

## Annex 3: Technical Information

### DEMETER Open Call #2 - DEPLOY

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## List of acronyms

Table 2: List of Acronyms

ACS	Access Control Server
AIM	Agricultural Information Model
AIS	Agricultural Interoperability Space
API	Application Programming Interface
BSE	Brokerage Service Environment
DEH	DEMETER Enabler Hub
DSS	Decision Support System
DPI	Data Preparation and Integration
DQA	Data Quality Assessment
FADN	Farm Accountancy Data Network
FIE	Functional Interoperability Enabler
GUI	Graphical User Interface
IdM	Demeter Identity Manager
OC	Open Call
PEP	Policy Enforcement Point
RA	Reference Architecture
REST	Representational State Transfer
RRM	Resource Registry Management
SOCS	Stakeholders Open Collaboration Space
WP	Work Package

## 1 Introduction

The goal of the DEMETER Open Call #2 – DEPLOY is to deploy high value and impactful pilots employing DEMETER model and technologies. In this document, the DEMETER technological ecosystem, available for the implementation of the new pilots, is presented.

Other complementary and interoperable technologies may be used to implement the new pilots.

## 2 Architecture

The DEMETER Reference Architecture (RA) follows a modular approach 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 (and which is described later in this report). 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, thus achieving the desirable interoperability between existing components and new enablers.

An overview of the key concepts of the DEMETER RA are presented in the figure below:

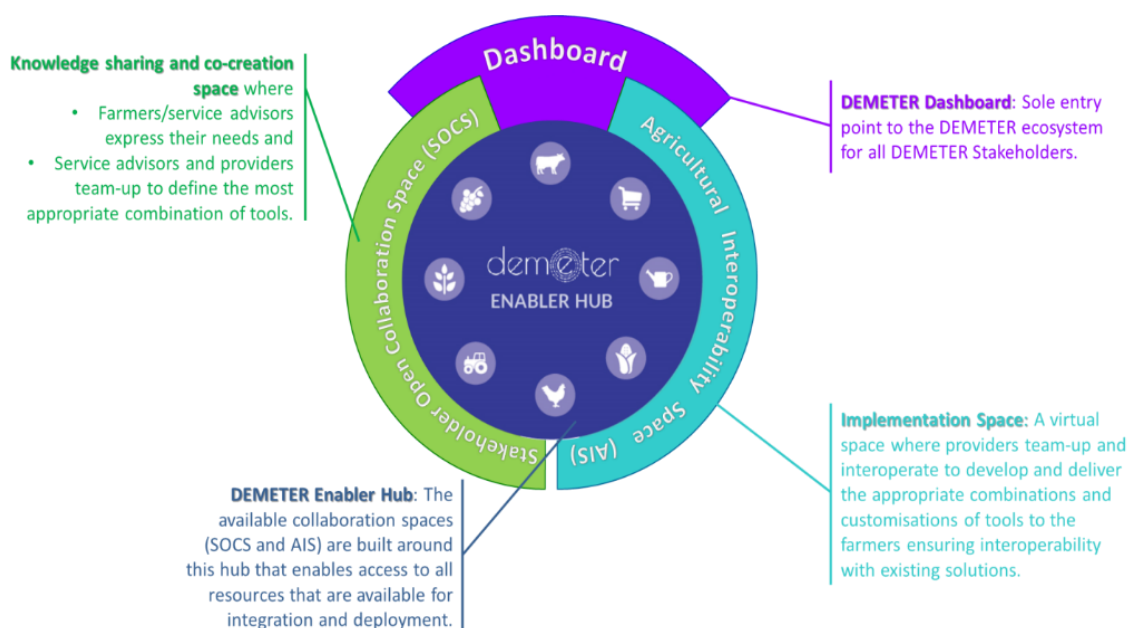


Figure 1: DEMETER Reference architecture

Central to the whole architecture is the **DEMETER Enabler Hub (DEH)**, which centralises the full description of all the components, devices, services, data sources and platforms, 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 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. In this way, the enablers have all the necessary information to execute the application. Another component crucial for this process is the DEMETER **Access Control Server (ACS)** that provides part of the security and authentication facilities needed.

The DEH and all related architecture tools developed are accessed via the appropriate dashboards offered by DEMETER by the appropriate stakeholders. 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. On the other hand, 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 SOCS and AIS 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, and, through these, to the DEMETER Enabler HUB (DEH).

In order to facilitate the interoperability between the various enablers of the architecture, a key component is the DEMETER **Agriculture Information Model** (AIM) which provides a common data model for any DEMETER enhanced entities and which is interoperable with the best-known ontologies and models used in AKISs. This can be seen in the following diagram, which presents the high-level view of the RA:

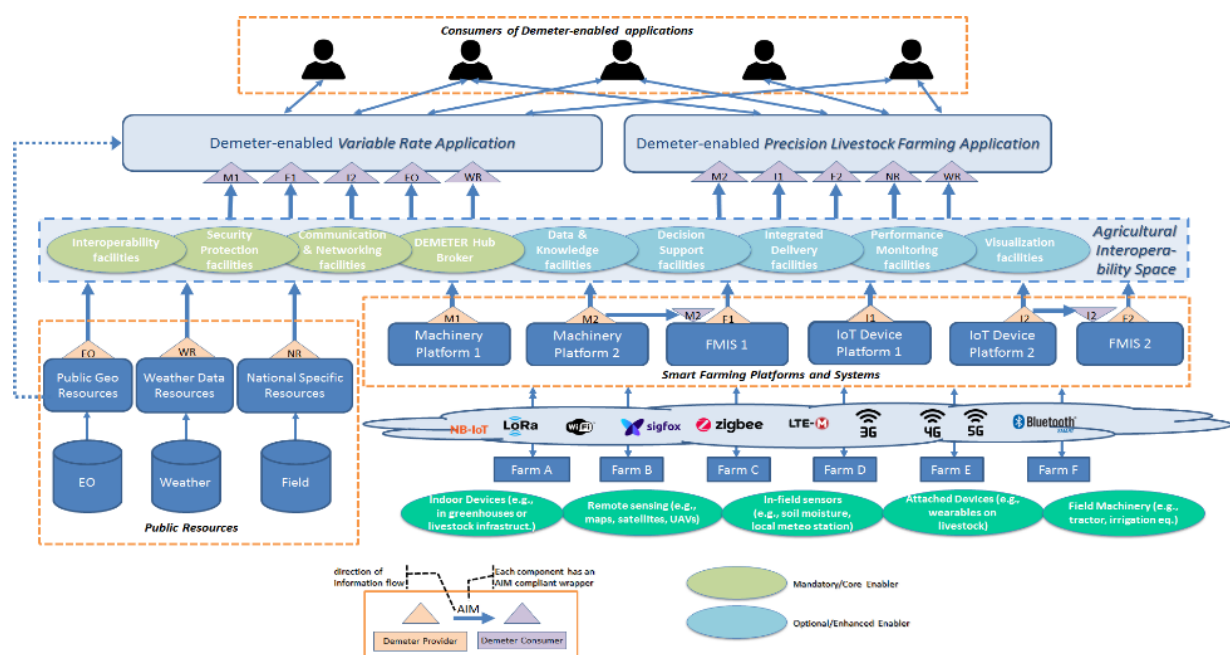


Figure 2: DEMETER Reference Architecture II

The proposed architecture consists of services available from DEMETER Providers and to DEMETER Consumers. 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 to and from widespread standardised ontologies and systems such as NGSI-LD, Saref4Agri, ADAPT, etc. To enable interoperability of heterogeneous data handling approaches, the DEMETER enablers, translate and exchange data based on the AIM common data format with the use of lightweight data wrappers/translators.

DEMETER enablers also maintain the necessary mechanisms for satisfying data security and privacy concerns. First, they need to be trusted to be deployed and hosted by the AKIS on their own cyber-premises (i.e., hosting environments). Furthermore, 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.

Now, to implement this high-level view of the architecture, DEMETER needs to provide several modules that interact with each other, with the various stakeholders as well as with a wealth of existing devices, platforms, systems and data sources. In addition to the DEH, SOCS and AIS which have already been presented previously in this document, key to this process are several needed enablers. These fall within two categories: mandatory **core enablers** and optional **advanced enablers**.

The **core enablers** provide key functionality that is needed in every DEMETER app and therefore must be included in every app. These include, first, enablers for *functional and semantic interoperability*, which work on top of the existing resources, e.g., platforms, devices, services or applications, and provide data wrappers that allow the resource to interoperate with other enablers. Second, another core enabler is the *Access Control enabler* used, e.g., to prevent access to unauthorized entities. Finally, the last type of core enabler is a *Client for the DEMETER Enabler Hub*, for any information that needs to be communicated with the DEH's runtime facilities, e.g., to get computing resources usage by other enablers which would be important when running DEMETER enabled apps.

The other type of enablers offered, the **Advanced Enablers** are optional and give additional functionality, as needed for each type of application. They are discoverable and accessible through the DEMETER Enabler Hub. The ones developed for the DEMETER pilots 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. 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. Furthermore, several other enablers have been developed for *Decision Support, Performance Monitoring and Benchmarking*, as well as *visualisation enablers* that convey the information and actions taken automatically (or needed) to the final users of the DEMETER applications, such as the farmers.

All the key components of the architecture together with the various enablers developed are presented later in this document.

### 3 DEMETER GitLab for the OC participants

GitLab has been selected to be used for managing source code and version control in DEMETER. GitLab is an open-source code management system based on Git, which includes a user management part that can be hosted online. DEMETER's code repository is using GitLab's online version where several private repositories have been created following the structure indicated by the partners involved. The group functionality offered by GitLab allows for code isolation, hence, to better accommodate privacy and IPR concerns among the consortium, subgroups have been defined where access is only granted to partners directly involved to the related component and task. In cases where public repositories are required, e.g., for public components, according to the Description of Action (DoA) commitments, source code that will be made public, and will, of course, be subject to licensing terms and conditions as agreed between the partners involved. GitLab provides the ability to allow access to external parties, such as the Open Call participants for which special groups (namely OpenCallDEPLOY) are created to host mainly documentation, tutorials, and other useful material related to DEMETER.

DEMETER GitLab also offers an option to setup an issue tracker for projects. DEMETER leveraged on this functionality by using issue trackers at different levels. Issue Trackers have been setup and configured for DEMETER internal use, but also one dedicated for the Open Call projects. Issue trackers can be used by Open Call selected applicants to create issues that DEMETER partners need to pick, review, and address.

Access to DEMETER is granted upon request, hence, any OC winner will get access to DEMETER GitLab requesting access to the specific groups his/her organization participates in (e.g., Open Call winners cannot get access to DEMETER internal groups/repositories but only to their designated one). An invitation will be then sent via email to the requested accounts. Notice: Only accepted OC projects can request access to DEMETER GitLab, not all applicants.

## 4 Tools

### 4.1 DEMETER Core Enablers

#### 4.1.1 Agricultural Information Model (AIM) - Semantic Interoperability

##### Description

The DEMETER Agricultural Information Model (AIM) provides a common language and model for all agri-data exchanged within DEMETER apps. Thus, it provides a common data format to be used by all apps and components, which has been created by reusing available (well-scoped) models from pre-existing well know ontologies, instead of defining new terms, whenever possible. More specifically, AIM fuses concepts from and is interoperable with the following models and vocabularies: FIWARE (and FIWARE Agri), Saref4Agri, ADAPT, INSPIRE (and FOODIE), AGROVOC, EO data and others.

The DEMETER AIM has the following subcomponents (layers):

- The AIM core metamodel, which defines the modelling language and rules of AIM and follows overall the NGSI-LD meta-modelling approach.
- The AIM cross-domain ontology layer, i.e., the set of generic models which provide common definitions for the entire agri-food domain and thus avoids conflicting or redundant definitions of the same classes at the domain-specific layer.
- The AIM domain-specific ontologies layer, which model specific concepts such as crops, animals, agricultural products as well as farms and farmers, etc. which are typically fused from existing well-known ontologies widely in use.
- The AIM pilot-specific ontologies layer: this comprises of tailor-made ontologies to our pilots which extend ontologies from the domain-specific layer and mostly define new concepts that exist in no other known agriculture ontology.
- The AIM metadata schema, which expresses semantics, related to meta-information about the datasets, based on the cross-domain and domain specific ontologies.

In the following figure, the AIM layers are presented as a diagram:

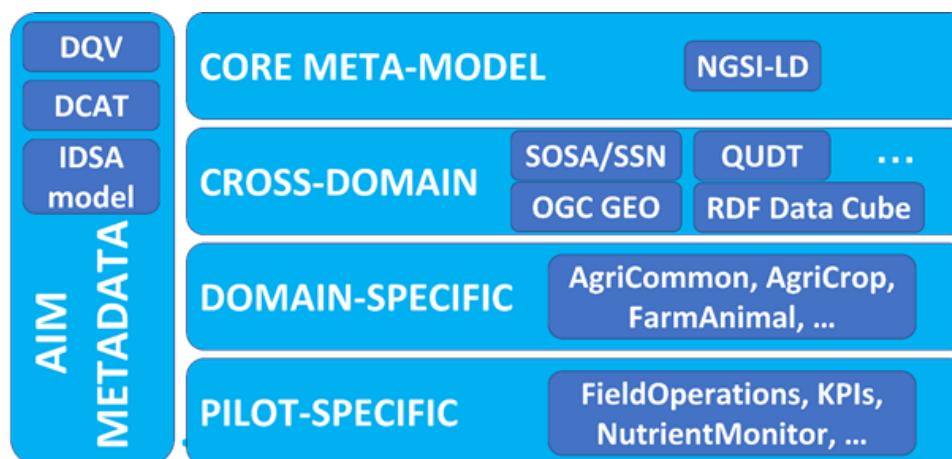


Figure 3: AIM Layers

Due to its modular structure, it can be extended as needed with new concepts and terms, e.g., by extending in most cases the domain-specific and the pilot-specific ontologies that it provides.

Now, in order to make all enablers used be DEMETER compliant, if these use another data model (not AIM) then appropriate data wrapper (i.e., translators) need to be provided that would transform any data to/from the AIM format.

### Use Cases & examples

To create the required data wrappers that translate existing models to and from the AIM, some brief guidelines are being provided on how to accomplish this. This procedure has been or is now being undertaken in several DEMETER pilots where data wrappers have been provided for different formats to/from AIM.

First, any data exchanged needs to use the JSON-LD format. JSON-LD is designed around the concept of a "context" to provide mappings from JSON to a shared/common model and links terms in a JSON document to elements in an ontology or vocabulary, i.e., AIM in the case of DEMETER. So, in order to generate AIM-based JSON-LD content, one needs to define the [@context](#) in the JSON document, and reference AIM context(s) from there, e.g.:

```
{
  "@context": "https://w3id.org/demeter/agri-context.jsonld",
  ....
}
```

Second, to find AIM terms and retrieve annotations, there are several different options:

- Load the whole ontology (<https://w3id.org/demeter/agri>) in an ontology editor like Protege.
- All modules of AIM domain layer can be searched on the OGC definition server.
- AIM is available in the agroPortal site: <http://agroportal.lirmm.fr/ontologies/DEMETER-AIM>.

In some of these sites and, in DEMETER deliverables (e.g. D2.3) sample code is also available.

Third, several concepts (especially those which are taken and mapped from other existing ontologies) are represented hierarchically and there are mappings between these concepts in other ontologies and AIM. For example, if we take the "farm" concept in AIM, this maps to "farm" in Saref4Agri and Adapt, to "AgriFarm" in FIWARE and to "Holding" in Foodie. However, a farm could be part of a larger area which contains multiple farms, and this is the "Plot" concept in AIM which semantically is mapped to "Parcel" in Saref4Agri, to "AgriParcel" in FIWARE, and to "Plot" in Foodie.

Finally, regarding *the validation of AIM code*: it is possible to use the json-ld playground: <https://json-ld.org/playground/>, which will only check that the elements in the code are resolvable,

but not the semantics. To validate the semantics as well, we are evaluating tools like SHACL: <https://shacl.org/playground/>, but this work is not complete yet.

#### 4.1.2 Access Control Server (ACS)

##### Description

Access Control Server (ACS) offers authentication, authorisation, and traceability functionalities to the brokerage environment. These functionalities have been implemented in six main security components: Identity Manager, XACML PDP, Capability Manager, PEP Proxy, Traceability Agent and Traceability blockchain repository.

The Demeter Identity Manager (IdM) component is based on the FIWARE Keyrock GE and will provide the Keyrock's REST API for authentication based on the OAuth 2.0 protocol. The XACML PDP manages the access control policies and decides who can access a resource and what actions they can perform with that resource. The Capability Manager is the component for generating capability tokens for the user in the event of an affirmative authorisation decision from the XACML PDP following a request about an action or access to a resource. The PEP (Policy Enforcement Point) is responsible for validating a generated assertion in an authentication token (X-AUTH-TOKEN) with the capability token that was already generated in a response by the Capability Manager to a user's authorization request. The traceability agent will expose a REST API to register authentication and authorisation events (POST) and retrieve their details (GET). The REST API has been designed to be flexible enough to be able to use different traceability blockchain repositories.

##### Use Cases & examples

The OAuth 2.0 protocol supports several grants ("methods") types for a client application to acquire an access token (which represents a user's permission for the client to access their data) which can be used to authenticate a request to an API endpoint. The Grant Types to be used for the Demeter components are:

- **Authorisation Code:** defined for apps running on a web server. The client will redirect the user to the authorisation server (Keyrock GE), and the user will then be asked to login to the authorisation server and to approve the client.
- **Password:** for logging in with a username and password.
- **Client credential:** the simplest of all of the OAuth 2.0 grants, this grant is suitable for machine-to-machine authentication where a specific user's permission to access data is not required.
- **Refresh token:** the access token obtained after being authenticated, provided with an expiration time; Keyrock GE provides a way to refresh the token which enables the client to get a new access token without requiring the user to be redirected.

The IdM provides functionalities to gain an identity within the system and manage the access privileges. Identity Manager Keyrock define the following common objects:

- **User:** Any signed-up user able to identify themselves with an email and password. Users can be assigned rights individually or as a group.
- **Application:** Any securable FIWARE application consisting of a series of microservices. Users or a group of users (i.e., organizations) will be granted permission to interact with the application.
- **Organization:** a group of users who can be assigned a series of rights. Altering the rights of the organization effects the access of all users of that organization. Users within an

organization can either be members or admins. Admins are able to add and remove users from their organization, while members merely gain the roles and permissions of an organization. This allows each organization to be responsible for their members and removes the need for a super-admin to administer all rights.

- **Role:** a role is a descriptive bucket for a set of permissions. A role can be assigned to either a single user or an organization. A signed-in user gains all the permissions from all of their own roles plus all of the roles associated to their organization
- **X-Subject-Token:** identifies who has logged in on the application. This token is required in all subsequent requests to gain access.

#### 4.1.3 Access Control Enabler (ACE)

##### Description

##### Authentication Security Enabler

The Security Authentication Enabler library provides to the DEMETER components and the pilots developments an abstract way to access to the Authentication OAuth 2.0 functionalities exposed by the DEMETER Authentication component REST API.

This library provides the following functions:

- Authentication by username and password
- Refresh authentication
- Revoke authentication token

The Security Authentication Enabler will interact with the Communication and Networking Enabler to obtain a secured communication channel to perform the authentication functionalities.

This enabler will also provide to the Security Authorisation Enabler(s) the authentication token needed to perform authorization functionalities.

The library needs to be imported in the programming language of choice, and the function imported.

##### Authorization Security Enabler

The authorisation enabler provides a solution for controlling the access to the resources stored in an information repository. It is based on a technology called Distributed Capability-Based Access Control, which basically decouples the traditional XACML framework, into two phases: one for receiving the authorisation, which is represented by the receipt of an authorisation token called Capability Token, and a second one for accessing the information repository where basically, the user/service inserts the previous Capability Token in the corresponding query so that a Policy Enforcement Point Proxy (PEP\_Proxy) could check if the query matches the content of the Capability Token. In case of a positive answer, the PEP\_Proxy acts as a mere intermediary between the user/service and the information repository.

The authorisation enabler comprises different sub-components, nevertheless, only the endpoint for the Capability Manager is provided to the other components. For this reason, it can be accessed by following a specific REST API. Additionally, a java library (jar) has been developed to make it easier to interact with the corresponding servers. As this library uses JAVA, it can be run on different OS's.

## Use Cases & examples

The functionalities provided by the security enablers will be used by the other Core/Advanced Enablers and other DEMETER components in order to obtain a secured communication channel and get direct access to DEMETER resources.

The authorisation enabler comprises different sub-components, nevertheless, only the endpoint for the Capability Manager is provided to the other components. For this reason, it can be accessed by following a specific REST API. Additionally, a java library (jar) has been developed to make it easier to interact with the corresponding servers. As this library uses JAVA, it can be run on different OS's.

### 4.1.4 DEMETER Enabler Hub (DEH)

#### Description

The DEMETER Enabler HUB (DEH) represents the digital space dedicated to (technically capable) end users of DEMETER where they are able to create and register their own resources. Users have two roles; they act as DEMETER Provider and DEMETER Consumer. A DEMETER Provider is able to offer and manage his resources (components, services, data sources, devices, platforms, etc), while DEMETER Consumers will be able to browse it and find suitable resources matching their requirements. In order to support this, the DEH involves communication between various DEMETER components. Taking this into account, each component inside DEH exposes endpoints through their internal API's. Data entities from any Platform, Thing, Application, Service will be managed through these APIs, but for the sole purpose of discovery and management of the resource registry maintained by the DEH. To make the solution more flexible and easier to maintain, all components inside the DEH will be developed as separate services and deployed as standalone Docker containers.

## Use Cases & examples

End-users as DEMETER Providers, through the DEH, can promote their resources that thus can be validated by different DEMETER Consumers; on the other side, DEMETER Consumers are able to browse the collection of registered digital tools and services, and find suitable resources matching their requirements.

Components such as Estimate Animal Welfare DSS and Milk Quality DSS were registered in the DEH by pilot 4.2 with the aim to improve the DSS solution and make its output more accurate. Indeed, to better exploit project results, all the pilot solutions (based on machine learning algorithm) will be adopted and validated in the field, so it is important to make them available and reusable through the DEH.

### 4.1.5 DEH Client

#### Description

DEH Client is a core component of Demeter Enabler Hub, whose core functionality is to communicate with Docker Host (i.e., where the DEH Enablers will be deployed as Container/s) over a secured channel, generate resource consumption metrics of all DEH Resources deployed. The generated metrics are reported back to Resource Registry Management (RRM) periodically over metrics POST API. The communication thus established between DEH Client and remote Docker Host is secured using OpenSSL.

DEH Client interface/ communicates with other DEMETER components like ACS, BSE & RRM, associates registration information along with the metrics data sent to RRM for tracking. DEH Client also provides a rich set of APIs, which end-user can use to download DEH Resources/ DEH Enablers

locally, Start instances of DEH Enablers as Docker Containers, Analyse Container logs, and Resource Discovery i.e. get Docker Containers deployed matching set of valid filters.

### Use Cases & examples

**Use Case for a DEMETER Provider:** DEH Client deployed on Consumer environment.

- DEH Client continuously monitors if any DEH Enabler/s is/are deployed as Docker Containers on configured Docker Host.
- If any Docker Container is found, validate if the Ancestor/Docker Image of the Docker Containers is registered with DEH RRM. If registered get RRM ID/UID.
- For those Docker Containers whose DEH Enabler is registered generate resource consumption metrics at regular intervals and periodically update the metrics data to DEH RRM.
- The metrics data thus updated are visualized in DEH Dashboard.

These metrics data will give valuable insights to DEMETER Providers' on how his/her DEH Enabler/s is/are used, with stats like

- Number of downloads.
- Container attributes tracked as part of metrics include.
  - Volume = Memory Usage & CPU Usage.
  - Time Usage = Duration of running containers.

**Use Cases for a DEMETER Consumer:** DEH Client deployed on Consumer environment.

DEH Client deployed, provides a rich set of RESTFUL APIs for

- Resource/ Docker Container Discovery based on filters: With this API, users can identify a set of Docker Containers matching search criteria like the current status of the containers & ancestor.
- Metrics API: With this API users can get the Resource Consumption Metrics of any Docker Container at RunTime by name or id or uid (RRM registration ID).
- DEH Resource Management APIs: With this set of APIs, users can download DEH Enablers and deploy the same Demeter Enablers as containers to a remote Docker Host.
- Log Parser API: With this API an end-user can parse and analyse any Container logs without having.

### Interoperability:

DEH Client established interface/ communicates with other DEMETER components like ACS, DEH RRM & BSE.

- ACS: Request for authentication token, which will be used to communicate with other DEMETER components.
- DEH RRM: The Client communicates with DEH RRM to check if the DEMETER Enabler is registered with DEH RRM. If found returns RRM ID/ UID.
- BSE: The Client communicates with BSE to check if the Docker Container is registered with BSE. If found returns BSE-ID.



- Both UID & BSE-ID are unique IDs generated to identify DEMETER Enablers, and these IDs will be included in the metrics data sent to RRM.

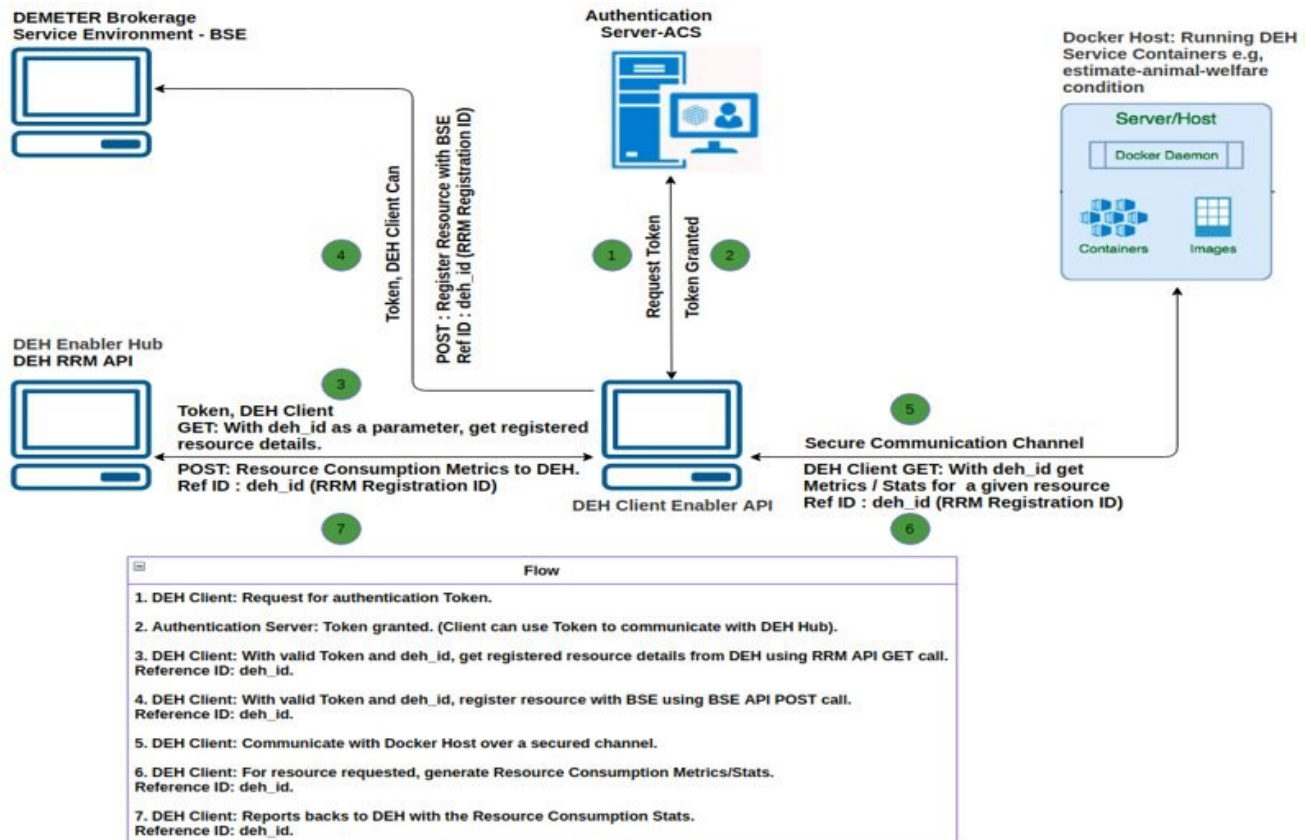


Figure 4: DEH Client flow diagram and interoperability (Interface with other DEH components DEH RRM & BSE)

#### 4.1.6 Brokerage Service Environment (BSE)

##### Description

The **Brokerage Service Environment (BSE)** is a core module of DEMETER architecture, which facilitates the registration, discovery and ultimately communication process for the DEMETER-enabled resources in a secure and privacy preserving manner. In the framework of DEMETER, a resource coupled with the necessary enablers (core and advanced) is named a DEMETER enhanced entity (DEE). A DEE, once authenticated and authorised by the BSE, can register as a service with the BSE specific registry. Subsequently, it becomes discoverable by all the other registered DEE's. Finally, based on the suitable core and advanced enablers that each DEE implement and after resource provisioning information from the BSE, DEE's can communicate directly with each other. In addition to the functionalities, BSE can interconnect (interface) with DEMETER HUB in case a useful flow is identified or required.

The BSE is implemented as a self-contained application that enables an external party to deploy it as a complete brokerage service solution. Each DEMETER-enabled application should utilise at least one BSE. The BSE accompanied by a publish-subscribe communication mechanism that addresses the required communication data throughput realises the backbone of the DEMETER reference architecture.



## Use Cases & examples

Developers and integrators (BSE is not meant for end users) can register their resources to the BSE so that other developers/integrators will then be able to discover them and use their functionality by e.g., consuming their declared APIs. Services registered to the BSE are services/resources that are available and accessible online. Note that the endpoints of the services are expected to be opened and accessible for others (allowed) to be used or provide information on how access can be obtained. It is up to the developer/integrator to parse and find the needed information (from the data retrieved by using the BSE) to use/call the discovered service (endpoint).

The BSE service registration is not to be confused with the resources registered on DEH which might be or might not be online.

BSE is not a web application, it does not have a Graphical User Interface (GUI), and also, BSE is not a database, it does not store any data from the registered DEMETER-enabler resources; only metadata for the registration, discovery, and provisioning information are stored.

Online documentation (Swagger) on how BSE API looks like can be found on <https://bse.h2020-demeter-cloud.eu/api/swagger/>

### 4.1.7 Functional Interoperability Enabler (FIE)

#### Description

**Functional Interoperability core Enabler (FIE)** is a core DEMETER enabler and can be regarded as the client-side of the Brokerage Service Environment. This Enabler provides all the services of the BSE to the rest of the DEMETER modules and enablers (Core and Advanced), and also to the Consumer's application. It serves as a wrapper for the Registration, Discovery, and Provisioning services offered by the BSE, but also offers the compatibility check feature, i.e., a compatibility check of a service to be registered, with the BSE data model. Despite initially envisioned being deployed on the consumers' application premises, aiming to ease its use remove complexity from the consumer, the Functional Interoperability (core) enabler is bundled with the BSE module and provides its functionality along with the BSE module.

## Use Cases & examples

BSE is checking the compatibility of our service (metadata content in the Service Register JSON body) using the Compatibility Checker functionality of the Functional Interoperability core enabler. The Functional Interoperability enabler functionality is embedded in the BSE API endpoints providing explanatory responses in cases the model needs modifications. FIE is not an enabler that needs to be deployed separately (it is already included in the BSE). Please, refer to the BSE documentation.

### 4.1.8 Stakeholder Open Collaborating Space (SOCS)

#### Description

The DEMETER SOCS is a digital space dedicated to all DEMETER stakeholders (farmers, advisors, and suppliers) where they can collaborate, share knowledge and best practices, and participate in the co-creation processes.

The SOCS provides the access point to the DEMETER ecosystem. Through the SOCS, all DEMETER stakeholders are able to interconnect into a unified digital community, where to find new contacts, share best practices and get inspiration, facilitate the emergence of new collaborations, find update on relevant topics, learn from the others' experiences, innovate, promote yourselves and create the

basis for new business, have access to skills and technologies as well farmer's requests and needs and expert advice.

One of the main functionalities offered by the SOCS is, undoubtedly, gathering and addressing farmers' needs according to a co-creation process. Through this process, farmers' needs can be better elicited, through the collaboration tools and thanks to the help of other users (i.e., advisors). The need expressed by a farmer is analysed and can evolve into a **challenge** which represents the area of interest that requires new solutions or approaches. The creation of a challenge aims to involve stakeholders in the creation of solutions (**ideas**) that represent their contributions to the requests expressed through the challenge. The final result of the challenge is the selection of the idea that best matches with the challenge and the elaboration of the optimal solution, relying on the resources present in the DEMETER Enabler Hub (DEH). The DEH centralises the full description of all the components, devices, services, data sources, platforms etc., that are accessible for deployment.

### Use Cases & examples

The importance of all the SOCS services varies based on a specific subgroup taken into consideration and their expressed needs. For example: a specific farmer subgroup could be interested more in the knowledge exchange about relevant topics with other users, a specific farmer subgroup could be interested to interact with advisors and IT providers and being involved in the innovation development, a specific farmer subgroup could be interested in the knowledge exchange and in the cooperation with the local authorities and farmers organisation, an IT providers subgroup could be interested to participate to discussions started from farmers and advisors to see how she/he can contribute with his/her experience/competences, an IT provider subgroup could be interested to contact other IT providers that have already solved a specific farmer problem, an IT provider subgroup could be interested to access to DEH and use components already validated for the elaboration of a new solution, and so on.

#### 4.1.9 Adaptive Visualisation Dashboards

##### Description

The Adaptive Visualisation Dashboard module is an advanced enabler, which facilitates the dashboard DSS implementation. The reference implementation is based on Knowage<sup>1</sup>, a solid visualisation and adaptive framework for building and developing user interfaces (business driven and not pilot specific). Given the great demand coming from DEMETER pilots, heterogenous both in the graphics and in the specific elements of each dashboard and given the multiplicity of user visualisation requirements gathered by the area and component leaders, Knowage was selected as the most suitable technology to support these challenges, leveraging the modular structure of its sub-components and integrated technologies that make it a complete visualisation suite.

##### Use Cases & examples

The Knowage-based module in DEMETER was used by all Pilots to create dashboards to their DSS. The interfaces are powered by data from the analytical algorithms implemented within WP2/WP4. The result of this activity was the implementation of a catalogue of agricultural dashboards, which saw the development and integration of more than 20 DSS dashboards. The DSS dashboards catalogue on agriculture follows the trend of the DSS areas defined in the context of WP4 and represents a list of user interfaces (UI) related to specific analytical components. The coverage areas of this catalogue range from a series of contexts ranging from Crop Growth, Status and Yield, Milk Quality to the Benchmarking, to other contexts such as Irrigation Management, Animal Welfare, Traceability and so on. The catalogue contains a list of heterogeneous visualisations, showing the

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<sup>1</sup> <https://www.knowage-suite.com/site/licensing/community-edition>

results of machine learning or computer vision algorithms to give the end-user a clear idea of what is being monitored.

#### 4.1.10 Benchmarking and KPIs

##### Description

The DEMETER benchmarking system aims to provide end-users with tools to evaluate the productivity and the sustainability of the practices adopted, as well as the efficacy of the developed digital solutions. The benchmarking components will enable the comparison for individual and peer to peer learning, linked to the impact of operational processes brought by DEMETER. The challenge of defining and measuring proper indicators has been undertaken in the implementation of the DEMETER benchmarking system to fulfil objective 04 *“Establish a benchmarking mechanism for agriculture solutions and business, targeting end-goals in terms of productivity and sustainability performance of farms, services, technologies, and practices based on a set of key performance indicators that are relevant to the farming community”*. In other words, the target of DEMETER benchmarking system is to create a framework to manage a complex set of indicators able to meet the needs of the 20 DEMETER pilots in evaluating the achievement of pilots’ objectives and the success in applying DEMETER technologies.

##### Use Cases & examples

The Benchmarking components have been published in the GitLab repository and can be installed at pilot premises, Moreover, there is an already available cloud version of the components. The benchmarking contains after the installation a list of common benchmarking indicators that have been evaluated collecting the needs of the pilots and cross-referenced with the Work Package 7 task to be the backbone to support the calculation of the farm-level KPIs of the project. These indicators include the three main areas: Economic, Environmental and Agronomic Indicators.

The Generic benchmarking on the cloud version has been integrated with the FADN database (Farm Accountancy Data Network) allowing the user for all the EU countries to query the database to define for their own farm the closest FADN categories, accessing the value of the main indicators. It has been created a User Interface that allows user with a valid DEMETER ACS account to enter the main farm data, convert them in the AIM data format and access the value of the indicators in the AIM data format. The Cloud version of the Benchmarking has been associated with an instance of the Knowage.

Online documentation (Swagger) on how Benchmarking API looks like can be found on <https://demeter-benchmarking.d.agricolus.com/doc/>

## 4.2 DEMETER Advanced Enablers

### 4.2.1 WP2 Advanced Enabler: Data Management

The Data Management module is about data storage, data retrieval process and information security management. The data management module block module consists of three main software sub-modules:

- ACS - Access control server
- DEH - DEMETER Enabler HUB
- BSE – Brokerage Service Environment

Each of these modules exposes standard APIs that depending on the case, perform specific tasks in the data management process. DEMETER data source (Data Provider) that wants to share its own

data and services interact with the data management module APIs. The data source, which in some cases translate the data into the AIM (Agricultural Information Model) data format, pushes the data to DEMETER management APIs. The entities are represented by users, resources and services; these latter entities are non-static entity that can expose specific endpoints or APIs. These APIs can be used within the DEMETER context from a Software-as-a-Service perspective by the Pilots who intend to use them for their own needs, in order to build their business scenarios. The data, acquired by the data management module APIs such as ACS (Access Control Server), DEH RRM (Resource Registry Management) and BSE (Brokerage Service Environment) are then stored in specific databases.

#### 4.2.2 WP2 Advanced Enabler: Data Preparation & Integration

The Data Preparation and Integration (DPI) Enabler<sup>2</sup> provides a simple yet powerful interface to the functionalities of data preparation & integration that are based on the use of linked data as a federated layer. The enabler has been developed through on the implementation of linked data pipelines as already described in D2.2. The enabler exposes a RESTful API that facilitates the exploitation of the pipelines' underlying components via a homogeneous layer, enabling other DEMETER enablers or enhanced entities to launch the whole Linked Data pipeline, or individual steps.

The goal of the enabler is to abstract the different types of interfaces and implementation details through an interface that is simple to use. Additionally, the enabler facilitates access to the integrated data, represented according to DEMETER AIM, available in the Data & Knowledge (D&K) repository. Accordingly, access to the data is possible in two different ways: i) via SPARQL queries directly submitted to the repository's SPARQL endpoint; ii) via the API that exposes pre-defined queries as simple access methods, which may be more convenient and require less effort from developers and client applications. The second way not only allows to execute pre-defined methods, leveraging AIM terms, but also allows users and developers to define their own queries that are converted on the fly to API methods. The enabler has been implemented as a CLI tool<sup>3</sup> and as a Web Service<sup>4</sup>.

#### 4.2.3 WP2 Advanced Enabler: Data Quality

Data Quality plays an important role in the data analytics pipeline. Before data is fed into downstream analytics and decision support tasks it has to be ensured that incoming data meets general quality criteria. Two types of data quality assessment components were implemented in Python, namely the DQA (Data Quality Assessment) component for **data quality assessment of structured data** and the DQA component for **data quality assessment of linked data**. Both need to be integrated in one single DQA service to the DEMETER platform. Both components use a JSON specification (Data-Spec) for the data source from which to load data, and a JSON specification specifying the measures to be performed on the data. Both specifications differ in certain aspects (e.g., to load structured data other parameters might be used as when to load linked data). In order to create an integrated version of the DQA, both specification types will be merged, and a small routing component will take over to delegate the DQA request to the needed component. The details about how that merging will be realized is ongoing work.

Also, we provide **Embeddable Data Quality Checks** which is an extension to the Data Quality Service, which is targeted towards Data Analytics and Data Fusion Enablers specifically. It offers a large set of

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<sup>2</sup> <https://docs.psnc.pl/display/DEM/The+architecture+of+dpi-enabler>

<sup>3</sup> <https://git.man.poznan.pl/stash/projects/DEM/repos/pipelines/browse>

<sup>4</sup> <https://dpi-enabler-demeter.apps.paas-dev.psnc.pl/api/swagger/>

quality metrics for Python-based machine learning pipelines. The library for embeddable data quality checks (DuckDQ) allows validating tabular data in different data sources, based on user-defined constraints. It is also suitable for equipping scikit-learn pipelines with data quality checks. DuckDQ stops the pipeline or generate a warning when user-defined constraints are not met. The library was implemented in Python 3.7 and uses DuckDB<sup>5</sup> as computational backend. It offers a data validation API similar to deequ<sup>6</sup> and additionally a tight integration with the scikit-learn machine learning library.

Besides, quality assessment of large RDF datasets is performed using open-source Semantic Analytics Stck (SNSA) that can scale out to a cluster of machines. SANSa inherits the following advantages from the semantic technology stack and machine learning research and distributed computing. We plan to provide examples in both standalone Scala and interactive-notebook formats using Apache Zeppelin. For example, we can assess the number of valid redirects of URIs or the number of incorrect numeric range for the given predicate and given class of subjects in a linked data (e.g., RDF). With regards to the following dimensions: availability, completeness, conciseness, interlinking, licensing, performance, relevancy, responsiveness, syntactic validity and understandability.

#### **4.2.4 WP2 Advanced Enabler: Pattern Extraction for Optimal Fertilizer Usage**

The Optimal Fertiliser Usage module tackles the challenge of estimating nitrogen status in rice and maize crops, based on indices extracted by processing UAV or satellite imagery. Advanced analytics can assist this task by estimating the level of nitrogen and consulting the farmer on whether an intervention should take place. This module is destined to be a component of a broader decision support system that consults farmers about the appropriate fertiliser usage and also on better scheduling of the aforementioned treatment, facilitating in-farm operations. The model deploys a randomized technique to choose the few most appropriate among all indices and then feed a model that estimates the aforementioned quantities. While conventional techniques try to estimate the exact Nitrogen content, this approach is based on random forest ML algorithm and subsequently, solves a classification problem. The dataset is appropriately transformed to support labelling instead of measuring. The component is implemented in Python programming language using the pandas and scikit learn libraries. As mentioned, random forest algorithm is being used to classify the plots and the final output of the component is a list of the nitrogen level in each plot included in the analysis. Specifically, there are three levels of nitrogen status, those being a) “urgent action needed”, b) “needs fertilization soon” and c) “no fertilization needed”.

#### **4.2.5 WP2 Advanced Enabler: Data Analysis for Irrigation**

This enabler takes as input UAV images of the rice field and can indicate in which places there is higher water salinity. So the farmer can identify where on the field should change the old water with fresh one. The application uses many salinity indices so that the user can choose which best fits for his needs. More specifically, a sophisticated algorithm is being implemented so that by using small number of ground salinity sensors (at least 2) we can identify the salinity levels to the rest of the rice farm field based only on UAV RGB/multispectral images. The application uses many Salinity Indices, based on literature research, so that the user can choose the appropriate index. The application can quantize the salinity index UAV image and colour it with up to 6 different colours so that it is more easily identified by the user the salinity levels on ground. Each colour stands for different salinity level range (EC) from low to high.

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<sup>5</sup> <https://duckdb.org/>

<sup>6</sup> <https://github.com/aws-labs/deequ>

#### 4.2.6 WP2 Advanced Enabler: Prediction Model Training Web Service

The Prediction Model Training Web Service enabler allows researchers / practitioners to train predictive models by machine learning tools via a web interface, validating their final performance / efficiency. The enabler is used by and integrated with the Olive Phenology Prediction Web Service module from WP4. It is not by itself deployed in isolation, yet it is deployed as an integrated part of the Olive Phenology Prediction Web Service module from WP4 mentioned above (which is currently deployed at a private cloud system).

The Models created based on this enabler are currently deployed at a private web service and are used in the pilot of VITO-Agricolus / Crop Growth, Status and Yield.

It also offers a separate user interface for model building. As already mentioned, the models created by this enabler can be integrated in prediction services such as olive phenology prediction service.

#### 4.2.7 WP2 Advanced Enabler: Pattern Extraction with Computer Vision

The pattern extraction with computer vision component provides the capability to detect specific patterns in pictures via computer vision tools. To do that, it is necessary to use a trained model to detect the desired patterns. This model can be either uploaded or generated by the component, providing, in the latter case, a rich dataset containing labelled images (which will define the quality of the results provided, depending on the number of images provided, complexity of the patterns to be identified and quality of both the images and the labelling). To detect the elements, the component needs as input an unlabelled image and it will return the areas of the images where the patterns have been identified by the model (over a given accuracy threshold).

All this functionality is provided by the enabler by exposing an API including all the possible operations with the component. The component has been developed with the objective of being compliant with AIM and, in order to do so, all its inputs/outputs are processed/created using such format. Additionally, it was integrated with MLFLOW to save/recover the data models and is currently being integrated with the core enablers of Demeter (i.e., DEH, BSE, ACS...)

#### 4.2.8 WP2 Advanced Enabler: Data Analytics "meteo/weather Forecast" component

The understanding of meteorological and climatic variables is essential for agriculture, in order to achieve the maximum production of the crop. Plants and by extension crops depend 100% on environmental conditions to be able to develop properly. All environmental and terrain parameters can become a limiting factor for growth if certain critical limits are exceeded. In agriculture, it is essential to control parameters like air temperature, relative humidity, rainfall, and the sun radiation. Other meteorological factors, such as the wind, can also be needed or even decisive in the case of very high gust values or associated with storms.

Several pilots in DEMETER need meteorological data not only to work with historical time series but also with weather forecast information. Thanks to the DEMETER architecture, a component to expose weather forecast data from trustworthy external sources (i.e., Openweather, Weatherbit, etc.) is provided by the DEH for these pilots to improve their functionalities, i.e., advising the farmers about how to optimise the irrigation in their crop fields.

This advanced enhanced enabler exposes, using DEMETER AIM data format and a REST API, hourly weather forecast data (i.e., air temperature, relative humidity, wind speed, etc.) for a given geolocation (latitude, longitude). It can use different weather services' APIs available (in most cases a new user must be registered to the weather service to get an API-key to be granted to get weather forecast data). Data is retrieved in raw format (i.e., json) and then modelled using DEMETER AIM.



#### 4.2.9 WP2 Advanced Enabler: Data Analytics for "Crop Irrigation based on ETo-Kc"

To minimize the impact of irrigation (the needed water resources and energy), an assessment must be made of the irrigation water requirement for every crop. Irrigation water requirement depends on the crop water requirement and the water naturally available to the crops (i.e., effective precipitation, soil moisture, etc.), where part can be estimated based on climatic conditions (i.e., rainwater, temperature, evapotranspiration, etc.) and part on physiological processes at plant level (i.e., the crop coefficients for the different crops and growing stages, etc.). This estimation of the crop's irrigation requirement means using data fusion with parametric mathematical models and, additionally, with machine learning techniques with different inputs for needed data from weather stations, IoT infield devices, satellite imagery, the crop plant, the soil, etc.

To this end, a component to calculate and expose a crop's irrigation requirement estimation has been developed. This advanced enabler uses a mathematical model based on an update of the procedure for calculating the reference evapotranspiration and crop evapotranspiration from meteorological data and crop coefficients, which was presented by first time in the publication of the FAO Irrigation and Drainage Series No. 24 «Crop Water Needs» and that is referred to as the "Kc ETo" approach. In this procedure, the effects of the climate on the water requirements of the crop are reflected in the crop reference evapotranspiration (ETo), obtained using the FAO Penman-Monteith method, and the effect of the crop itself incorporated in the crop coefficient (Kc). It also uses other information related with the crop, the soil, the irrigation system, and climate:

- Plot area (it is the same as the crop area) (m<sup>2</sup>)
- Crop category ("arable" or "woody")
- Number of plants (i.e., seeds planted, number of trees, etc.)
- Distance between plants in a row (m)
- Distance between rows (m)
- Crop plant family ("cereal", "poaceae", "herbaceus" or "fruit trees")
- Crop plant cup diameter (needed only for "woody")
- Soil percolating efficiency value.
- Water irrigation type ("drip" or "sprinkler")
- Water irrigation conductivity (dS/m at 25 °C)
- Rainwater (liters/day)

#### 4.2.10 WP2 Advanced Enabler: Predictive Model Training web service

Smart farming makes agriculture more efficient and effective with the help of high-precision algorithms. Those algorithms for benchmarking or prediction purposes can be obtained applying machine learning methods to representative data sets. The machine learning procedure can be simplified to the steps: independent and dependent (target) feature selection, feature analysis and model comparison. This enabler provides an interface to apply those steps over a data set selected by the user.

Technically, this tool supplies a Prediction Model Training Web Service that can be launched locally from a Docker image. More precisely, this enabler allows researchers / practitioners to train predictive models by machine learning tools via a web interface, validating their final performance / efficiency. Through the web service, the following three functionalities are available: 1. the selection of relevant input and output / target features, 2. the analysis of the selected features and the training of prediction models, and 3. the comparison of different trained models in terms of their quantitative performance / relative error on a validation data set. The enabler is currently used at least by the Olive Phenology Prediction Web Service module from WP4.

#### 4.2.11 WP2 Advanced Enabler: Data Analysis for Optimal Pesticide Usage

The Data analysis for optimal pesticide usage is a component with a REST API, using temperature and humidity data as an input to quantify and return back the instructions as a decision support to farmers. The decision support provides forecast of the fungal disease occurrence by quantifying the risk index for 4 different fungal diseases in vineyards.

Technically the tools are deployed locally as a part of the commercial service and the code is proprietary as it represents the company's IPR. Nevertheless, the dockerised version of the service without the actual access to the code is being provided within DEMETER and the integration with the hub and other DEMETER components is ongoing.

#### 4.2.12 WP2 Advanced Enabler: Fusion of Weather information

This enabler takes as input numerical data pertaining to weather (e.g. air temperature or humidity) from several sensors in a geographical area and fuses the information into an overall measure of the feature examined, using both temporal and spatial correlations of the input data. This enabler is currently in development.

#### 4.2.13 WP2 Advanced Enabler: Model Management and AIM-Compliant Serving

**Model Management** is an essential component of a modern, production Machine Learning infrastructure. Model Management solutions are concerned with storing and versioning Machine Learning experiments in a multi-user setting. The Model Management component is intended to be used by ML-training scripts of Targeted Analytics/Fusion Modules in order to store ML-Models (and associated metrics) in a managed way. Apart from an on-premises deployment, the DEMETER Model Management component is also available as managed service, hosted by Fraunhofer FIT. This service is available to all DEMETER developers but is meant for testing purposes only. For more info on the design of the MLFlow-based Model Management server, visit: <https://demeter.fit.fraunhofer.de> (user: 'admin', pw: '|mlflow@123|').

The **AIM-compliant Serving** component is complementary to the Model Management component. Models which were registered using the Model Management component can be fetched with an AIM-compliant Serving module and generate predictions on-demand. The result of the prediction will be returned in AIM-format, while the input data will be checked for quality, using the Embeddable Data Quality component. This establishes a standardized but flexible way to access data analytics and data fusion enablers. It also allows for a better integration with downstream components such as the DSS, while maintaining semantic interoperability between all these services by using AIM format to send and receive data.

#### 4.2.14 WP2 Advanced Enabler: Traceability

Following up on the Access Control System (ACS) presented earlier in this document and which forms the heart of the DEMETER authentication and authorization, two other enablers have been developed that tie together with ACS to provide additional functionality. The first one is the authentication and authorization traceability component; this enabler logs the access to DEMETER resources by logging the issue and use of authentication and authorization tokens. These tokens contain the information about the user who is logged to the system and the resources the user is intended to access.

The traceability agent exposes a REST API to register authentication and authorization events (POST) and retrieve their details (GET). The REST API has been designed to use traceability Ethereum/Quorum blockchain repository. The events logged contain information about the receiver



of the token, the sender of the token, the timestamp, the token details, and an optional data field to extend the information of the event.

A permissioned version of a blockchain repository has been chosen to provide the characteristics of immutability, privacy and compatibility required by the DEMETER Traceability Component. It supports both public and private transactions and smart contracts, and their states derived from a single, common, complete blockchain for transactions validated by every node in the network. Thus, using this enabler it is possible to trace back any (authorised) access to various enablers and components of DEMETER.

#### 4.2.15 WP2 Advanced Enabler: Confidentiality

The second related enabler provides Confidentiality and encryption of (private) data and is provided by the Communication Encryption Enabler. It is based on ComNet, a cryptographic class library written in C++. It can perform encryption and decryption of textual elements inside an xml or json file. The library can be compiled on both Windows and Linux operating systems, and can be easily imported in a new or existing project.

The access point to the functionalities of the library is a method (startEnabler) which accepts as inputs the following elements:

- A number to identify the type of file to be considered (10 for a json file and 11 for a xml file).
- The path to the file the program has to read, minus the file name and the extension.
- The name of the file, minus the extension.
- A list containing the labels corresponding to the values to be encrypted (or decrypted) inside the file.
- A number to specify the type of action to be performed on the values (20 for encryption and 21 for decryption).
- The encryption/decryption key to be used.

Once called on a file, the library shall encrypt or decrypt the values corresponding to the labels taken as input, and produce a new file (appending the text “\_ENCRYPTED” or “\_DECRYPTED” to the file name, accordingly) into the same folder of the original one. The Encryptor and Decryptor components of the library make use of the open-source C++ class library Crypto++, whilst base64 encoding is used on the encrypted text for a better display.

#### 4.2.16 WP4 Advanced Enabler 4.A.1 – Plant Yield Estimation

The yield prediction component will receive a field as input, including attributes such as geometry and crop information (with start date of crop). A request can be made against the field which will return the predicted yield. The request can only be made 1 to 4 weeks before expected harvest date. Yield prediction is currently based on NDVI/Fapar timeseries derived from Sentinel-2, but meteorological data will be added in the future. This yield prediction component at the moment only includes functionality to predict the yield based on a pre-trained model. An additional module is being added allowing the user to train his/her own yield prediction model based on his/her own training data.

#### 4.2.17 WP4 Advanced Enabler 4.A.2 – Plant Phenology Estimation

The DSS component on Plant Phenology Estimation provides the farmer with a prediction of the olive phenology state for the next six days. In other words, it allows the farmer to estimate the best day to harvest as well as being a tool to monitor growing conditions. The internal functionality design of this component is based on data extracted from external weather API Meteostat. The final

output of this component is presented to the farmer using the DEMETER visualisation and adaptive framework module, Knowage. In addition, this DSS component employs a previously trained Random Forest Model, a model that has been constructed using the DSS of the WP2 Prediction Model Training Web Service Enabler.

#### **4.2.18 WP4 Advanced Enabler 4.A.3 – Plant Stress Detection**

Plant stress can come from many causes such as: extreme temperatures (scorching heat and winter harshness), lack/excess of water, etc. The composition of the NDVI vegetation plan will be used as a modern method of determining plant problems. Plant Stress Detection is responsible with detection of plant stress using a combination of remote sensing data, meteorological data and in-situ data. The main functionalities of this component are to automatically locate on the map the less favourable areas from a cultivated plot, but also to estimate the vegetation condition. The indication of the affected areas by various factors will be done by taking NDVI images from Terrascope service and applying automatic pixel classification method. The classification of pixels involves the process of grouping them into 3 categories according to the values of the vegetation index: Low Stress Detected, Medium and High. Another agropedoclimatic parameter is the intensity of the heat during the summer and the harshness of the winter in the cold season. Its calculation is done by a mathematical algorithm that gathers the degrees that exceed a certain threshold, in a certain number of days.

#### **4.2.19 WP4 Advanced Enabler 4.A.4 – Crop Type Detection**

The goal of this component is to detect the crop type for a given polygon and a given timeframe (growing season of the crop), using Sentinel-1 and Sentinel-2 time series data as input. The model for crop type detection in this component is implemented as a Recurrent Neural Network (RNN) using the TensorFlow deep learning framework. A recurrent architecture is chosen because we need to take into account not just individual images, but timeseries of images. Instead of looking at individual pixels in the field, the timeseries is composed of data averaged over the parcel, e.g., 1 NDVI value per field per timestep. The crop type prediction component is by default equipped with a crop type detection model trained for the most common crop groups in Western-Europe based on training data from Belgium. However, a user also has the possibility to provide a custom model, as long as it solely uses Sentinel-1 and Sentinel-2 timeseries as model inputs.

#### **4.2.20 WP4 Advanced Enabler 4.A.5 – Estimate Beehive**

The Estimate Beehive component will receive a field as input, including attributes of the field that may affect the calculation of pollination requirements. Once the field has been registered with the component, a request can be made against the field which will return the estimated number of beehives required to optimally pollinate the identified field.

#### **4.2.21 WP4 Advanced Enabler 4.B.1 – DSS for Irrigation Management**

The DSS component for Irrigation Management provides the farmer with information to estimate the irrigation water needed for a crop using other components and data retrieved from the pilot cloud platform. The final output of this component is presented to the farmer using the DEMETER visualisation and adaptive framework Knowage module.

#### **4.2.22 WP4 Advanced Enabler 4.B.2 – Reference Evapotranspiration Prediction**

This component presents a solution for the prediction of the reference evapotranspiration ( $ET_0$ ). This component uses an ensemble prediction model to estimate the  $ET_0$  based on the *Penman-Monteith* model using weather forecast and historical data (temperature, humidity, wind speed, and solar radiation) for a given location (latitude, longitude, and elevation) from trustworthy external sources (i.e., OpenWeather, Weatherbit, AEMET, etc.), and predictive time series models such as naive approaches to complex autoregressive neural nets.

#### 4.2.23 WP4 Advanced Enabler 4.B.3 – Soil Moisture Estimation

This component presents an optical trapezoidal model (OPTRAM) algorithm to infer the surface soil moisture with physical units using ML techniques and data fusion with remote sensing using satellite multispectral imagery and local sensing using ground soil moisture probes data.

#### 4.2.24 WP4 Advanced Enabler 4.B.4 – Crop Water Status Anomalies Detection

This component provides the farmer with information to estimate the needed irrigation water for a crop using other components. It presents a solution for plant water status anomalies detection. This component, developed in R language, is based on multispectral analysis of images provided by Sentinel-2 satellite. The images, corresponding to the crop over several seasons, are compared with the last image obtained to classify using ML the pixels in several categories according to the expected behaviour extracted from the history of the same crop or the adjacent ones.

#### 4.2.25 WP4 Advanced Enabler 4.C.1 – Nitrogen Balance Model

This component describes a crop nitrogen balance model that estimates crop nitrogen requirements and provides the scheduling of fertilisation. SIMAVI (pilot 1.4 DSS to support maize crops) will develop a nitrogen balance model which will be integrated in platform along with remotely sensed indices. This model can be used by other pilots dealing with fertilisation management. A component that estimates crop nitrogen needs and the crop fertilisation scheduling during the season to optimise nitrogen fertilisation, avoiding nitrogen excess. The main input for this component is NDVI satellite imagery. The images from the Terrascope service are passed through a supervised classification process through which 3 areas are obtained: Optimum nitrogen level, Medium and low. The amount of fertilizer is transmitted in the form of text, following a mathematical algorithm that has as parameters such as: previous crop, soil type, climate type, etc. The information will be transmitted automatically, only if all the parameters have been completed by the farmer. All previous values will be kept, so that, when queried, the last record will be sent. Another useful recommendation for the farmer is the one related to the weather conditions. Based on the weather forecast, the decision will be made whether it is an optimal time for the nitrogen distribution or to postpone the agricultural works.

#### 4.2.26 WP4 Advanced Enabler 4.C.2 – Nutrient Monitor

The Nutrient monitor component estimates the quantity of crop seeds to be applied to different areas. The analysis performed by the DSS takes into account data samples from two types of sources: data from farmers such as field coordinates and geometry etc.; and data from external systems such as satellite images and weather forecasts. The analysis of the parameters will determine recommendations for the future planting, allowing an increase in agricultural productivity.

#### 4.2.27 WP4 Advanced Enabler 4.D.1 – Emission

The component on emissions will receive engine data as input, including data from the engine after treatment system. This data will be analysed and as an output there will be an overview of the status of different engine conditions. In case of malfunctions there will be instructions and/or recommendations for the farmer.

#### 4.2.28 WP4 Advanced Enabler 4.D.2 – Field Operation

The component provides the table with a list of drivers and list of machines with details about the driver behaviour, machine distance covered and vehicle average speed. The components receive data about latitude, longitude, speed, breaking and fuels consumption as an input in the DEMETER AIM format. These data are then analysed, and the output of the classification process is then provided to the dashboard output including the data about the users' behaviour, distance covered and average speed. The component is generic in a sense it can be used not only for field operations,

but with slight adaptation it can be employed in any use cases involving transport, where it is necessary to monitor the driver behaviour, or the performance of the vehicles (for low fuel consumption, high-risk and sensitive merchandise, etc.).

#### **4.2.29 WP4 Advanced Enabler 4.D.3 – Variable Rate**

The variable rate application component provides a taskmap in AIM format, based on a WatchItGrow service that generates a polygonization of a Sentinel-2 NDVI image. Each individual polygon within the field will receive its own variable rate value. The component will start a flask server on localhost:5000, to which you can send a HTTP POST request containing, as payload, an AIM JSON object holding the field information, notably the field geometry, and a Treatment description containing a base application rate and also the definition of the application width of the field machinery that will execute the variable rate actions. The service will then check for a cloud-free Sentinel-2 NDVI image for the 30 days prior to the date specified in the Treatment “interventionStart” parameter. All acquisition dates with a minimum 95% of cloud-free pixels are withheld, and of those dates the last one is chosen to retrieve the NDVI information.

#### **4.2.30 WP4 Advanced Enabler 4.E.1 – Pest Estimation with Sterile Fruit Flies**

The Pest Estimation with Sterile Fruit Flies component aims at monitoring the fruit fly pest tracking providing an estimation of the current and future population. To do so, this DSS component has been designed to receive images taken from fruit fly traps and get an estimation of the flies captured. This estimation is carried out by using a WP2 component (pattern-extraction-with-computer-vision) that performs element identification in images from a trained model. This module keeps track of the different estimations over time and calculates a tendency based on the last observations.

#### **4.2.31 WP4 Advanced Enabler 4.E.2 – Estimate Temperature-related Pest Events**

The DSS component on the estimation of temperature-related pest events provides the farmer with a prediction of the occurrence and of the trend of pest flight. As target species, the olive fruit fly (*Bactrocera oleae*) has been selected since it is the most harmful pest of the olive tree causing dramatic quality deterioration and product loss. The component is focused on specific pest events: (i) absence (no flight), (ii) start of the flight, (iii) peak of the flight, (iv) end of the flight. The broader aim of this component is that it should be easy to apply to other pests and crops.

#### **4.2.32 WP4 Advanced Enabler 4.F.1 – Estimate Milk Production**

The Estimate Milk Production component will receive milking events for an individual cow as input, including attributes describing the individual cow’s current lactation. The component then returns a forecast describing the estimated yield still remaining in the current lactation.

#### **4.2.33 WP4 Advanced Enabler 4.F.2 – Poultry Feeding**

This component presents the overall animal feeding quality based on a food and water level in the silo with estimated water and food consumption intake. The component provides the UI dashboard with food level in the silo with estimated consumption. The animal feeding quality can be then assessed by farmers based on the level of the food in the silo.

#### **4.2.34 WP4 Advanced Enabler 4.G.1 – Estimate Animal Welfare Condition**

The DSS module on animal welfare makes it possible to evaluate the state of health of the analysed cows to determine the degree of well-being, in terms of nutrition, hygiene, rest and movement and consequently also to evaluate their productivity (which is strictly connected to their welfare).

The information flows, containing the data relating to the nutritional and milking values of the milk produced by the livestock farm, and those relating to the activities and rest periods of the analysed

cows, are acquired by Knowage module, which processes them both to visualise the results of the training and prediction algorithm analysis. The data related to cows' health status, based on the pathologies like ketosis, mastitis, and lameness, obtained by processing data from the Random Forest algorithm, are shown in a dashboard hosted by the Knowage module. The DSS dashboard provides the monitoring of the health status of the livestock using graphical widgets. Through this DSS, the farmer can establish their current health status, by means of specific ML predictive algorithms. Through these predictions the farmer can understand and optimise the health of the herd.

#### **4.2.35 WP4 Advanced Enabler 4.G.2 – Poultry Well-Being**

This component for poultry well-being provides the overall poultry stress based on parameters from environment and patterns detected from environment and video/ microphone. The component provides the UI dashboard with the following data: Air temperature, Humidity, Air flow, Light intensity, CO<sub>2</sub>, Power losses, Animal species, Detected stress level, Flock age, Safety instruction.

#### **4.2.36 WP4 Advanced Enabler 4.H.1 – Milk Quality Prediction**

The DSS on Milk Quality Prediction, within the milk processing chain, allows to evaluate the analysis of raw and processed milk samples coming from dairy farm, to determine the quality level of the milk, thus identifying the goodness both of the milk arriving at the processing company and of the processed milk ready for packaging, in order to understand if and what choice to make in order to improve its quality.

The analysis of the milk samples considered by the DSS is related to two main events: samples collected on arrival of the tanker before unloading, and samples collected before packaging.

The samples are processed by Pilot machinery, a device which analyses them using FTIR (Fourier Transform InfraRed Transform) spectroscopy. The DSS dashboard, produced using adaptive visualisation module (T4.3), provides monitoring of the quality degree of milk using Knowage graphical widgets. This DSS enables the farmer to establish the current level of milk quality, by means of specific predictions of Machine Learning algorithms. These predictions enable the farmer to understand and optimise the quality of the milk produced by their whole herd.

#### **4.2.37 WP4 Advanced Enabler 4.H.2 – Transport Condition**

This component for transport condition covers the post-farm cycle for poultry and it provides output of the classification for the environmental conditions during the transport. The overall assessment of the environment based on parameters collected from IOT devices enables direct insight to farmers and involved stakeholders over the UI dashboard if transport conditions are meeting the requirements.

#### **4.2.38 WP4 Advanced Enabler 4.H.3 – Field Book and FaST**

The Field Book and FaST component will record information about farms, including all the information related to phytosanitary treatments. This field book is currently being done on paper, which is a tedious process and does not allow this information to be exploited properly. Each region, even those within the same country, requires different entries, so the main objective of this component is to make it easier for the farmers to maintain this field book by providing them with a tool that allows them to do it digitally and that can be adaptable to the different mandatory entries.

#### **4.2.39 WP4 Advanced Enabler 4.I.0 – Indicator Engine for Benchmarking Purpose**

The main target of this component is the management of indicators to evaluate the efficacy of the practices adopted and of the digital solutions delivered to boost economic, environmental, and agronomic sustainability at the farm level. Indicators managed with this component, will be used in “generic farm comparison”, “neighbour benchmarking” and “technology benchmarking”

components described in the following paragraphs. The indicator engine component (i) publishes and keeps track of the list of indicators defined in D4.3, (ii) enables pilot developers to calculate the indicators and to extend the list of indicators following the provided framework, (iii) stores the indicator results if the values are needed for benchmarking components.

#### **4.2.40 WP4 Advanced Enabler 4.1.1 – Generic Farm Comparison**

The DSS component “generic farm comparison” provides a set of basic economic indicators (plus simple agronomic indicators) to obtain a basic benchmark of the farm economic activities. This component is usable by all EU farms, as it requires a minimum set of requested inputs. This component has been designed to provide a benchmark solution reducing the amount and the quality of data required to calculate economic indicators, since it delivers economic comparisons even if the farm has no data to share. The economic indicators provided by this component allowing farm comparisons are based on the database of Farm Accountancy Data Network (FADN) which delivers a set of reference values calculated with data of similar farms (e.g., same area, similar surface per crop) belonging to the FADN network.

#### **4.2.41 WP4 Advanced Enabler 4.1.2 – Neighbour Benchmarking**

The DSS component on the neighbour benchmarking allows a group of farms belonging to the same area and of the same typology (e.g., DEMETER pilot, consortia, cooperatives) to share data in order to compare performance. The component provides comparison of agronomic, economic, and environmental indicators.

#### **4.2.42 WP4 Advanced Enabler 4.1.3 – Technology Benchmarking**

The aim of DSS component - technology benchmarking is to support the general DEMETER Objective 3: “Establish a benchmarking mechanism for agriculture solutions and business, targeting end-goals in terms of productivity and sustainability performance of farms, services, technologies, and practices based on a set of key performance indicators that are relevant to the farming community”. The component has therefore two potential types of use: (i) allow a farmer or a group of farmers to evaluate the impact of a technology in terms of agronomic, economic, and environmental sustainability (e.g., compare the value of a specific indicator before and after the adoption of a technology); (ii) support the overall DEMETER benchmarking by using data collected at the farm/pilot level for the calculation of the DEMETER KPIs.

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<sup>i</sup> H2020 Call Objective H2020-DT-2018-2020 TOPIC: Agricultural digital integration platforms, <https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/dt-ict-08-2019>