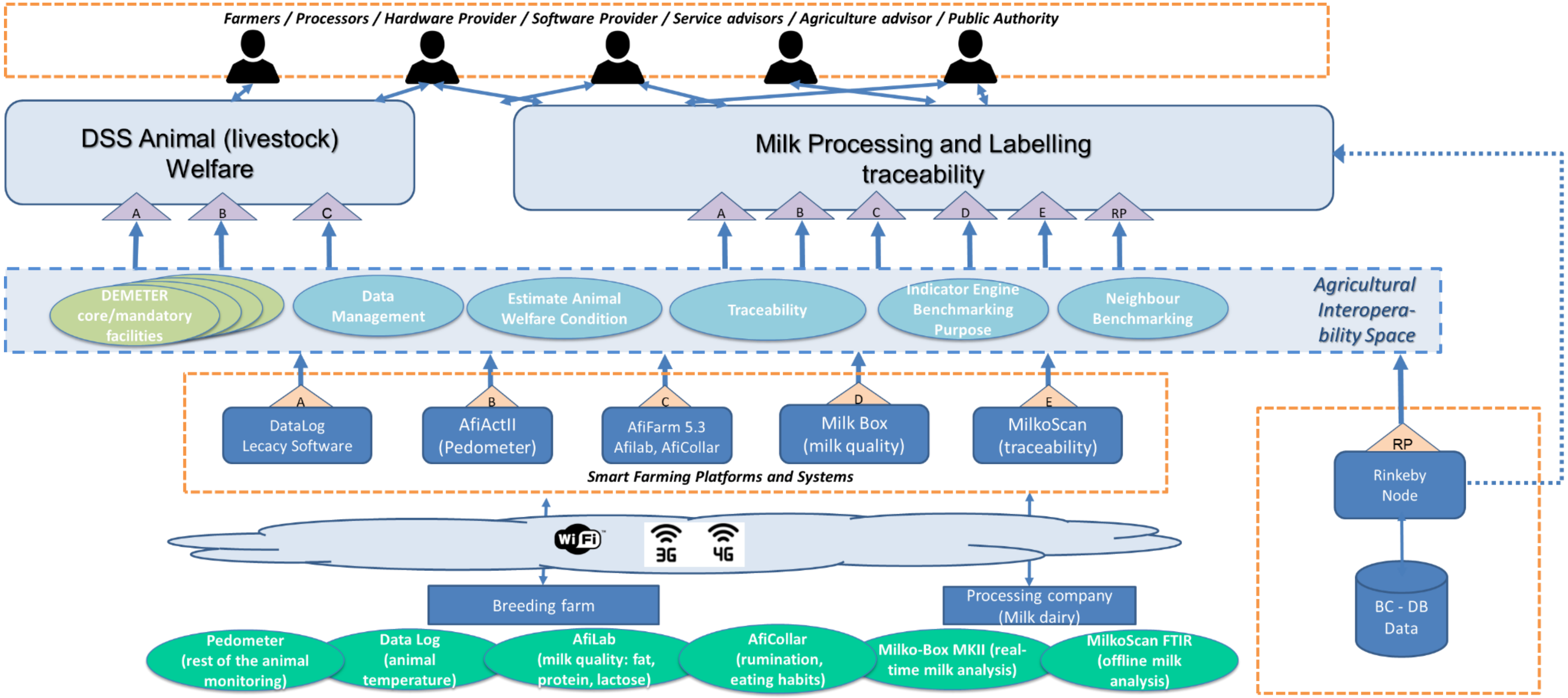

Figure 59. Pilot 4.2 – DEMETER Revised Reference Architecture instantiation

12.14 Pilot 4.3: Proactive Milk Quality Control

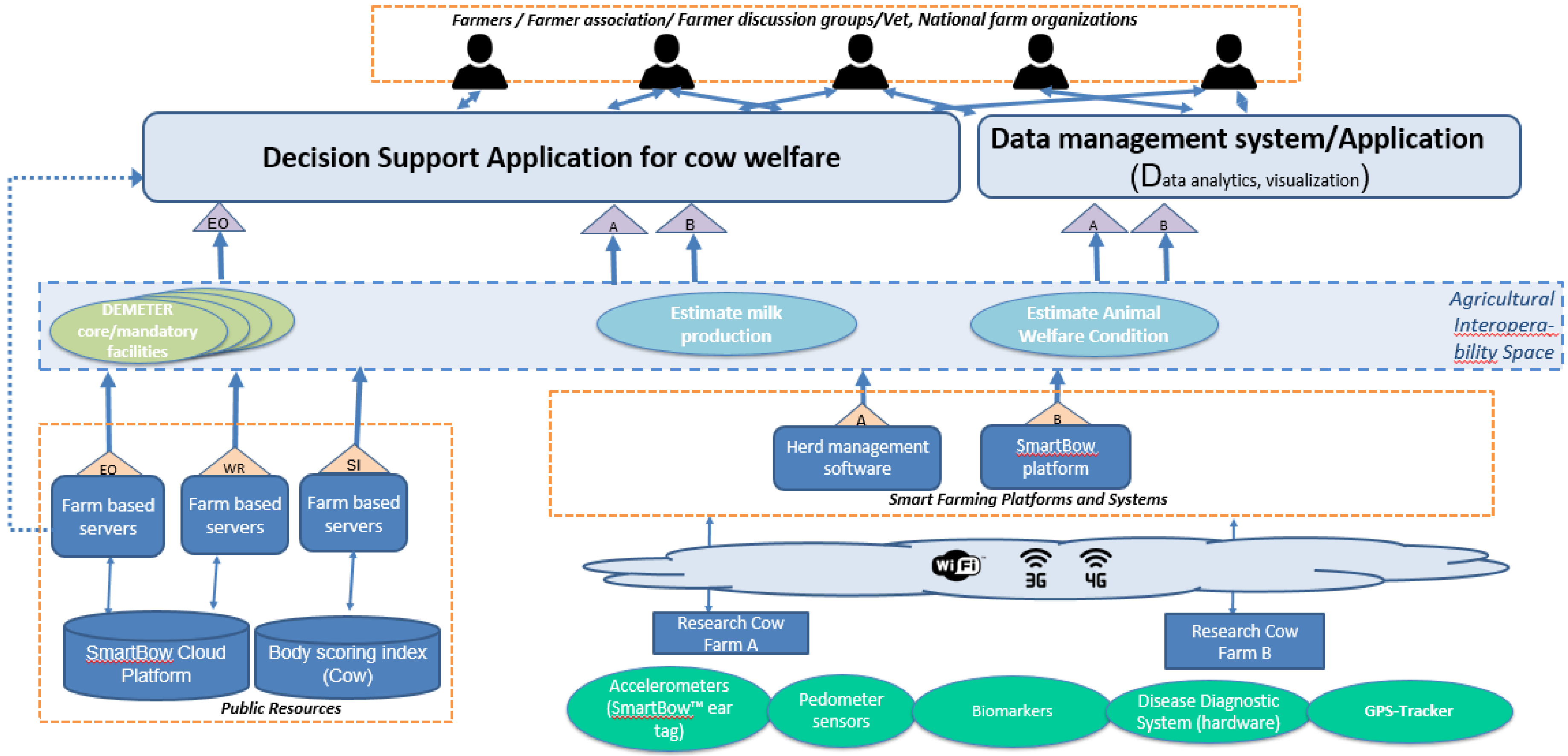

Figure 60. Pilot 4.3 – DEMETER Revised Reference Architecture instantiation

12.15 Pilot 4.4: Optimal Chicken Farm Management

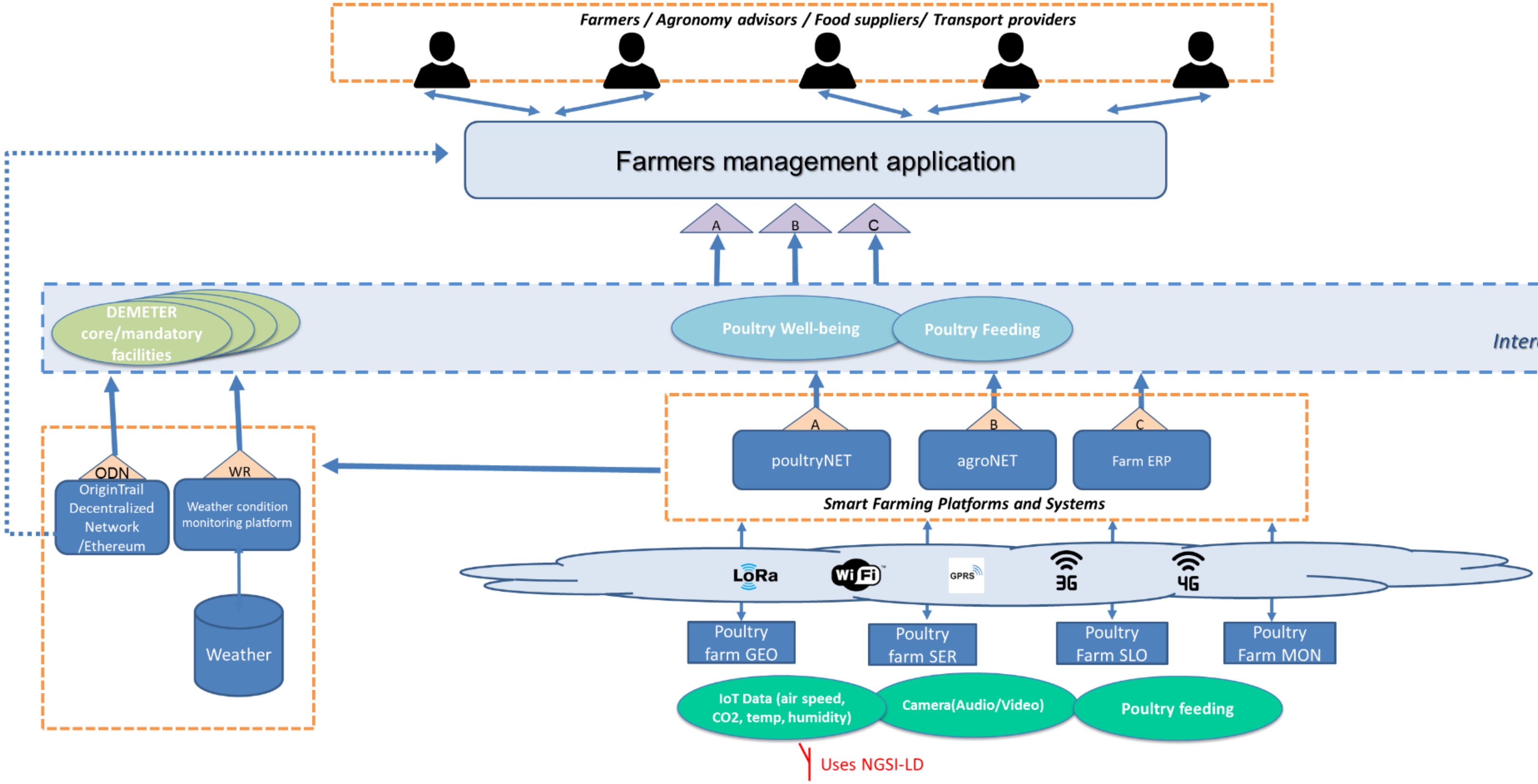

Figure 61. Pilot 4.4 – DEMETER Revised Reference Architecture instantiation

12.16 Pilot 5.1: Disease Prediction and Supply Chain Transparency for Orchards/Vineyards

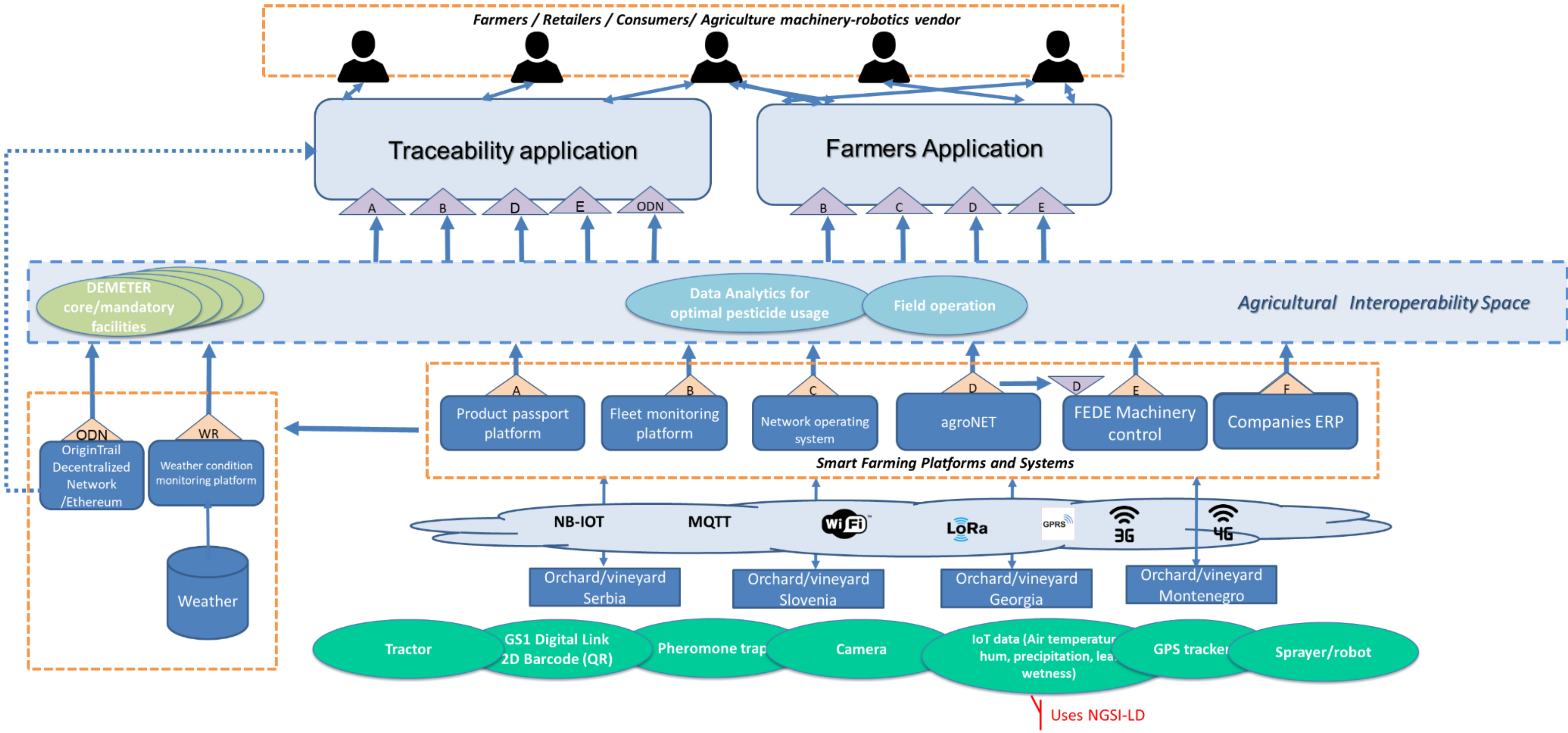

Figure 62. Pilot 5.1 – DEMETER Revised Reference Architecture instantiation

12.17 Pilot 5.2: Farm of Things in Extensive Cattle Holdings

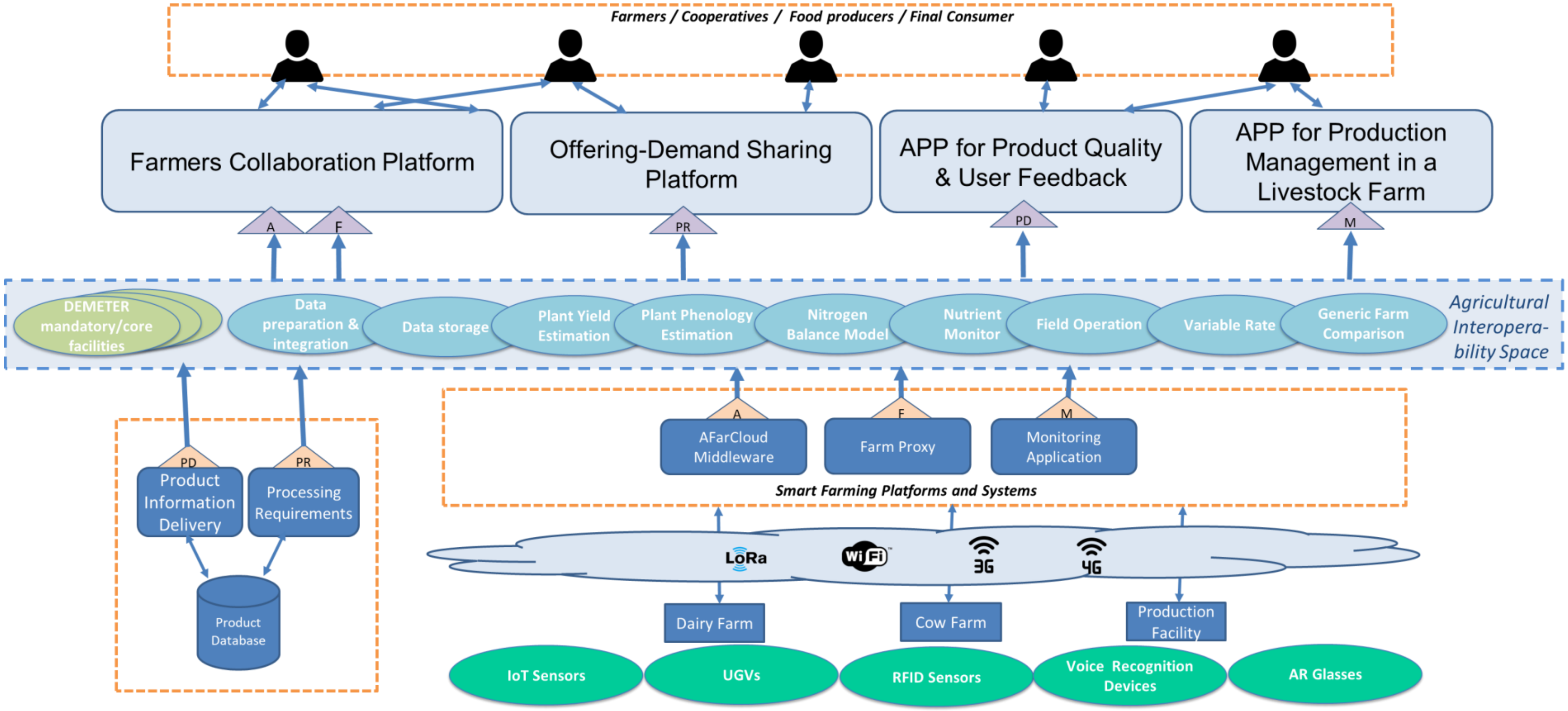

Figure 63. Pilot 5.2 – DEMETER Revised Reference Architecture instantiation

12.18 Pilot 5.3: Pollination Optimisation in Apiculture

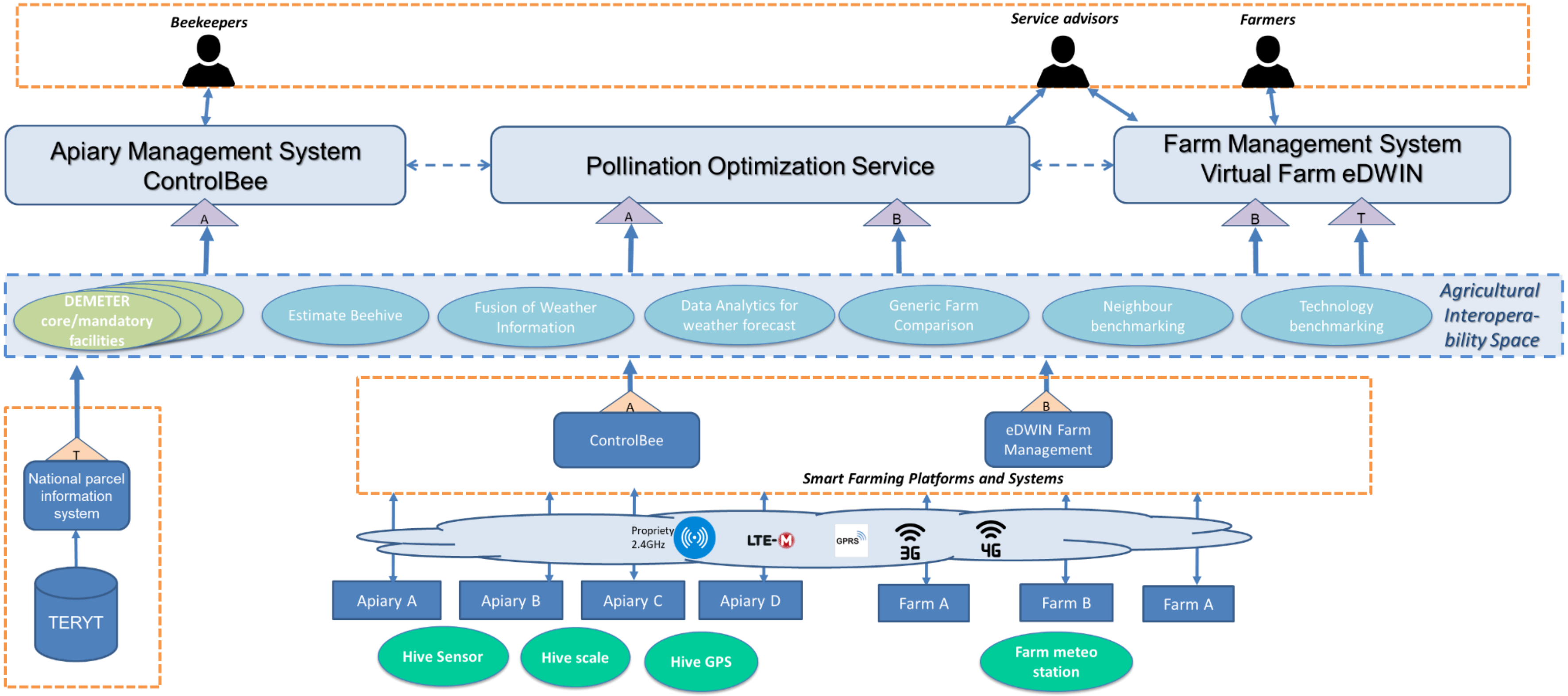

Figure 64. Pilot 5.3 – DEMETER Revised Reference Architecture instantiation

12.19 Pilot 5.4: Transparent Supply Chain in Poultry Industry

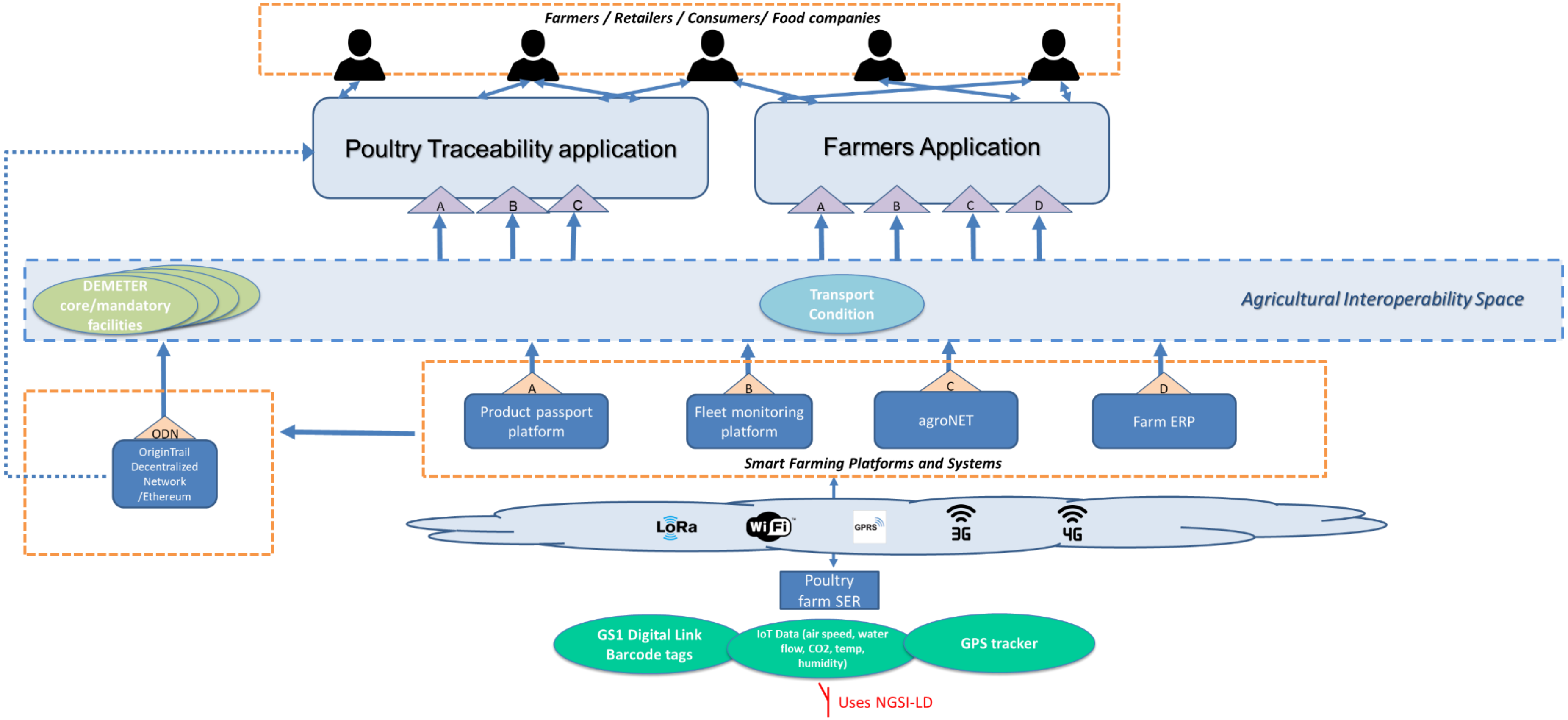

Figure 65. Pilot 5.4 – DEMETER Revised Reference Architecture instantiation

13 Conclusions / Next Steps

This deliverable describes in detail the DEMETER Reference Architecture as revised and updated since its original description in D3.1, as well as all related concepts and tools. It initially presents the motivation behind the revisions together with an overview of the changes and updates to the Reference Architecture. As part of the motivation for the changes, an updated state of the art review is then provided, focusing mostly on the newest initiatives such as the EU data strategy, the GAIA-X initiative and other projects that had not been considered in D3.1 and which influence the architecture revisions. Afterwards, it presents the questionnaire findings which were used to distil the experiences of the DEMETER developers and pilot partners during the development, implementation and integration of DEMETER, especially during the first round of DEMETER pilot deployments; this experience and the adaptations required to get the most out of the DEMETER implementations was after all a key driver of the RA revisions. Subsequently, the key DEMETER concepts and the respective terminology is presented, before providing a detailed elaboration on the updated DEMETER Reference Architecture, where six architecture views are again (as in D3.1) thoroughly presented: i.e., high-level view, functional view, process view, data view, deployment view and business view. Next, the updated and revised interfaces between the main DEMETER architecture blocks are discussed. Finally, instantiations of the DEMETER Reference Architecture for all 20 DEMETER pilots are presented as updated to conform to the lasted implementation to each pilot and of course the updated DEMETER RA.

The content of this deliverable is the result of the collaborative work of partners in every single work package of the project, as their experiences and input were instrumental in driving the architecture revisions. In particular, while most of this document has been prepared by Task 3.1 (which is responsible for this deliverable), Section 7 has been prepared based on the input to questionnaires by all partners, while the pilot architecture instantiations in Section 11 have been contributed by the pilot leaders in WP5.

This deliverable contributes to the achievement of Milestone 6 (DEMETER Enablers, Hub, Spaces and Applications Release 2) planned for June 2021.

As already mentioned, the updated Reference Architecture as elaborated upon in this deliverable will be complemented by five more deliverables expected in the next few months, which detail the updated reports regarding the various DEMETER tools and enablers, i.e.:

- D2.3 DEMETER data models and semantic interoperability mechanisms – Release 2 (April 2021)
- D2.4 DEMETER data and knowledge extraction tools – Release 2 (May 2021)
- D3.4 DEMETER technology integration tools – Release 2 (June 2021)
- D4.3 Decision Support, Benchmarking and Performance Indicator Monitoring Tools – Release 2 (May 2021)
- D4.4 Decision Enablers, Advisory Support Tools and DEMETER Stakeholder Open Collaboration Space - Release 2 (June 2021)

These deliverables will provide additional information regarding the updated and revised implementation of AIM as wells as the various DEMETER enablers developed, and finally the updated report for the technology tools developed for DEMETER and the architecture; all of which are not discussed herewith.

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