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Comparative analysis of KDPs resources versus RMIS 2.0 needs

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GENERAL INTRODUCTION

The aim of Mintell4EU work package 5 entitled '**Improvement of KDPs' applications and interaction with the RMIS and the GeoERA Information Platform**' is **to set up the rules of communication/interaction** between the existing Knowledge Data Platforms (KDPs) and their applications, developed within EU-FP7 and H2020 projects, and the Raw Materials Information System (RMIS) version 2.0 launched in November 2017 by the European Commission DG JRC. The ambition of the RMIS 2.0 is to become '**the one-stop information gateway and knowledge service centre** for non-energy, non-food primary (e.g., extracted through mining) and secondary (e.g., recycled, recovered from mining waste) raw materials and materials/commodities.'

Together the different KDPs constitute the European Union Raw Materials Knowledge Base (**EURMKB** – see the EIP-SIP) that will be 'exploited' by the RMIS. The RMIS is thus both a **high-level application producing knowledge** through exploitation of the EURMKB in parallel with the exploitation of external sources and a **high-level interface toward end users**.

Work package 5 will (i) define how structured data and information and non-structured information and knowledge can be delivered to, and be exploited by the RMIS 2.0 via its thematic interface(s), using either web services such as WMS and WFS (possibly coupled with ETL process), or more sophisticated and dedicated Application Programming Interfaces (APIs) and (ii) design the prototypes of such applications, having in mind key-functions of the RMIS such as providing information for the Raw Materials Scoreboard.

This report examines and assesses the different situations, whether structured or unstructured data, aggregated data, services or applications already developed or under development, and how the RMIS could benefit - in a simple, effective and perennial way - of these data, information and services. On the other hand, it does not enter into the detail and the complexity of the datasets, aspects that will be addressed in the other tasks of the work package 5 (e.g., in particular T5.3 which will deal in detail with the automation and the integration of the e-Minerals Yearbook and T5.4 which will address in detail the case of the Scoreboard's feed).

EXECUTIVE REPORT SUMMARY

Most of the KDPs recently developed (e.g., the IKMS for REE (EURare), the EU-MKDP for all deposit types (Minerals4EU), the EU-UMKDP for the urban mine (ProSUM), the EU-CRMKDP for CRMs (SCRREEN) are providing data and information and generally store and manage thematic unstructured Knowledge. Some of them have sophisticated applications to exploit their contained data e.g., the e-Minerals Yearbook included in the Minerals4EU geospatial portal and the e-Stat ProSUM module, which now looks like a standalone application and has been renamed 'the Urban Mine Platform'. Different in its spirit and design, the EU-RMICP (Raw Materials Intelligence Capacity Platform) developed in the frame of the H2020 MICA project (and connected to other above mentioned platforms) is an ontology-based Expert System that can act as a decision-aid tool on all questions related to mineral resources.

All these 'services' and 'applications' are of interest to the RMIS, knowing that the RMIS cannot maintain this data and the harvesting systems or compilation processes that are behind them. The platforms must therefore maintain a certain autonomy, under the control of their original consortium, to ensure all the necessary evolutions (data and architecture) to their survival and thus also that they can feed the 'super architectures' such as the EGDI and the RMIS.

The WP5 task T5.1 entitled 'Comparative analysis of KDP's resources versus RMIS 2.0 needs' will thus examine how KDPs can/should deliver their resources to the RMIS. This report will focus on three main objects:

- **Data** (all platforms): Two types of data are considered, those related to primary resources and those related to secondary resources. The latter include mine waste on one side and the urban mine (WEEE, ELV and spent batteries) on the other. This task will examine how these data can be utilised by the RMIS and what are the implications for this in terms of selection, format, and conveyor.

- **Applications** - with a focus on the e-Minerals Yearbook and the ProSUM e-Stat module: what are the needs of the RMIS? Raw data for their incorporation in in-house applications for building for example indicators or pre-computed views?

- **Knowledge** (all platforms): the idea is to facilitate the RMIS to carry out powerful thematic searches within non-structured knowledge related to REE, CRM, mineral deposits, the urban mine, etc. which is managed by the KDPs, in addition to more generic web-related searches.

The assessments made in this report show that there are several ways to deliver data, information and knowledge from existing platforms to the RMIS. This report tried to evaluate the possible solutions and to compare them, in terms of ease of implementation, maintenance and sustainability and therefore cost.

Results can be summarized as follows:

- For structured data related to primary resources and delivered by the Minerals4EU EURare and SCRREEN platforms, the use of standard web services (WFS) coupled with an ETL process is not recommended because of the difficulty of implementation and maintenance. Implementing such an ETL process supposes that the data model is stable and the data format will not change over time. It is like a kind of bet on the future, with absolutely no certainty. The development of a dedicated API, based on a full-fledged data model, relatively simplified, but nevertheless very complete and fully operational such as ERML-Lite[1] seems on the other hand possible. This would allow the ScoreBoard developers to carefully select the data they need.
- For structured data related to Mining Wastes (secondary resources) the recommendation is the same, as they can also be 'managed' through ERML-Lite.
- For structured data related to the Urban Mine (WEEE, ELV and BATT), and dealing with data on products and stocks, flows and composition, the development of a dedicated API is recommended, in synergy with the SCRREEN project. Pre-computed views based on those prepared for the Urban Mine Platform could be added if necessary.
- For structured data aggregated at the national level and harvested in the frame of the automation of the e-Minerals Yearbook developed by Minerals4EU, the recommendation would also be to develop a dedicated API, with possibly pre-computed views based on those presented in the Minerals4EU portal. This task can benefit from the synergy with the ORAMA project.
- For knowledge from EURMKB Knowledge Bases, the solution seems clearly to develop in collaboration with the SCRREEN project a dedicated OpenSearch API which would allow the RMIS searching and extracting knowledge from already constituted corpus related to REE, CRM, occurrences, mineral and ore deposits and mines, wastes…
- For wisdom or intelligence, and for having a decision-aid tool, the RMIS via its own Search Capability can be connected with the ontology-based MICA Expert System. This connection operates via the creation of new Sheets related to the RMIS 'hot' topics and JRC' skills, which are entered and indexed by the MICA System. This type of connection is currently being tested within the SCRREEN project for CRM, and the acquired experience can be easily transferred to Mintell4EU for a possible extension to other topics under consideration.

Note that through the GeoERA Information Platform Project (GIP-P) the e-Minerals Yearbook will be integrated into the European Geological Data Infrastructure (EGDI) in which data from Minerals4EU and EURare are also already integrated.

[1] See: http://earthresourceml.org/: EarthResourceML-Lite is a model and schema for simple map services (eg, WMS and WFS Simple Features). It is an abridged version of the full EarthResourceML model and can be used to deliver simplified views on mineral occurrences and their commodities, mines, mining activities and mine waste products.

GLOSSARY OF KEY-TERMS USED IN WORK PACKAGE 5

API: an **Application Programming Interface** is a set of functions and procedures allowing the creation of applications that access the features or data of an operating system, application, or other service.

BATT: Spent batteries (secondary resources).

Catalogue services support the ability to publish and search collections of descriptive information (metadata) for data, services, and related information objects. Metadata in catalogues represent resource characteristics that can be queried and presented for evaluation and further processing by both humans and software. Catalogue services on the Web (**CSW** or **CS-W**) are required to support the discovery and binding to registered information resources within an information community. (OGC definition: http://www.opengeospatial.org/standards/cat).

CORS: Cross-origin resource sharing is a mechanism that allows restricted resources on a web page to be requested from another domain outside the domain from which the first resource was served. A web page may freely embed cross-origin images, stylesheets, scripts, iframes, and videos. Certain "cross-domain" requests, notably Ajax requests, are forbidden by default by the same-origin security policy. CORS defines a way in which a browser and server can interact to determine whether or not it is safe to allow the cross-origin request. It allows for more freedom and functionality than purely same-origin requests, but is more secure than simply allowing all cross-origin requests.

Data model: A **data model** organizes data elements and standardizes how the data elements relate to one another. The ProSUM unified data model, as well as the **INSPIRE MR data model**, is an entity-relationship model (ERM). This is an abstract conceptual data model (or semantic data model) used in software engineering to represent **structured data**. This model is transformed into a relational model, which in turn is implemented in a relational database management system. These conceptual entity/relationship models are developed using **UML** Class Diagram notation. Thus, **data models describe the structure, manipulation and integrity aspects of the data stored in data management systems such as relational databases. They typically do not describe unstructured data**, such as word processing documents, e-mail messages, pictures, digital audio, and video.

Diffusion database: The role of the (Central) Diffusion Database (DB) is to provide the ProSUM portal with data. These data are sent to the portal using Web services (**WFS, JSON**). In order to speed the process, the structure of the Diffusion DB is optimized for diffusion. This means that its structure does not follow exactly the **data model** which has been 'flattened' or simplified without altering the data. For this project, the (Central) Diffusion DB is hosted by BRGM in France. At the origin – before optimization – the **Diffusion DB** is a copy of the **Harvesting DB** made by using **SQL** scripts.

Distributed architecture means that the data served by the platform are regularly uploaded from data providers (national data provider or EU provider…) through a 'harvesting' system using web services. Data are sent to a central database (DB) (actually composed of two distinct DBs, one being dedicated to harvesting, the other one to diffusion) which only acts as caching mechanisms. The central database is used to minimize the drawbacks of a pure distributed architecture: a user of the system may search for occurrences of commodities throughout Europe; in case all information is available on distributed servers, such a query will have to be executed at every data provider, resulting in a high risk of low performance. Therefore the data is stored centralized to act **as an optimized search index**. It also reduces the risk of having actually inaccurate results if local services are down or unreachable.

EGDI: European Geological Data Infrastructure (http://www.europe-geology.eu/). EGDI is developed by members of EuroGeoSurveys (the organization of geological surveys in Europe) and organizes and gives access to results from a number of current and previous projects on mineral resources, geo-energy, groundwater, geochemistry, geophysics, geohazards, etc. EGDI will be extended to support data and other results from all GeoERA projects.

ELV: End-of-Life Vehicles (secondary resources).

ERML or **EarthResourceML** data model: This is the 'international – world-wide' fully compliant version of the **INSPIRE MR** data model (http://www.earthresourceml.org/). This data model is managed by the IUGS/CGI/ERMLWG and used in Europe, North America and Australia.

ETL: Extract, Transform and Load process in database management that performs data **extraction** from homogeneous or heterogeneous data sources; data **transformation** for storing in the proper format or structure for the purpose of querying and analysis; and data **loading** into the final target.

EU-CRMKDP: the European Union Critical Raw Materials Knowledge Data Platform developed in the frame of the H2020 SCRREEN project.

EU-MKDP: the European Union Minerals Knowledge Data Platform developed in the frame of the EU-FP7 Minerals4EU project. This platform serves data related to primary resources and also mining wastes.

EU-UMKDP: the European Union Urban Mine Knowledge Data Platform developed in the frame of the H2020 ProSUM project. This platform serves data related to secondary resources, and in addition to urban mine data related to WEEE, ELV and BATT, it also serves data related to mining wastes and thus communicates with the EU-MKDP through web services (mostly **WFS** & **WMS**), in order to avoid any data duplication.

EU-RMICP: The European Union Raw Materials Information Capacity Platform developed in the frame of the H2020 MICA project. This Platform **lays the foundation of a modern expert system for the raw materials domain** with notably an ontology-based Dynamic Decision Graph and a database of methods and tools used in mineral intelligence, in geology and mining. In practice, the system helps a user to gain understanding and to find information on almost any topic related to mineral resources and the whole supply chain from prospecting to recycling, taking into account the environmental, political and social dimensions.

GeoSciML: The **GeoSciML data model** is an XML–based (conversion of a **UML** package) data transfer standard for the exchange of digital geoscientific information. It accommodates the representation and description of features typically found on geological maps, as well as being extensible to other geoscience data such as drilling, sampling, and analytical data (see: http://www.geosciml.org/).

Harvesting system: The **Minerals4EU (Central) Harvesting System** including the database periodically refreshes the information available about mineral resources by requesting data from the data providers using INSPIRE compliant Web services (**WFS**). This DB is structured in such a way that a large part exactly reflects the **INSPIRE** Mineral Resources (MR) data model, but it also includes the ProSUM mining waste modifications. During the harvesting phase the data that is received is checked whether code lists conform to the INSPIRE registry code list values and other data have the correct format (e.g., dates, numbers…). The **Minerals4EU Harvesting DB** is hosted by the Geological Survey of Slovenia (GeoZS) and connected to the **Diffusion DB** using **SQL** scripts. This Harvesting DB delivers data related to primary mineral resources and mining wastes. **The ProSUM Harvesting DB** has been built using the **ProSUM unified data model**, and is dedicated to the urban mine (WEEE, ELV & BATT). It is hosted by the Geological Survey of Danemark and Greenland (GEUS) and data is currently extracted from Excel sheets that have a standardized format (**portrayals**) provided by the different ProSUM work packages.

IKMS: Integrated Knowledge Management System developed in the frame of the EU-FP7 EURare project. This platform serves data related to REE in Europe.

INSPIRE: The INSPIRE directive lays down a general framework for a Spatial Data Infrastructure (SDI) for the purposes of European Community environmental policies and policies or activities which may have an impact on the environment. The INSPIRE Directive entered into force on 15 May 2007. INSPIRE is based on the infrastructures for spatial information established and operated by the Member States of the European Union. The directive addresses 34 spatial data themes needed for environmental applications, among which Mineral Resources and Geology. To ensure that the spatial data infrastructures of the Member States are compatible and usable in a community and transboundary context, the INSPIRE Directive requires that additional legislation or common Implementing Rules (IR) are adopted for a number of specific areas (metadata, interoperability of spatial data sets and services, network services, data and service sharing and monitoring and reporting). These are published either as Commission Regulations or as Decisions. See: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007L0002&from=EN

INSPIRE MR data model: This is the European approved data model for mineral resources (MR), including both primary and secondary (i.e., Mining wastes) resources. However, mining wastes do not belong to the core part of this data model, being only an extension. One objective of the ProSUM project has been to improve and extend the mining wastes part of the INSPIRE MR data model:
http://inspire.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_MR_v3.0.pdf (See ProSUM deliverable D5.5). The mineral resources data model used

in ProSUM is the M4EU data model (Minerals4EU project) directly derived (with **GeoSciML** extensions for geology) from the INSPIRE MR data model.

JSON (**JavaScript Object Notation**) is a data-interchange format. Although not a strict subset, JSON closely resembles a subset of JavaScript syntax. Though many programming languages support JSON, JSON is especially useful for JavaScript-based apps, including websites and browser extensions.

Modal: In user interface design for computer applications, a **modal window** is a graphical control element subordinate to an application's main window. It creates a mode that disables the main window, but keeps it visible with the modal window as a child window in front of it. Users *must* interact with the modal window before they can return to the parent application. This avoids interrupting the workflow on the main window. Modal windows are sometimes called heavy windows or modal dialogs because they often display a dialog box.

SQL (script): **SQL** or **Structured Query Language** is a special-purpose programming language designed for managing data held in a relational database management system (RDBMS), or for stream processing in a relational data stream management system (RDSMS).

Structured data refers to any data that resides in a fixed field within a record or file. This includes data contained in relational databases and spreadsheets. Structured data first depends on creating a **data model**, i.e., a model of the types of business data that will be recorded and how they will be stored, processed and accessed. This includes defining what fields of data will be stored and how that data will be stored: data type (numeric, currency, alphabetic, name, date, address) and any restrictions on the data input (number of characters; restricted to certain terms...). Structured data has the advantage of being easily entered, stored, queried and analyzed.

ToolStack refers to a set of tools/softwares needed to perform a complex task such that no additional tools/softwares are needed to support this task.

UML, the **Unified Modeling Language** is a standardized general-purpose modeling language in the field of software engineering. It is a graphical language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system.

Unstructured Data (or **unstructured information**) refers to information that either does not have a pre-defined data model or is not organized in a pre-defined manner. Unstructured information is typically text-heavy, but may contain data such as dates, numbers, and facts as well. This results in irregularities and ambiguities that make it difficult to understand using traditional programs as compared to data stored in fielded form in databases or annotated (semantically tagged) in documents.

Web service: is defined by the World Wide Web Consortium (W3C - https://www.w3.org/) as 'a software system designed to support interoperable machine-to-machine interaction over a network'. Several types of web services are used by the EU-UMKP such as Web Feature Services (**WFS**) allowing the transfer of data, and Web Map Services (**WMS**) allowing the visualization of maps.

WEEE: Waste Electrical and Electronic Equipment (secondary resources).

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1 THE RMIS 2.0 GENERAL ARCHITECTURE AND ITS LINK WITH THE EURMKB

The wording used in the publication entitled ‘Raw Materials Information System (RMIS): Towards v2.0 – An interim progress report & roadmap (Manfredi et al., 2017) for describing the relationships between the RMIS and the EURMKB (European Union Raw Materials knowledge Base – European Commission, 2013) is sometimes confusing for an external reader.

In some places, it is clearly said that the *‘RMIS provides an entry point to the EURMKB’*, and that the EURMKB itself *‘aims at providing EU level data and information on raw materials from different sources in a harmonized and standardized way’.* However in some other places, the RMIS is ‘located’ in the center of the EURMKB, or it *‘acts as a core to the EU Knowledge Base, facilitating the availability of data and information in a coordinated manner.’*

This wording, which is very likely used to stress/emphasize the importance of the RMIS role, contributes to generate confusion particularly when attempts are made to understand and graphically represent the EURMKB-RMIS relationships.

If the intention is that the RMIS 2.0 becomes ‘*a one-stop information gateway’*, i.e., an entrance or an access to information sources and knowledge, then it would be better represented as an interface making the link between the end users and the data and knowledge repository represented by the EURMKB (Figure 1).

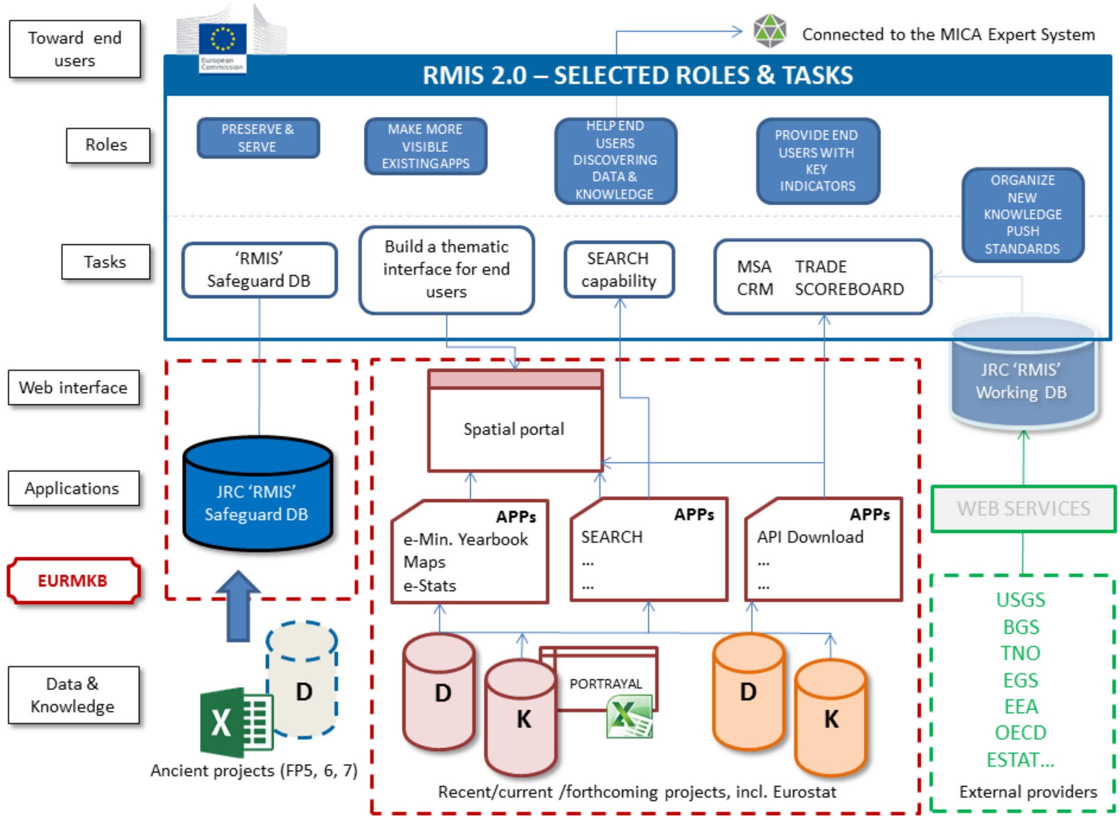

Figure 1. The RMIS 2.0 with some of its most striking roles and tasks, and the ways it can use data, knowledge and applications stored in the EURMKB, from both national and European levels, and exploit external sources.

Some key points related to the general architecture of the whole 'RMIS and EURMKB' system are worthy of note:

- The EURMKB is seen here as a composite of layers, including (i) databases for structured data (D) and unstructured data (K for knowledge), (ii) applications or services (e.g., map viewer, search and download capabilities, dedicated statistical modules like the e-Minerals Yearbook…) and (iii) web interfaces, such as spatial portals. This description complies with the vision of the EURMKB expressed in the Strategic Implementation Plan (SIP) for the European Innovation Partnership (EIP) on Raw Materials (European Commission, 2013, pages 41 and following). The EURMKB is thus not a simple data/knowledge warehouse. The Integrated Knowledge Management System for REE (IKMS - EU-FP7 EURare) (Cassard et al., 2014a, 2017a), the EU-Minerals Knowledge Data Platform (EU-MKDP - EU-FP7 Minerals4EU) (Cassard et al., 2014b), the EU-Urban Mining Knowledge Data Platform (EU-UMKDP – H2020 ProSUM) (Huisman et al., 2016), the EU-Critical Raw Materials Knowledge Data Platform (EU-CRMKDP – H2020 SCRREEN), etc., are built in the same way and are some of the most striking bricks of the EURMKB.

- The RMIS 2.0 is seen as an overarching structure with key roles and tasks, being at the same time:

    (i) **a high-level application producing new knowledge** through the exploitation of the EURMKB's content in parallel with the exploitation of external sources, and

    (ii) **a high-level interface toward end users**, putting at disposal both the EURMKB's content and the new knowledge created.

- This organization schema is in accordance with the '**Cooperation concept**' developed in the Roadmap (Manfredi et al., op. cit.). It is based on an intelligent exploitation and preservation of what has already been done in EU-FP7 and H2020 projects and the intention to build on them in order to provide the end users with enhanced syntheses. This is an application of the well-known **principle of subsidiarity:** the *Oxford English Dictionary* defines subsidiarity as, "the principle that a central authority should have a subsidiary function, performing only those tasks which cannot be performed at a more local level."[2]

2 THE EUROPEAN UNION KNOWLEDGE DATA PLATFORMS CHARACTERISTICS

Several European Knowledge Data Platforms (EU-KDPs) have been developed these last years in the frame of the EU-FP7 and H2020 programs. Two EU-FP7 projects contributed to set the foundations of the EURMKB:

- The **ProMine** project which:
    - collected and collated a great amount of data related to both primary and secondary mineral resources over the whole Europe (Cassard et al., 2015);
    - contributed to define the INSPIRE Mineral Resources data model (European Commission, 2007 ; INSPIRE Thematic Working Group Mineral Resources, 2013) and to improve the EarthResourceML data model (ERML).
- The **EuroGeoSource** project which:
    - collected and collated numerous energy and mineral resources data over several European countries;
    - implemented an INSPIRE compliant distributed architecture.

[2] See: https://en.wikipedia.org/wiki/Subsidiarity

All the developments done in EURare and Minerals4EU, and then in ProSUM and SCRREEN, reuse and develop the skills acquired within these two projects. These platforms represent the first bricks of both the EURMKB and of the European Geological Data Infrastructure (EGDI). The technical choices were made to assure effective and sustainable systems designed for facilitating data updates and maintenance, and for offering a full and seamless access to information related to the complete mineral resources value chain.

The technical solutions implemented include:

- The management of both **structured data** from national databases and **semi- and non-structured information**: syntheses and statistics (graph charts and time-series), related to primary and secondary resources, from exploration, production, reserves and resources evaluations to waste characterization… in various formats (text files, PDF files, images…) (Figure 2).
- A **system fully INSPIRE compliant** based on INSPIRE v.3 and EarthResourceML (ERML) v.2 data models, which internally communicates through- and delivers web services.
- A sustainable system always kept up to date with the adoption and development of **a distributed architecture**.
- A robust architecture with a Central Harvesting Database synchronized with a Central Diffusion Database. The first one controls data quality and the second one is optimized for diffusion. Synchronization is made using SQL scripts (Figure 3).

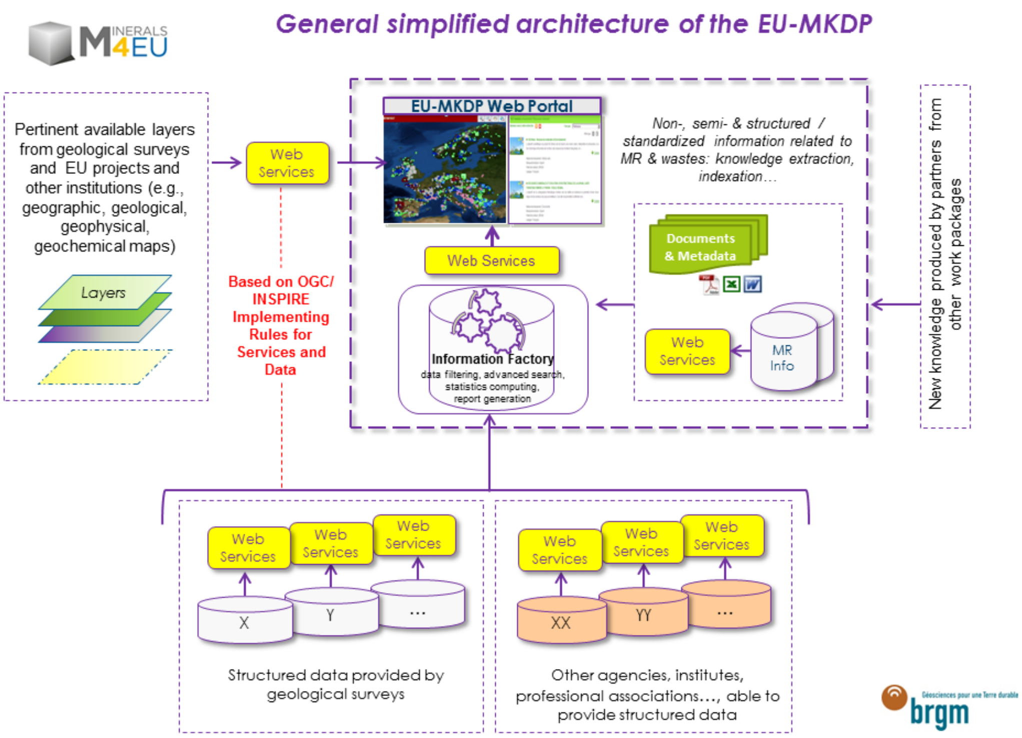

Figure 2. General simplified architecture of the EU-MKDP (Minerals4EU EU-FP7 project).

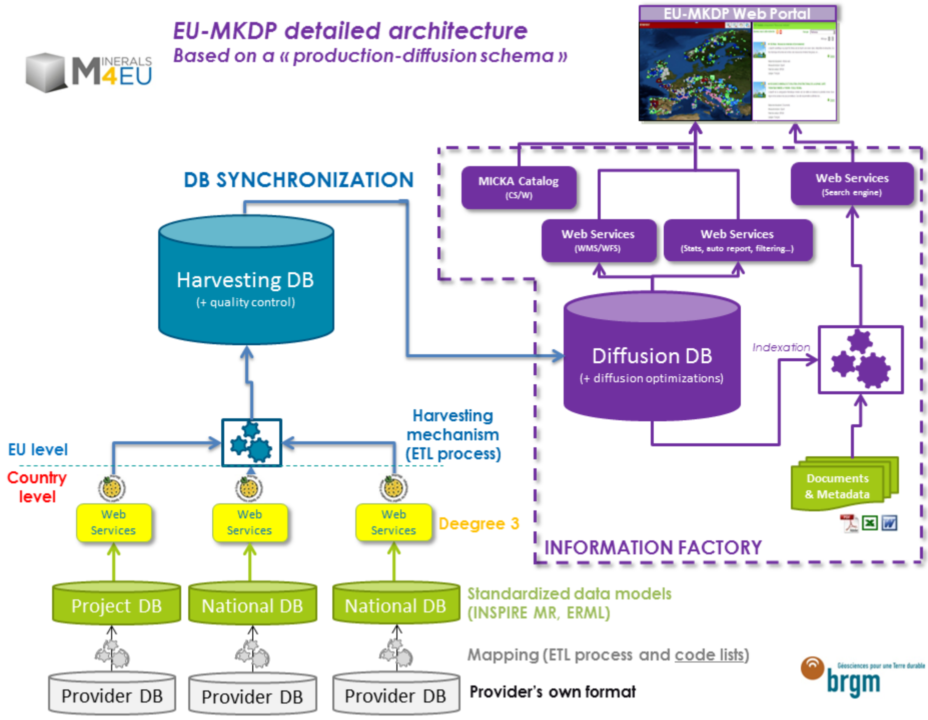

Figure 3. EU-MKDP detailed architecture, based on a 'production-diffusion' schema (Minerals4EU EU-FP7 project).

The technical characteristics of the ProSUM Urban Mining Knowledge Data Platform (EU-UMKDP) slightly differ from this general schema as for WEEE, ELV and BATT, there are no national providers. Data are coming partly from the Eurostat database, but most of them are compiled by international professional associations and universities (Figure 4). This has considerable consequences in terms of maintenance of such a platform.

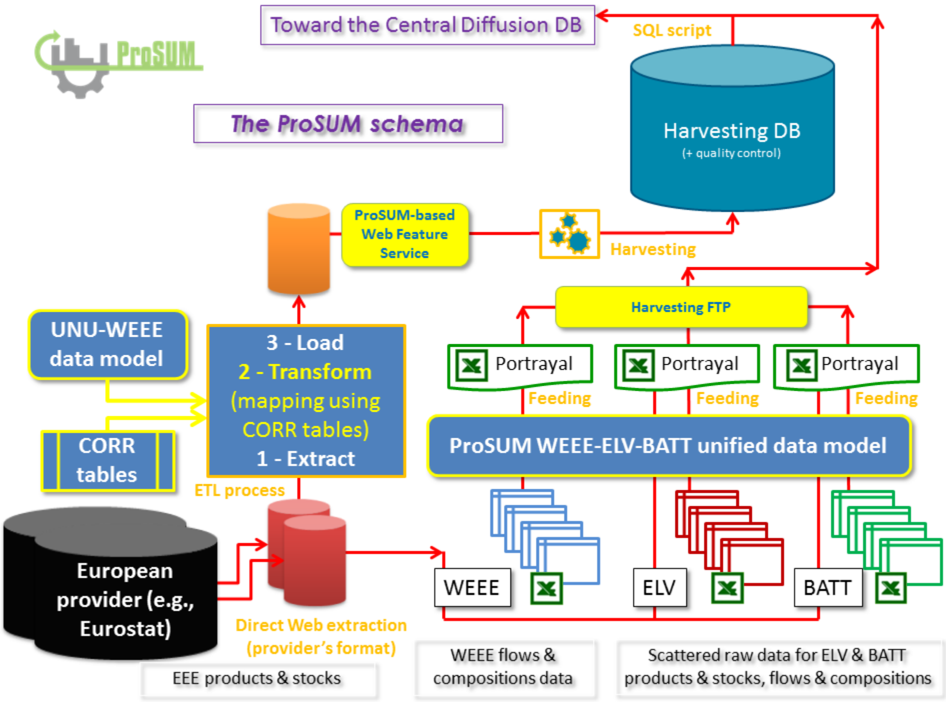

Figure 4. The ProSUM EU-UMKDP architecture. Extract from Cassard and Tertre (2017).

All the platforms are equipped with a geospatial portal making the interface with the end user and allowing him to access to:

- A spatial viewer.
- A powerful Search Capability which allows to search simultaneously in the Central Diffusion PostgreSQL Database (i.e., structured data), the documents corpus and its metadata (i.e., non-structured data), the CS/W Metadata Catalog for structured data (called here 'MICKA') and some external databases (if any).
- A set of dedicated applications like the e-Minerals Yearbook (EU-MKDP, Minerals4EU) or those developed in the EU-UMKDP (ProSUM) which exploit the content of the PostgreSQL database and produce on the fly always updated diagrams.
- A Download Capability currently implemented only in the IKMS (EURare) and which will be extended to other platforms.

These characteristics show that the EURMKB is far more than a simple data/knowledge warehouse. The EURMKB is a composite of layers, including:

(i) databases for structured and unstructured data,
(ii) applications or services and,
(iii) Web interfaces, such as spatial portals.

This description complies with the vision of the EURMKB expressed in the Strategic Implementation Plan (SIP) for the European Innovation partnership (EIP) on Raw Materials (Part II, Final version – 18/09/2013 – pp. 41-44).

3 A UNIFIED VISION OF EU KNOWLEDGE DATA PLATFORMS

In practice, several Knowledge Data Platforms, because they are built on the same data model, share the same database infrastructure. There is one single Harvesting DB and on single Diffusion DB for the IKMS (REE data), the MKDP (all types of mineral resources), the CRMKDP (CRM data) (Figure 5).

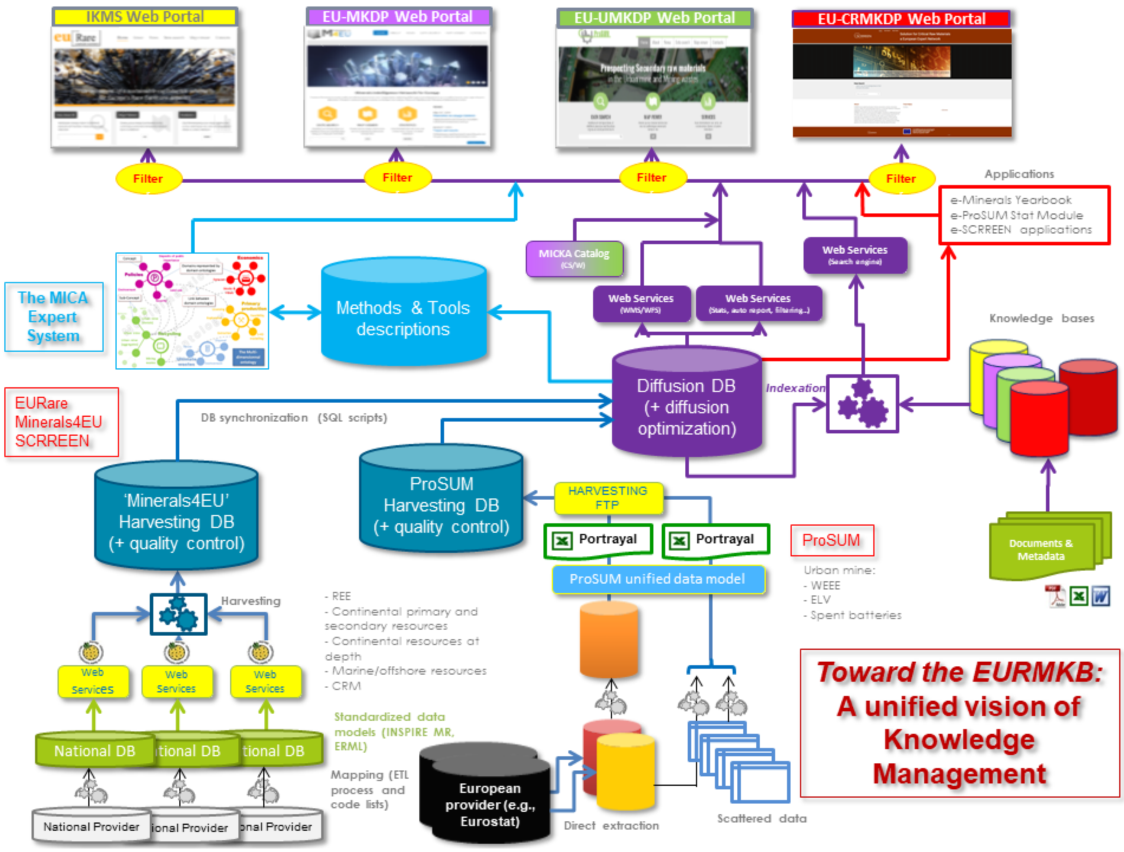

Figure 5. A unified vision of Knowledge Management in the Raw Materials domain, and the first steps for building the EURMKB.

Data sent from the Central Diffusion DB to the different geospatial portals are filtered on one or several criteria (e.g., commodity, nameSpace…) depending on the portal thematics.

Two platforms do not share the same architecture as the others: the ProSUM EU-UMKDP and the MICA EU-RMICP. The EU-UMKDP is dealing with the urban mine and secondary resources from WEEE, ELV and BATT (see Glossary), and the features to modelize and the ways to get the data were so different from primary resources that this necessitated the development of a dedicated data model, 'the ProSUM Unified data model', the use of portrayals and the development of a specific harvesting DB. The EU-

RMICP, can be considered as an Expert System allowing a end user to find an answer of the type 'how to proceed' when he has a question/query (simple or complex) related to mineral resources. The system is based on a Dynamic Decision Graph (DDG) allowing the navigation over a Raw Materials Ontology coupled with a database of Methods and Tools elaborated by experts. This system is also connected to other information platforms, including recently the RMIS 2.0 (through the SCRREEN project) (see also Figure 1 – upper part).

This review does not pretend to be exhaustive. It is mostly based on European projects led in a broad sense by EuroGeoSurveys partners, i.e., the Mineral Resources/Mining departments of European Geological Surveys that were/are also strongly involved in the implementation of (i) the INSPIRE directive (European Commission, 2007 ; INSPIRE Thematic Working Group Mineral Resources, 2013) and (ii) the FAIR guidelines (European Commission (2016a). There is thus presently a homogeneous set of data that can be provided to JRC for the development of the RMIS.

4 ABOUT DATA

Before examining more in depth what can be retrieved or downloaded from EU-KDPs and also from major EU and worldwide sites dealing with Raw Materials, it seems useful to briefly come back on the different types of data RMIS 2.0 will have to deal with, depending on the different applications which will use, combine, 'consume' this data.

4.1 Data, information and knowledge: which difference?

Perhaps, a first point to agree on is the difference between data and information. Data is simply facts or figures, i.e., bits of information, but not information itself. When data is processed, interpreted, organized, structured or presented so as to make it meaningful or useful, it is called information. Information provides context for data.

Data usually refers to raw data, or **unprocessed data**. It is the basic form of data, data that hasn't been analyzed or processed in any manner. Once the data is analyzed, it is considered as information (http://www.differencebetween.info/difference-between-data-and-information). When information is combined with experience and intuition, it results in knowledge (Figure 6).

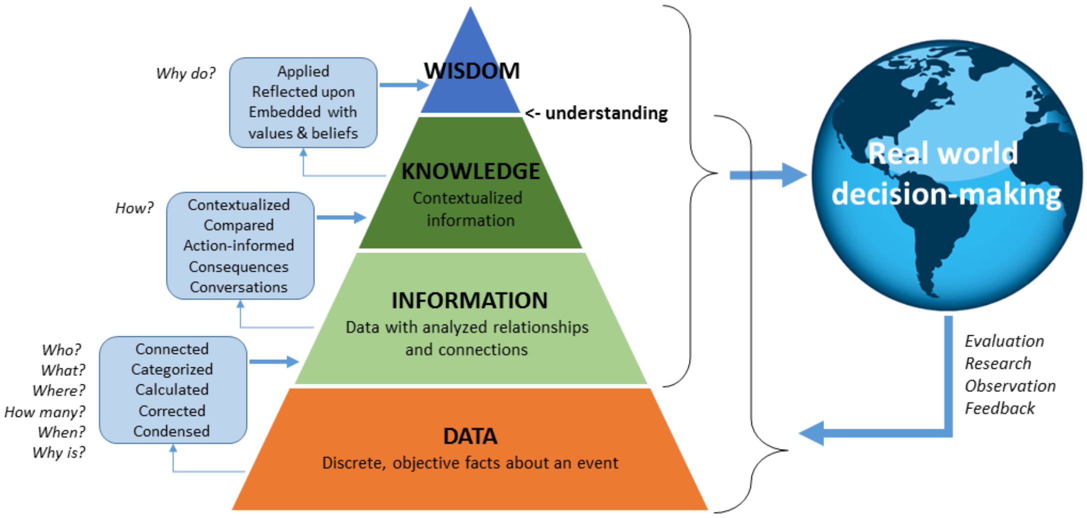

Figure 6. The DIKW pyramid is a model for representing functional relationships between data, information, knowledge, and wisdom (or intelligence) (https://www.climate-eval.org/blog/answer-42-data-information-and-knowledge).

Existing Knowledge Data Platforms (IKMS, EU-MKDP, EU-UMKDP and EU-CRMKDP) are dealing at the same time with true structured data stored in a DBMS (DataBase Management System – PostgreSQL), and unstructured data stored in a custom storage solution which can represent information and/or knowledge.

4.2 Original data vs. pre-processed and processed data

As seen above, the difference is particularly important between raw original data and data which has already been pre-processed or processed and which is actually already information.

Each dataset should be accompanied by its metadata, for example the Dublin Core type (http://dublincore.org/ and http://wiki.dublincore.org/index.php/User_Guide) which brings information related to a series of elements among which the Title, Subject, Description, Type, Source, Relation, Coverage, Creator, Publisher, Contributor, Rights, Date, Format, Identifier, Language, Audience, Provenance, RightsHolder, InstructionalMethod, AccrualMethod, AccrualPeriodicity and AccrualPolicy. This is even more critical with datasets which have been pre-processed or processed: each treatment has been performed with an idea in mind, i.e., with a particular objective. Not having the information related to this (pre)treatment – which should be mentioned within the metadata and explained – may make the dataset totally useless, or at least extremely dangerous to reuse.

4.3 Structured data

Structured data refers to **kinds of data with a high level of organization**, such as information in a relational database. When information is highly structured and predictable, search engines can more easily organize and display it.

Another definition (https://brightplanet.com/2012/06/structured-vs-unstructured-data/) confirms the first one and shows the main difference with unstructured data: 'For the most part, structured data refers to information with a high degree of organization, such that inclusion in a relational database is seamless and readily searchable by simple, straightforward search engine algorithms or other search operations; whereas unstructured data is essentially the opposite. The lack of structure makes compilation a time and energy-consuming task'.

It is particularly interesting to note that both definitions consider that structured data, only because of its high level of organization (based on some data model such as the MR INSPIRE one for Mineral Resources [INSPIRE Thematic Working Group Mineral resources, 2013] for example) is already information.

Semi-structured data is a form of **structured data** that does not conform to the formal structure of data models associated with relational databases or other forms of data tables, but nonetheless contains tags or other markers to separate semantic elements and enforce hierarchies of records and fields within the data. An example of semi-structured data is typically the one of Excel spreadsheets.

4.4 Unstructured data

Unstructured data (or unstructured information) refers to information that either does not have a pre-defined data model or is not organized in a pre-defined manner. Unstructured information is typically text-heavy, but may contain data such as dates, numbers, and facts as well.

Unstructured data are thus essentially documents of various types - reports, articles, conferences abstract, books and monographs, thesis, statistical studies, images and videos… and thus of different formats, e.g., .doc(x), .pdf, .xls(x), .jpeg, .png, …, .avi, .mp4, etc.

These data, which for some of them are already information and even knowledge, should be accompanied by their metadata as any other data s.l. when uploaded in any system.

4.5 Spatial and non-spatial data

In practice, a distinction is often made between these two types of data:

- **Spatial data**, which can be plotted over a map and displayed through a map viewer, and which are often stored in databases and thus called **structured data**. The format of these data is (often but not always, depending on the theme) governed by the INSPIRE directive which guarantees their interoperability. An example of such data is the data related to primary mineral deposits.

- **Non-spatial data** typically include **unstructured data**, i.e., data coming from reports, articles, conferences abstract, books and monographs, thesis, statistical studies, images and videos… However this should be slightly modulated: due to the combined use of powerful indexation engines and the use of metadata accompanying each unstructured data, it is possible to attribute to a document – whatever its format - a more or less precise location on a map or an area to which it refers. This possibility is already implemented in all the Knowledge Data Platforms above mentioned, (i) allowing powerful geographical searches able to retrieve any data (structured or unstructured) and information in a polygon drawn by the end user, and (ii) getting the results of the search in the form of both a list and a series of polygons (areas 'covered' by the documents of the list) in a dedicated map viewer (Figure 7).

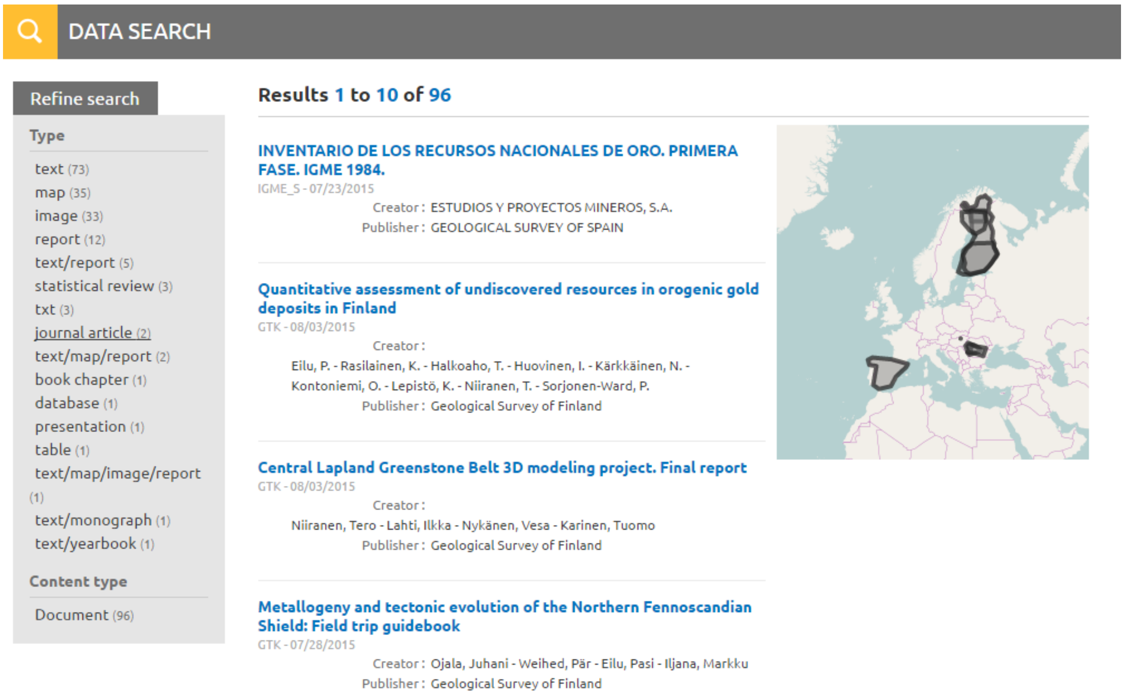

Figure 7. Example of a search performed with the EU-MKDP Search capability on 'Gold deposit' & 'Document', and location in the map viewer of the areas 'covered' by the documents which have been retrieved.

Aggregated data at national level, often represented as pie charts, cannot be considered as 'really' spatial as their minimum resolution is the country level.

4.6 Aggregated data at national level

Aggregated data are particularly useful (i) when available structured data have a too limited quality/accuracy or are incomplete, or (ii) when they are straight lacking, whatever the reason.

The first situation appears for example with primary mineral resources structured data which limited quality makes impossible any production of reliable statistics related to reserves and resources at the EU level. Now, several countries do produce national aggregated datasets, which are supposed to overcome the problems encountered with raw single/individual records per mineral/ore deposit. These aggregated datasets are generally prepared by national experts, and they are based on official, exhaustive and controlled data elaborated from producers' legal reporting to their supervising authority (hence the aggregation before publication, notably if the producers number is limited, the object being the maintenance of commercial activity). The use of these aggregated data to get a European vision however raises a problem of harmonization as the different countries are far from using the same reporting system…

The second situation appears for example for secondary raw materials, and particularly for the urban mine, where it is extremely difficult to get data at a level lower than the country level. It seems that such a situation partially results from a lack of transparency of certain activities, and the will of certain players to not put the light on their business.

Aggregated datasets have thus their importance, and they should be able to be harvested/uploaded, and displayed in any information system as individual structured data is.

4.7 Getting external data for doing what?

Having rapidly reviewed what the main types of data are, the question which arises is: getting data from external sites for doing what?

External data can be used for various purposes (after Svensson, 2014, modified):

- (1) Enrich your system data with new information you are unable to collect on your own;
- (2) Validate information you have captured in your own system;
- (3) Update information you have captured to improve the quality of the data;
- (4) Use it as reference data to provide additional information without fully integrating it into your system;
- (5) Use it as a source of test data for environments where data privacy prevents usage without masking but valid data is required.

Regarding the RMIS, among the possible uses listed above, points 1 and 4 are those which better fit with the roles and tasks of RMIS 2.0 as described in the Interim Progress Report & Roadmap (Manfredi et al., 2017). The question of 'full integration' of the external dataset within the system, raised in point (4), is a key question. In most of the cases, the incoming data will need some processing before its integration with other (internal, in-house or not) datasets, and the use of a 'JRC 'RMIS' Working DB' was suggested (Figure 1), in order to allow data transformation, harmonization and/or pre-computation, and store the results, keeping in mind that the external data will evolve with time.

Whatever the solution retained for the incorporation of external data from third parties, one challenge is the heterogeneity of the used formats and the missing of agreed upon definitions. Strand and Wangler (2004) and Niklasson (2004) made an interesting study, summarizing the different types of problems possibly encountered when incorporating external datasets, from identification to usage (Table 1).

Identification	*Integration*	*Usage*
- Identify new suppliers	- Time-consuming	- Data correctness
- Establish relations	- Data representation and structure	- Data completeness
- Select suppliers	- Storage	- Data freshness
- Identify relevant data	- System consistency	- Data overload
Acquisition	- Data completeness	- Biased data
- Time-consuming	- Time-stamps	- Data reliability
- Acquire data	- Data overload	- Conflicting sources
- Large datasets	- Conflicting data	- Exists without influencing the decisions
- Dynamic sources	- Tools	- Restricting laws
- Source stability	- Conceptual understanding	- Ethical aspects
- Expensive	- Metadata	

Table 1. Overview of problems possibly encountered when trying to incorporate external data (from Niklasson, 2004).

5 FEEDING THE RMIS WITH STRUCTURED DATA FROM EXTERNAL SOURCES

The main objectives of RMIS 2.0 are to provide end users with key indicators related to the EU Raw Materials Scoreboard, Critical Raw Materials, Material System Analysis and Trade. Depending on the data needed, its origin, its format…, several possibilities can be foreseen, that have also to take into consideration among others, the possible – or not – automation of the importation process and JRC' security access rules.

5.1 Getting external data via 'standard' web services

Automated data recovery can be performed through OGC Web Services (OWS) such as Web Map Services (WMS) and Web Feature Services (WFS). These services describe themselves and provide requests to retrieve maps (in the case of WMS), or access to raw data (in the case of WFS). In general, these types of services are easy to integrate in Web applications using third parties libraries like OpenLayers[3] or Leaflet[4]. These libraries allow integrating in a website maps that use OWS and integrating data coming from other Web Services as long as they have a geographical component[5].

Figure 8 below, briefly presents different types of OGC / INSPIRE Web Services that can be set up to feed the RMIS.

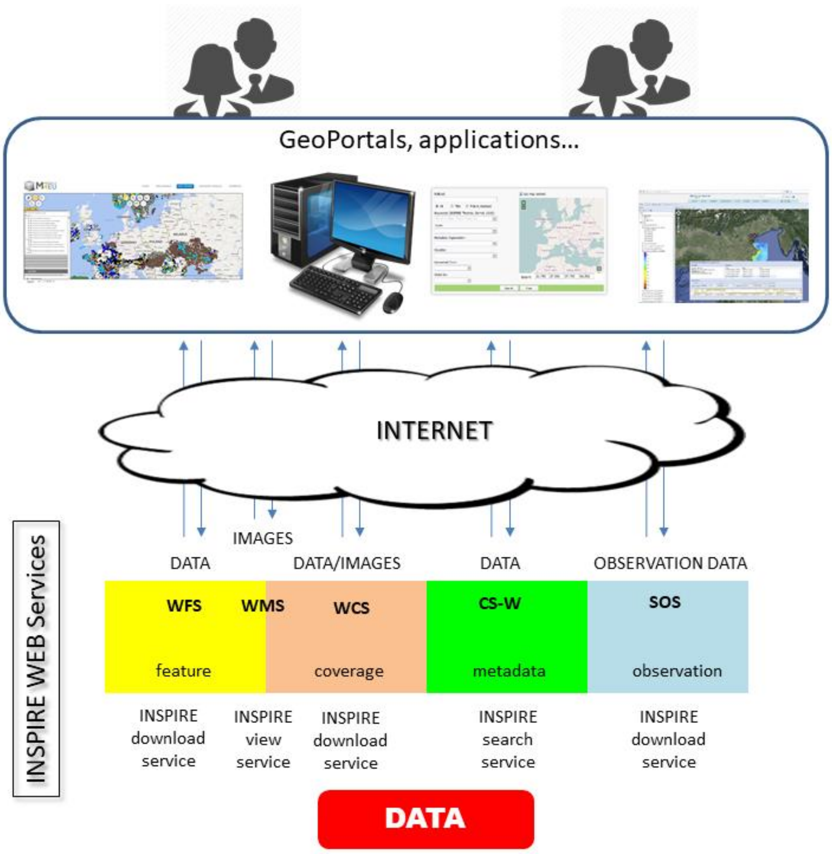

Figure 8. Different types of Core OGC Service Standards and their roles.

[3] https://openlayers.org/
[4] http://leafletjs.com/
[5] Sometime, data does not have a geographic component but has instead a reference to a geographic term (i.e., the name of the area related to the object, e.g., Paris, London, France…). In that case, **the use of Table Join System** that will link a geographic term to its geographic definition (the polygon of the area or its centroid) can help to represent non-geospatial data.

5.2 Setting up an ETL process

Depending on the format of structured data provided by the external source, the development and the use of an ETL (Extraction – Transform – Load) tool could be an interesting solution regarding the import of external data into the RMIS 2.0:

- **Extract** is the process of *reading data* from a data source (database, web service…).
- **Transform** is the process of *converting the extracted data* from its previous form into the form it needs to be in so that it can be stored into another database. Transformation occurs by using rules or lookup tables or by combining the data with other data.
- **Load** is the process of *writing the data* into the target data repository (database, data file, post to a web service…).

The ETL process is thus used to migrate data from one database to another, to form data marts and data warehouses, and also to convert databases from one format or type to another (see http://www.webopedia.com/TERM/E/ETL.html).

Regarding RMIS 2.0, the ETL process could intervene as follows (Figure 9):

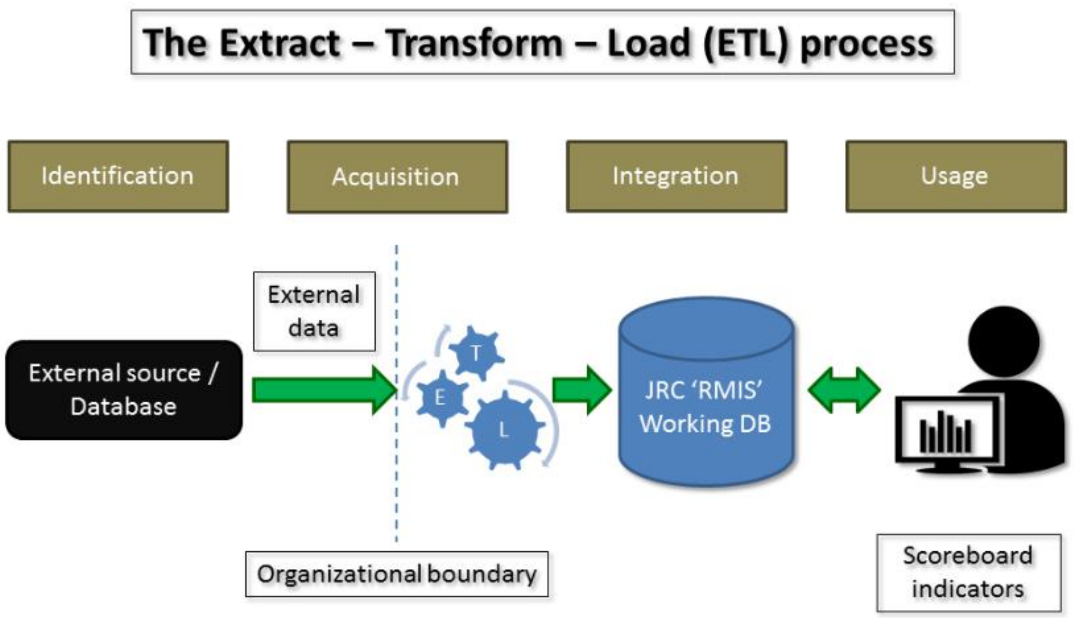

Figure 9. The Extract - Transform - Load process (ETL) applied to RMIS 2.0 for the incorparation of external data. Inspired from Strand and Wangler (2004).

If an ETL process is implemented, it will operate on the client side (here the JRC's RMIS), and will read the data from a WFS 'sitting' on the top of the M4EU Central Diffusion DB. It will then have to transform the data from its initial format based on the M4EU data model into a format exploitable by the RMIS, and upload this transformed data into a dedicated DB, that could be here the JRC 'RMIS' Working DB (see also Figure 1).

This scheme is quite feasible but, for several years, professionals[6] have been drawing attention to the constraints or defects associated with the implementation of an 'ETL' solution. One of the biggest challenges enterprises face is setting up and maintaining a reliable extract, transform, and load process to extract value and insight from data. Traditional ETL tools are complex to use, and can take months to implement, test, and deploy. After the ETL jobs are built, maintaining them can be painful because data formats and schemas change frequently and new data sources need to be added all the time. And this can apply to RMIS too.

5.3 Feeding the RMIS: the Raw Materials Scoreboard use case

The RMIS 2.0 will propose multiple applications related to MSA, Trade, and CRM…. The observations made in the following paragraphs for the Scoreboard also apply to these different thematic applications, even if the case of CRM is particular[7].

The production of the Raw Materials Scoreboard (European Commission, 2016b) is one of the key tasks of the RMIS 2.0. It's a masterpiece work consisting of 24 indicators grouped into 5 thematic clusters (Raw materials in the global context, Competitiveness and innovation, Framework conditions for mining, Circular economy and recycling, and Environmental and social sustainability). Having in mind the general architecture of the RMIS 2.0, it is interesting to examine how the production process could be automated, at least partially for some of these indicators, and what this would imply in terms of data retrieval and treatment.

5.3.1 The 'classical' manual approach

Among the indicators presented in the Scoreboard (2016 edition), some necessitate a manual approach for their elaboration. This is notably the case of some of those of the thematic cluster 'Framework conditions for mining', namely '***11. Mining activity in the EU***' and '***12. Minerals exploration***'.

<u>Remark</u>: The sources used to build the 'Metal mine production in the EU (2014)' map (Indicator 11, figure 25 of the 2016 edition), and the 'Metallic mineral exploration in the EU (2014) per development stage' map (Indicator 12, figure 26 of the 2016 edition) are commercial and/or non-European public sources (respectively SNL Metals & Mining,

[6] See for example: https://apigee.com/about/blog/technology/etl-api-%E2%80%93-changed-landscape-enterprise-data-integration or https://www.openlegacy.com/blog/etl-vs-api-understanding-the-implications-for-legacy-modernization/

[7] Due to the methodology implemented for the critical raw materials assessment (Blengini et al., 2017; G.A. Blengini, pers. comm., 2017), and the intervention of a group of experts preparing and exploiting the data, it is not certain that the use of a database (e.g., the JRC 'RMIS' Working DB) is needed for storing and serving the results. It could probably be an option, but the possible advantage(s) (e.g., a partially automated feeding of the CRM Fact Sheet) has to be evaluated.

USGS and NOAA). The outcomes of European projects were not used because they do not cover the whole area and are sometimes not enough detailed/accurate.

A 'manual approach', means that a human intervention is needed at some stage(s) of the production process, to download certain data, to get additional data from other sources via collaborations, to collate data, remove possible duplicates, and harmonize selected data. In order to give more room to European sources, the 2018 version of indicator ***'11. Mining activity in the EU'*** will mix SNL and Minerals4EU data (G.A. Blengini, pers. comm., 2017). Manual interventions will occur in practice at two different stages:

1. The preparation of Minerals4EU data. As of today, no extraction or download service on the Minerals4EU database exists, and thus a dedicated extraction from the PostgreSQL database is needed. The extraction process necessitates performing a sophisticated query accompanied by a refactoring of extracted data as the initial database is multidimensional (i.e., data are exploded in multiple tables and the links between these tables can have a cardinality 'many-to-many') and the resulting file (either an Excel spreadsheet or a shape file) is a simple '2D' table (the mechanism consists in the aggregation of multiple rows in a single column using concatenation and the duplication of some lines). This also applies to the production of the 'Mineral deposits, occurrences and showings in the EU-28' map (Indicator 12, figure 27 of the 2016 edition).

2. The merging of the two datasets, with all the stages already described above, from collation to harmonization.

Until now, there was no way to bypass these manual interventions, and the production of these indicators was relying on the cooperation of JRC with data providers.

5.3.2 Toward an automated approach, constraints and feasibility

As of today, the Scoreboard is a paper report. One of the aims of the JRC's RMIS 2.0 could be to dematerialize this report into an electronic version (an e-Scoreboard). With this in mind, the automated approach for feeding it takes on its full meaning. An automated approach will be able to always retrieve the latest data and propose 'quasi-on the fly' updated indicators.

Such an automated approach necessitates some pre-conditions to be fulfilled:

- The rules to compute the indicators must be well defined and be enough precise to allow automatic calculation.
- As the indicators will be automatically updated, the accompanying texts and explanation of the indicators will not be relevant as they cannot be automatically re-written and require the intervention of an expert to interpret the figures. This leads to the conclusion that the design (composition, structure…) of an e-Scoreboard has to be revamped compared to the current version.
- Data sources used to compute the indicators must be perennial in term of availability, format and origin (how the data has been prepared). If one of these

factors is not fulfilled the indicators might be not calculable or incoherent with previous versions.

- Some mechanism might be needed to technically retrieve the data to feed this e-Scoreboard. Due to the security and technical limitations imposed for the JRC's applications by the IT Department of the Commission (Th. Ciuta [JRC], pers. comm., 2017), the solutions are quite limited. **The impossibility to have heavy server-side application to process the data, leads to client-side only applications that will have to access by themselves the data and to process it** (see Figure 10 & Figure 11) . This limitation can be very problematic for two points:

    - Direct access to external data by a client-side application requires this application to be allowed by the provider of the data (i.e., the website which provides access to its data). This authorization is managed by Cross-Origin Resource Sharing (CORS) which is a mechanism used to allow some resources (data or other) served by a domain to be requested from another domain. Some data (like images, videos...) can be requested freely from other domains, but some other data (notably retrieved by AJAX requests) are by-default forbidden, due to the same-origin security policy. The CORS is a mechanism which defines how a server and a client (browser executing a client-side application) can interact to determine if it is safe or not to allow the cross-origin requests. In most of the cases, servers do not define any CORS policy, which means that the data they are serving cannot be retrieved from outside their domain (except with a proxy solution which cannot be used in the case of JRC's RMIS 2.0 due to the restrictions in terms of IT). Some (rare) servers define a CORS policy very permissive with a wildcard Access-Control-Allow-Origin that allows all other domain to access these resources. Some other servers can propose an 'on demand' Access-Control-Allow-Origin which lists the domain allowed to request the data. This last solution can be considered in the case of the JRC's RMIS 2.0 with the possibility for JRC to request some collaboration, via a MoU, with some data providers to let the JRC RMIS 2.0 access their resource.

    - Browsers can be limited regarding the quantity of data they can process. Large datasets or huge processing can be problematic in terms of performances for the whole browser and in some cases can be too slow for a comfortable use of the application or, in the worst case, can lead to the crash of the browser.

5.3.3 Lessons learnt

For the 'standard' paper version of the Scoreboard, the use of the JRC 'RMIS' Working DB can be simplified by the use of an ETL (Extract, Transform and Load) process that can help to reproduce some repetitive tasks **on data that will keep the same format over time**. Besides this constraint (not mastered by the client!), this solution is not easy to implement and has a real cost in terms of maintenance.

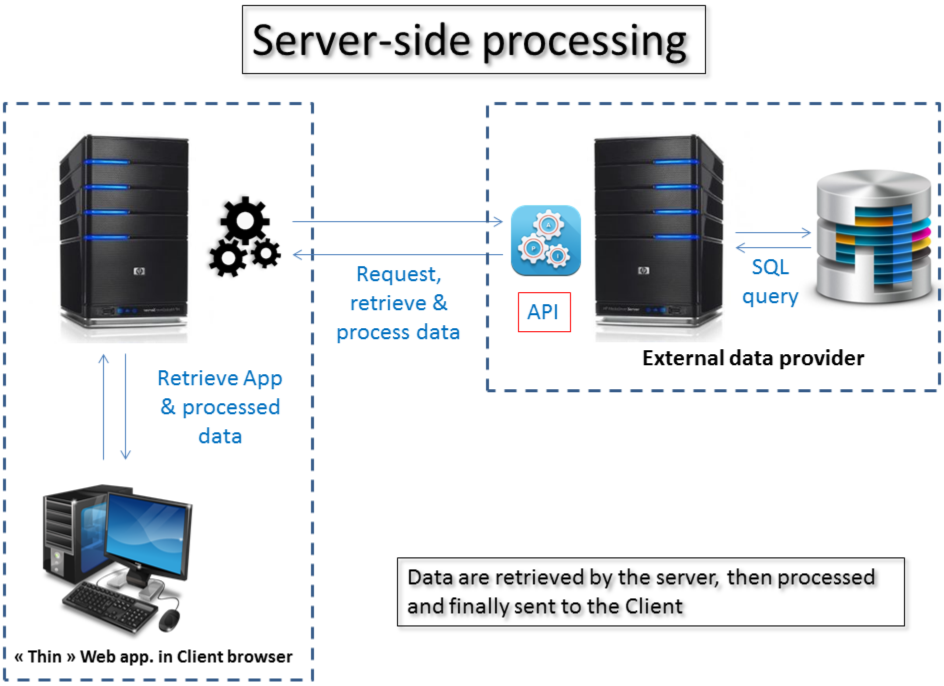

Figure 10. Server-side processing and ‘thin’ Web application in client browser.

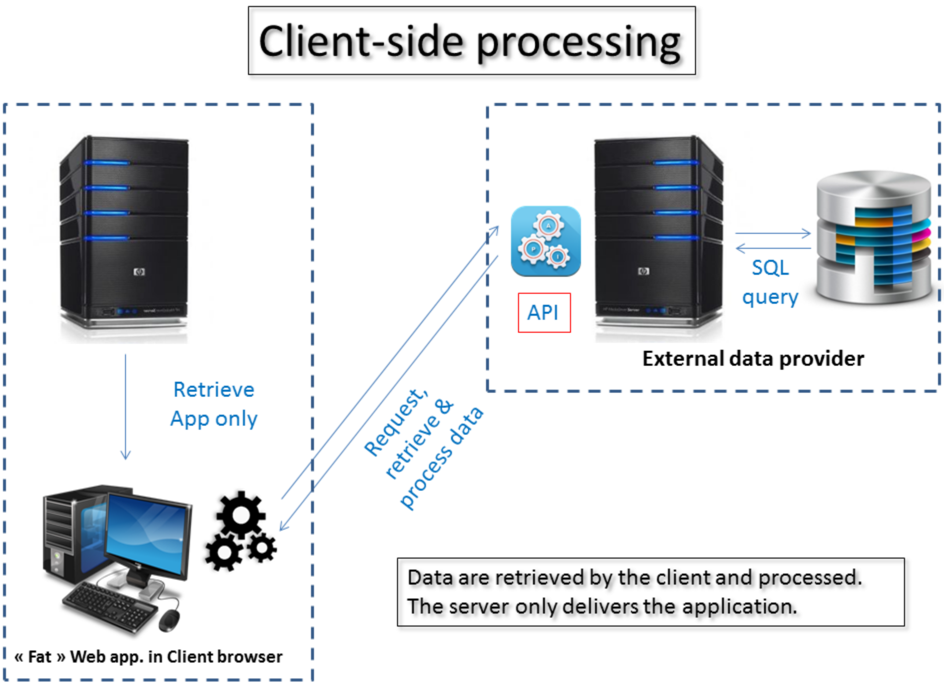

Figure 11. Client-side processing and ‘fat’ Web application in client browser (JRC’ strategy for RMIS 2.0).

In the perspective of an e-Scoreboard, the restrictions applied to EC-hosted websites would lead to limited functionalities and complex developments for the client-side part. It is anyway not sure that a completely automated approach can be implemented, notably if different sources have to be used and blended under an expert supervision (e.g. because of quality gaps…). However, the next step forward in this perspective probably goes through an easier access to data and the possibility to select directly at the source level which data is useful or not, in order to simplify and speed further treatments.

This leads to seriously considering the use of APIs. But the development/existence of an API depends on the provider policy in terms of data delivery/dissemination. This also means that there is probably a need for JRC to negotiate and sign Memorandum of Understanding (MoU) with certain data providers to get an access to their resources for the RMIS 2.0.

5.4 Automated data recovery using APIs

Automated data recovery can be performed through OGC Web services (Web Map Services [WMS] and Web Feature Services [WFS]) **which can be seen as very simple APIs** (Application Programming Interfaces). These services describe themselves and provide requests to retrieve maps (in the case of WMS), or access to raw data (in the case of WFS) (see 5.1). One also could speak of 'Standardized API' for OGC services vs. 'Custom API' for more elaborate and dynamic Web APIs[8]. Said in other words, all Web services are APIs but all APIs are not Web services.

API's are a more sophisticated approach as they allow a full parametrization of the data access process. Only a few sites among those likely to feed the RMIS propose such a component, e.g., UN Comtrade Database, USGS, WITS and the World Bank. Figure 12 briefly summarizes the relationships between a client and an external server which delivers the data in the expected format via an API.

[8] See for example: https://blogs.mulesoft.com/dev/api-dev/apis-versus-web-services/ or http://www.differencebetween.net/technology/internet/difference-between-api-and-web-service/

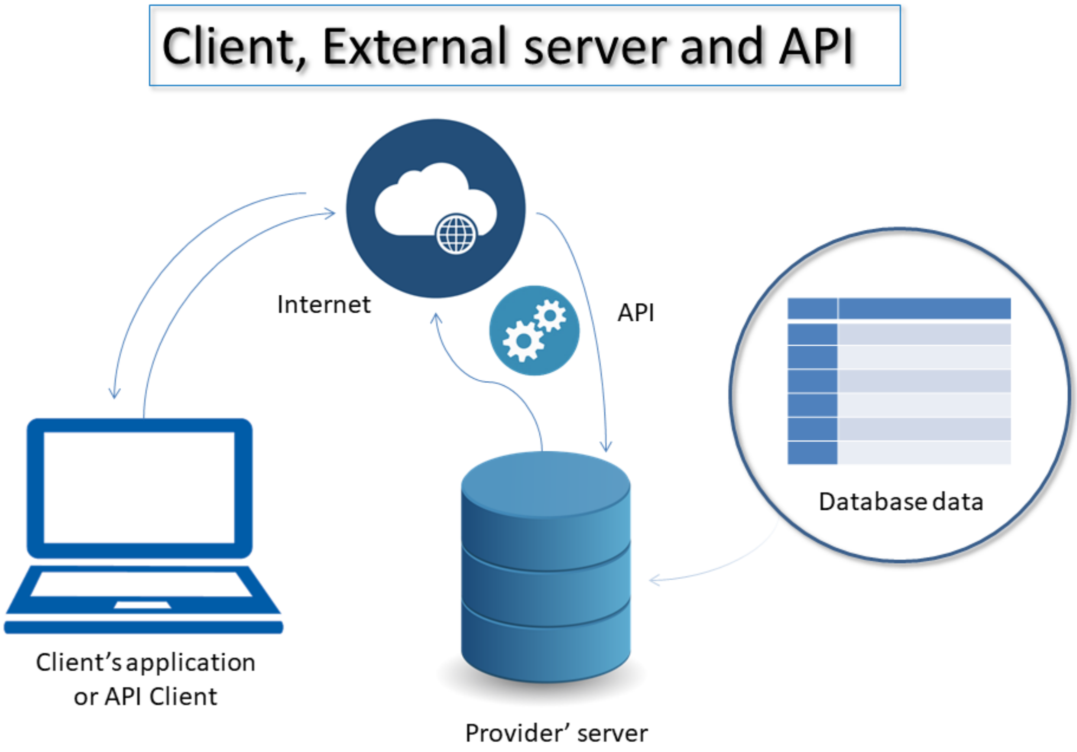

Figure 12. Overview of the relationships between a client and an external server via an API.

An API is a set of functions and procedures allowing the creation of applications that access the features or data of an operating system, application, or other service. Said differently, an API is a code that allows two software programs to communicate with each other.

An API is the tool that makes a website's data digestible for a computer. Through it, a computer can view and edit data, just like a person can by loading pages and submitting forms.

APIs are made up of two related elements. The first is a specification that describes how information is exchanged between programs, done in the form of a request for processing and a return of the necessary data. The second is a software interface written to that specification and published in some way for use.

When systems link up through an API, it is said they are integrated: on one side the server that serves the API, and the other side the client that consumes the API and can manipulate it (Figure 13). The software that wants to access the features and capabilities of the API is said to call it, and the software that creates the API is said to publish it.

In the case of the RMIS and the access to the Minerals4EU dataset (i.e., structured data), the development of a ERML-Lite-based API can be considered, this initiating a very first step toward a e-Scoreboard. Because a new, fully operational, version of ERML-Lite[9] (Vuollo et al., 2018) has just been released, and because ERML-Lite is now stable and incredibly easier ‘to manipulate’ than the full version of ERML, this makes possible to even envisage such a development in the frame of Mintell4EU T5.4.

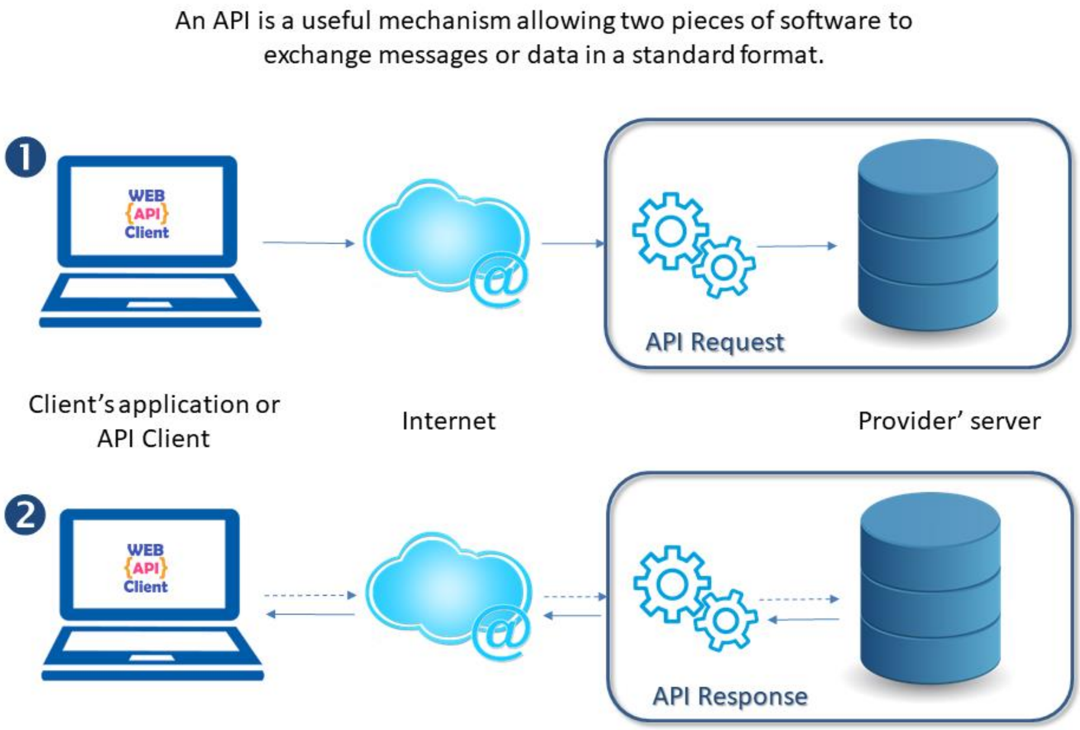

Figure 13. API: the provider' server side and the client's application.

In the same way, and in synergy with the H2020 SCRREEN project (Work Package 9 ‘Knowledge management'), the development of a ProSUM-based API related to the urban mine (WEEE, ELV & BATT), and dealing with data on products and stocks and flows and composition can be envisaged in the frame of Mintell4EU, thus providing the RMIS with essential data for material flow and system analysis (see Cassard et al., 2019a)

5.5 Pre-computed view: a cool and useful SQL pattern

The example of ProSUM discussed in the previous paragraph leads to also propose a complementary approach to deliver data to the RMIS. For the ProSUM e-stat module

[9] ERML-Lite v.2.0.1 is a fully-compliant but eased/lightened version of ERML. The splitting of the full ERML schema into several dedicated ‘views' makes ERML-Lite easier to use, favouring new developments. See: http://earthresourceml.org/

(http://www.urbanmineplatform.eu/homepage and Figure 14), a large number of charts have been prepared, carefully elaborated with ProSUM partners, combining different data in order to identify the most striking features and trends. Such 'views' could be of interest 'as they are' for the RMIS and some others can be prepared.

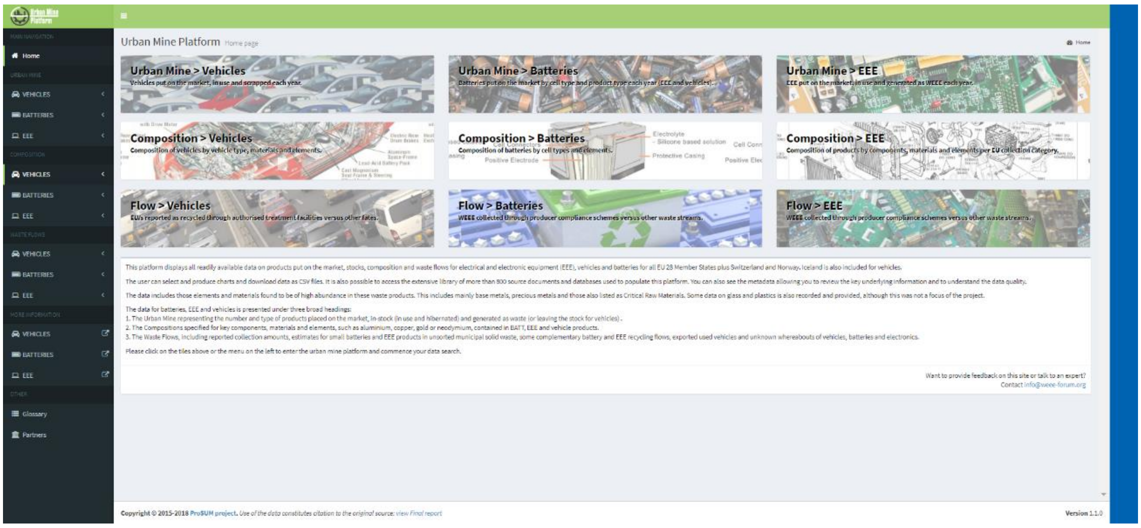

Figure 14. View of the ProSUM e-Stat Module (http://www.urbanmineplatform.eu/homepage).

In database terminology, a view is a named query that typically aggregates data from multiple tables. When using views, it is important to remember that querying a view will evaluate the query that defines the view. Repeated evaluation of the view – say from within a nested query – may seriously impact or even kill the performance of your application.

One solution to this performance problem is to use a "pre-computed view"[10]. Unlike an ordinary view, a pre-computed view is stored in a table rather than computed on demand. When data in one of the aggregated tables changes, the update operation also updates the pre-computed view table.

A great thing about pre-computed views is that they can be implemented fully in SQL. Any code that accesses the database sees a pre-computed view as a regular table. Also, if you have an existing regular view, you can change it into a pre-computed view without having to modify any code that queries the view.

[10] For additional information see: http://igoro.com/archive/precomputed-view-a-cool-and-useful-sql-pattern/

6 AGGREGATED DATA AT NATIONAL LEVEL AND THE E-MINERALS YEARBOOK

6.1 The present situation[11]

This is still a major concern for the Commission, to not be able to produce reliable statistics related to reserves and resources at EU level from Minerals4EU data. Historically, the INSPIRE MR and its derived M4EU data models were not really designed for such an application. They were conceptually built for describing individual/single mineral/ore deposits, dealing more with the spatial representation of mineral potential and applications for mineral/ore deposit geology and metallogeny.

It progressively appeared that **the gaps in the Minerals4EU spatial cover and the data quality problems identified** make that **it is presently quasi impossible to get an accurate picture of EU reserves and resources 'summing' or 'adding' records related to single ore deposits / mines**.

Hence the idea to harvest aggregated data at national level: what would that change?

As briefly indicated in section 4.6, the advantage to harvest directly aggregated datasets at national level relies on the fact that these datasets are generally prepared by national experts, **and based on official, exhaustive and controlled data**. The only reserve, and it is important, is that they are still **NOT compiled according to a harmonized European reporting system.** This is thus a solution which will limit certain drawbacks of the present situation without solving all the problems. As indicated above the obligation to follow internationally recognized systems of reporting (e.g., JORC, PERC, NI43-101…) for statistical data on resources and reserves is still pending.

The possibility to directly harvest aggregated data at national level was not exploited by the e-Minerals Yearbook developed in the frame of Minerals4EU (http://minerals4eu.brgm-rec.fr/m4eu-yearbook/) (Figure 15) essentially for budget and time reasons and this makes now the maintenance of such an application quite costly. Estimations above several hundred k€ per year, make this maintenance quasi-impossible.

This is why the possibility to harvest aggregated datasets at national level and to – at least - partially automate the feeding the e-Minerals Yearbook with these data will be tested in the frame of ORAMA (WP3, T3.2), in synergy with the Mintell4EU project (WP5, T5.3) and if successful, will be progressively extended to the whole Member States.

[11] Situation in June 2019, before the implementation of work done in H2020 ORAMA WP3, task T3.2.

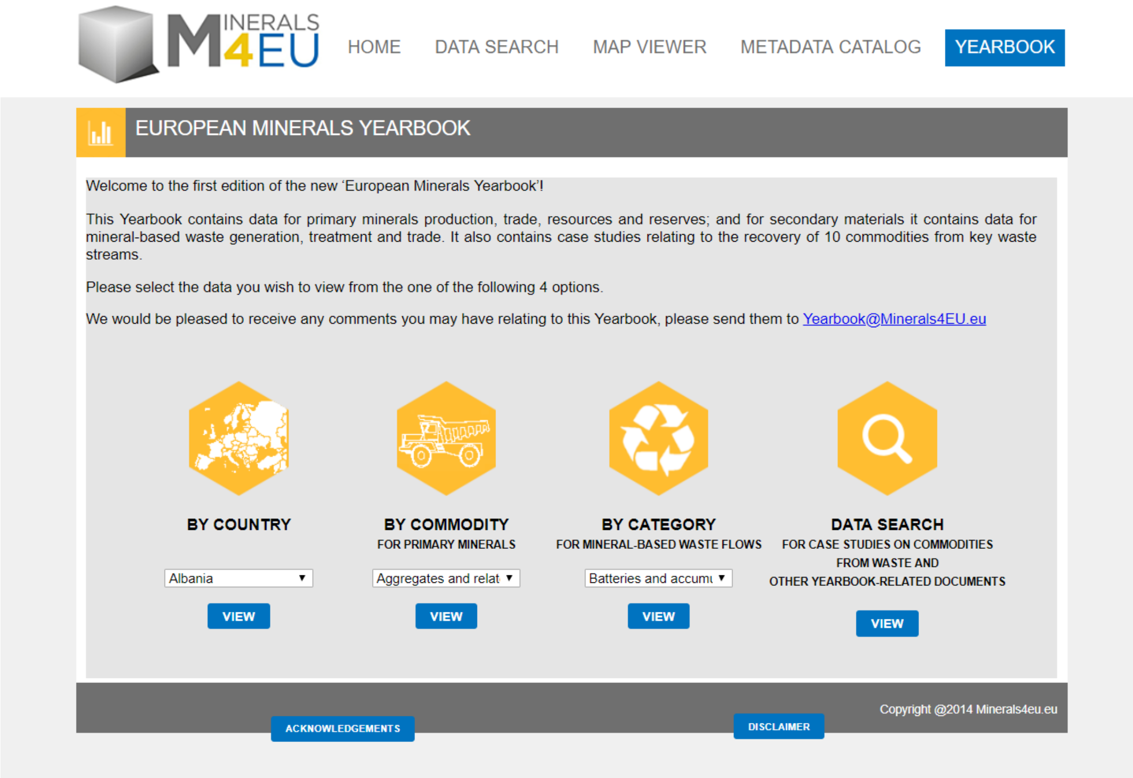

Figure 15. Interface of the e-Minerals Yearbook within the Minerals4EU portal.

6.2 Foreseen evolution

In synergy with H2020 ORAMA (WP3, T3.1 & T3.2), the detailed data flow from the harvesting of aggregated datasets by GeoZS, to their delivery to BGS for checking and integration with other sources, and to their transmission to BRGM for diffusion in the Minerals4EU portal has been set up (Figure 16).

The use of the M4EU DB which was initially envisaged for storing this new data (Central Harvesting DB) is being reconsidered. The M4EU data model based on the INSPIRE MR / ERML data models is not the best one to handle this data that is significantly different from single deposit data. The data model should manage:

- ▶ Country
- ▶ Year
- ▶ Commodity (will necessitate a mapping between INSPIRE MR/CGI CommodityCodeValues and BGS list of commodities, with a probable loss of precision, BGS list being more detailed for some commodities)
- ▶ Classification System (JORC, NI43-101, UNFC…)

▶ Classification sub-categories (inferred, indicated, measured, probable, proven, UNFC code…)
▶ Quantity (value + unit)
▶ Statistical Type (or something equivalent, which can take the following values)
- ♦ Production
- ♦ Reserve
- ♦ Resource
- ♦ Exploration
  - ❖ Number of active licences
  - ❖ Number of licences issued
  - ❖ Number of companies exploring
  - ❖ The area covered by exploration licences
  - ❖ The amount of expenditure incurred
- ♦ Trade (data not harvested, only provided by BGS for diffusion)
  - ❖ Import data
  - ❖ Export data

▶ Note/Comment

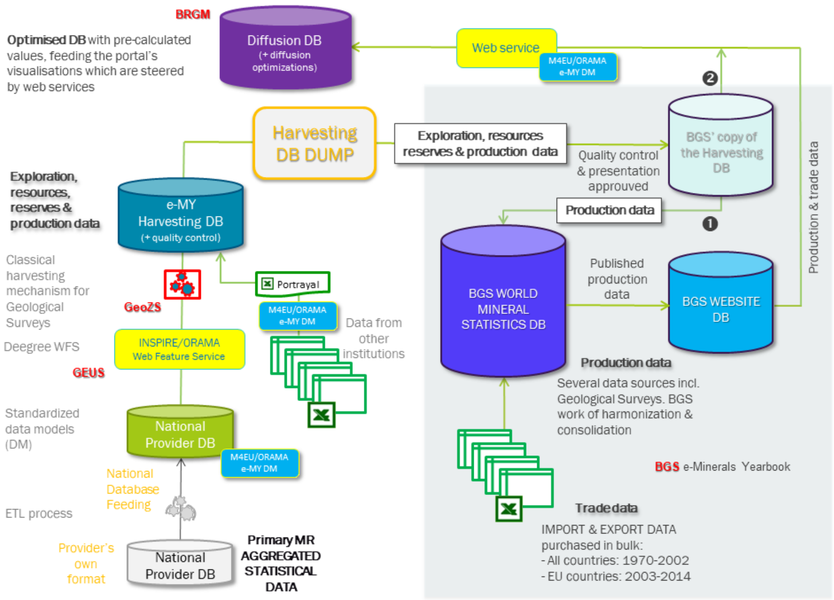

Figure 16. E-Minerals Yearbook. Data flow from the aggregated data harvesting to their diffusion (extract from ORAMA D3.1, Cassard et al., 2019b).

Three options are currently evaluated: (i) to extend ERML-Lite, which means to develop a new view that will have to be agreed by the CGI, (ii) to use for the first time O&M[12] (ISO

[12] See e.g.: http://www.opengeospatial.org/standards/om, https://en.wikipedia.org/wiki/Observations_and_Measurements, https://www.spatineo.com/2012/02/what-is-an-om-observation-and-why-should-you-care/

19156, Observations and Measurements), or (iii) to adjust the M4EU data model, modifying the MineralProducingCountry feature.

Regarding the delivery to the RMIS, two options can be considered, depending on the needs which will have to be precised. The development of a dedicated API could be useful if data has to be incorporated in some other application. Alternatively or additionally, pre-computed views could be prepared (see also section 5.5).

7 A POWERFUL SEARCH CAPABILITY CONNECTED TO EXISTING ONES

All the Knowledge Data Platforms developed by the EGS Core Team (BRGM, CGS, GeoZS, GEUS) are endowed with a powerful Search Capability.

This Search facility is based on a search engine indexing (via Apache Solr - http://lucene.apache.org/solr/) the Central Diffusion Database (i.e., structured data), the documents corpus and its metadata (i.e., non-structured data), the CSW Metadata Catalog for structured data (called here 'MICKA') and some external databases (if any). A user interface allows end users to retrieve data from the whole Knowledge Data Platform using either a simple input like a Google-like search, i.e., a simple sentence (What?)[13] or using some specialized interfaces[14]. Almost all the indexed concepts have geographic and temporal extents (coming from the INSPIRE MR/ERML (and other possible) data model(s) for the Diffusion Database, or coming from the Dublin Core metadata for the documents). These extents allow the user (i) to perform geographic searches using the spatial interface (Where?) and (ii) to retrieve the most accurate response(s) for his search (Figure 17).

[13] Searching in the whole KDP

[14] Searching for specific concepts using their main attributes, e.g., selecting a data source and searching in the 'Creator' field and/or in the 'Title' field of the document, or for Mining Wastes, searching according to the name of the related mine, or to the commodity…

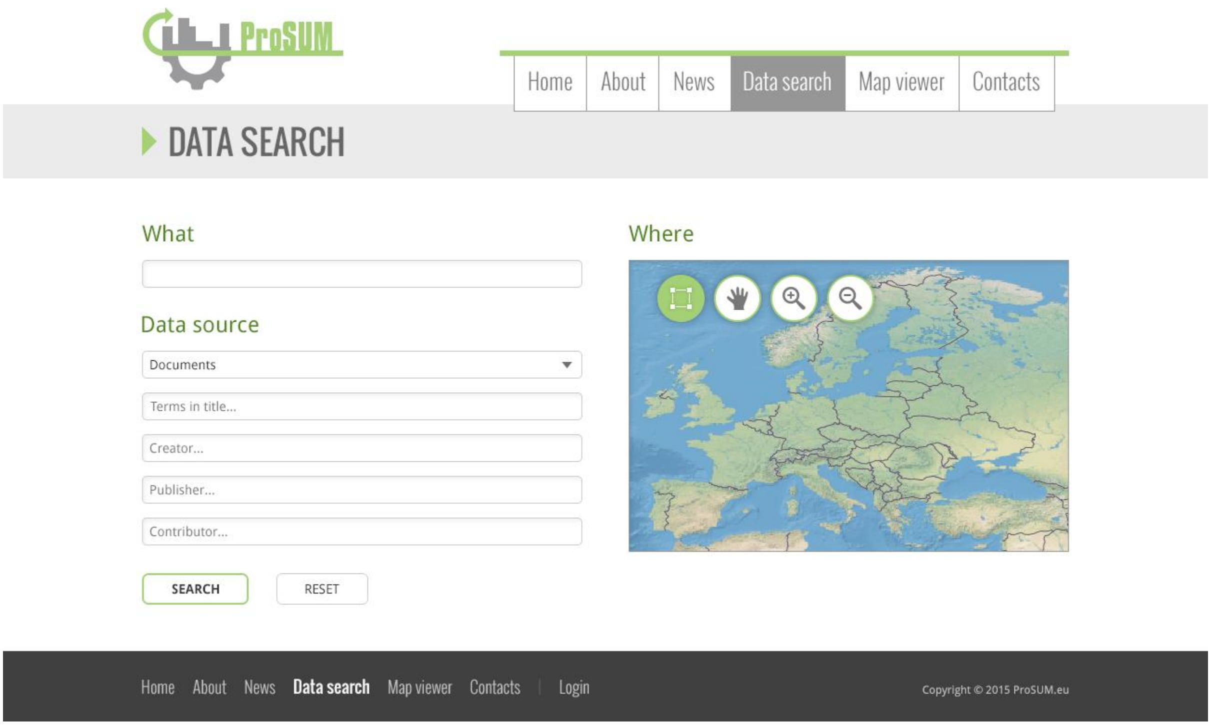

Figure 17. The Search interface of the EU-UMKDP (H2020 ProSUM project).

It is quite conceivable that the RMIS 2.0 could connect to these different Search capabilities as suggested in Figure 1. In addition to its own search facilities, this would allow this information system performing more targeted searches (e.g., on CRM, on secondary resources like WEEE, BATT or ELV…) and benefiting from already constituted corpus of information and knowledge.

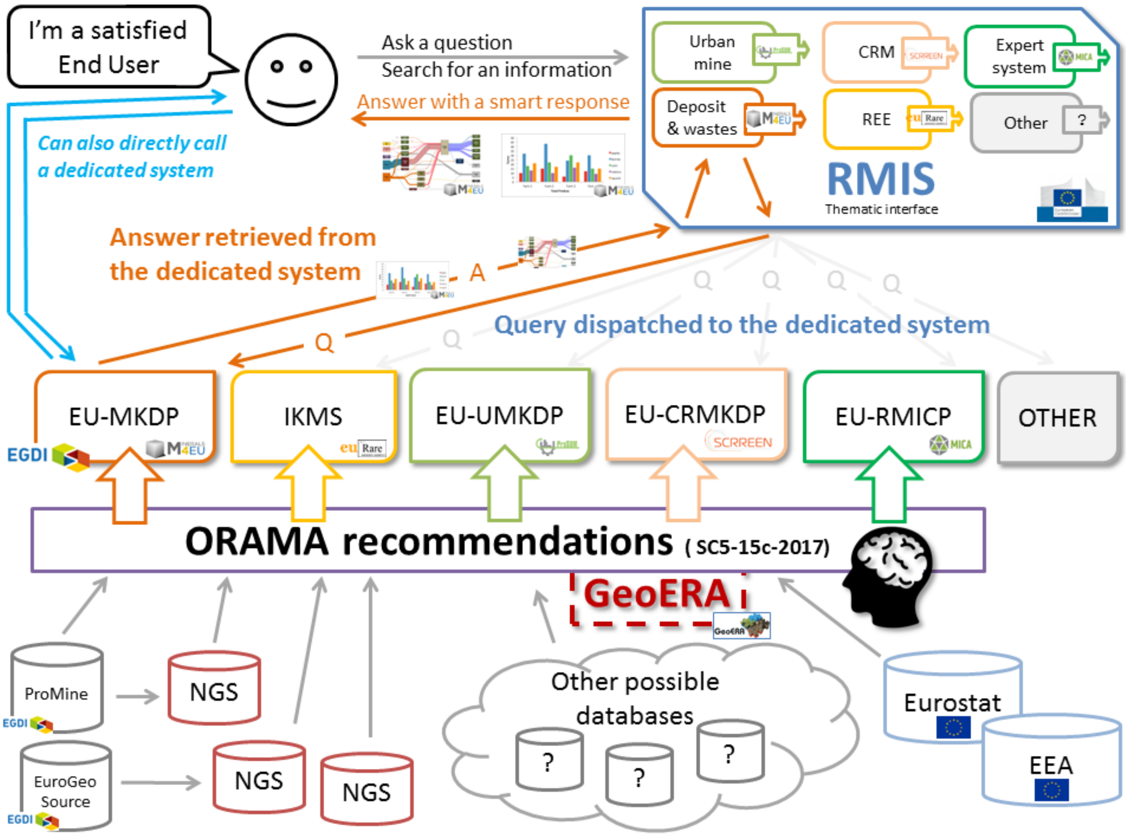

Figure 18. Relationships between the RMIS 2.0 and external services and applications, and the role played by ORAMA and the GeoERA program in the improvement of datasets. The MICA expert system is represented by the brain. Extract from Cassard and Tertre (2017), modified.

As in the 'Application' interface (see Figure 1), a dedicated 'Search' Capability interface should be developed in the RMIS, allowing at the same time the end user to perform generic and/or more targeted searches. The idea is for the end user to be able to perform the search directly through the RMIS 2.0 interface, the results being displayed to him within this same interface. This solution relies on the search capabilities of the existing KDPs that are part of the EURMKB. The end user obviously also has the possibility to search directly in the original platform (Figure 18).

Technically, this supposes that existing KDPs propose a search interface (API) that can be requested from the RMIS (with the CORS limitation seen before). These search interfaces need to be standardized and the use of **OpenSearch**[15] might be considered (at this stage, none of the Minerals4EU, EURare or ProSUM KDPs propose such kind of search interface). Then the RMIS would have to implement the client-side of OpenSearch to be able to request these KDPs.

[15] http://www.opensearch.org/Home

OpenSearch is a collection of technologies that allow publishing of search results in a format suitable for syndication and aggregation. It is a way for websites and search engines to publish search results in a standard and accessible format (see https://en.wikipedia.org/wiki/OpenSearch for a brief description and http://www.opensearch.org/Home for more details).

Figure 19 summarizes how OpenSearch works:

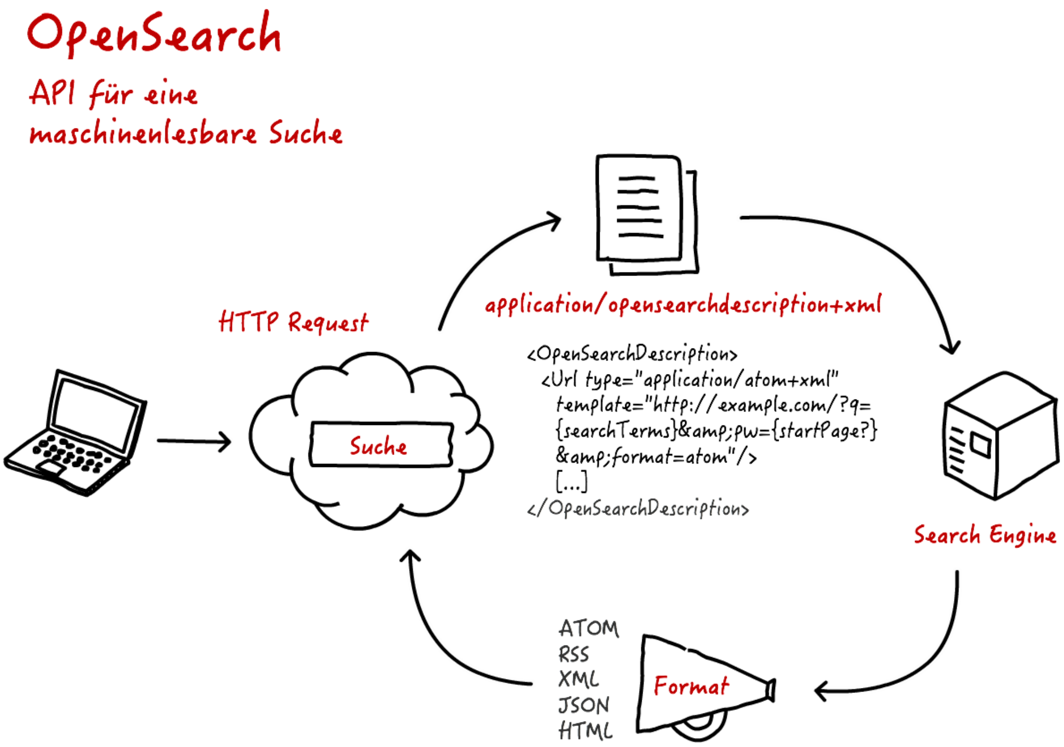

Figure 19. OpenSearch API is a collection of simple formats for the sharing of search results (see https://github.com/dewitt/opensearch).

Mintell4EU will benefit from the synergy with the H2020 SCRREEN project. An attempt to make the RMIS benefiting from the SCRREEN CRM Knowledge Base content is currently underway in Work Package 9 'Knowledge Management'. Once the various problems related to this implementation will be resolved (incl. security access problems), it is here, in this project, perfectly conceivable to extend the connection of RMIS to other Knowledge Bases such as the IKMS, EU-MKDP and EU-UMKDP ones for respectively REEs, all deposit types and the urban mine non-structured data.

Note that under the GIP-P the usefulness of a general approach to Knowledge Bases will be studied.

8 CONNECTION TO THE MICA EXPERT SYSTEM

The MICA Expert System (Cassard et al., 2017b, Ziébelin et al., 2018) has been developed in the frame of the H2020 MICA project and more precisely within its work package 6 entitled 'The European Raw Materials Intelligence Capacity Platform (EU-RMICP)' whose partners were BRGM, BGS, GeoZS, GEUS, GTK, JRC and LIG (Laboratoire d'Informatique de Grenoble).

The description of the project can be found on the project website (http://www.mica-project.eu/). To briefly summarize: MICA (Mineral Intelligence Capacity Analysis - 2016-2017) has among its objectives to develop a platform of knowledge, the EU-Raw Materials Intelligence Capacity Platform (or EU-RMICP), integrating metadata on data sources related to primary and secondary resources and bringing end users with an expertise on the methods and tools used in mineral intelligence. In practice, the system owes be capable of bringing relevant 'answers' of the type 'how to proceed for…' on almost any question relative to mineral resources, on the whole supply chain, since the prospecting until the recycling, taking into account the environmental, political and social dimensions.

To meet this challenge, the EU-RMICP is based on an ontology of the domain of mineral resources (coupled with more generic cross-functional ontologies, relative to Commodities, Time and Space, Methods & Tools, the Supply-Value Chain), which represents the domain of questions of users (experts and non-experts). The user navigates this ontology by using a Dynamic Graph of Decision (DDG) which allows him/her to discover the solutions which he/she is looking for without having to formulate any question. The system is coupled with a 'RDF TripleStore', a database storing the ontologies, factSheets, docSheets and flowSheets (i.e., specific formatted forms) related to methods and documentation, scenarios and metadata (Figure 20 & Figure 21).

This particularly innovative system can be widened (perimeter or scope and granularity) and represents a prototype of a modern expert system.

In practice, this system will be connected with the existing Knowledge Data Platforms (e.g., the IKMS, the EU-MKDP, the EU-UMKDP, the EU-CRMKDP…, and also the EGDI), allowing them to make their users benefitting of the Expert System, and knowing that these platforms will also 'bring' to the MICA system their data (see Figure 20).

Considering the overlap of the topics/domains covered by the RMIS 2.0 and the EU-RMICP ('Primary' and 'Secondary Mineral Resources', 'Industrial Processing and Transformation', 'Raw Materials economics', 'Raw materials Policy & Legal Framework', 'Sustainability of Raw Materials' and 'International Reporting' – see Figure 22) the MICA DDG should also be connected to the RMIS, as suggested in Figure 1 (upper part).

This connection between the MICA DDG and the RMIS is established through the creation of new linkedSheets (i.e., links to documents or pages that are external to the MICA system, but annotated within this system) **to the RMIS resources. This is currently being done within the H2020 SCRREEN project (WP9 'Knowledge**

Management'). There can also be new factSheets (documents with knowledge inside) or flowSheets (linking of different methods and tools to answer to a complex question) that will be added to the MICA system by the RMIS JRC team. They will be then annotated using the MICASheet Editor (Figure 20 & Figure 21) and become retrievable through the MICA DDG (see Figure 22).

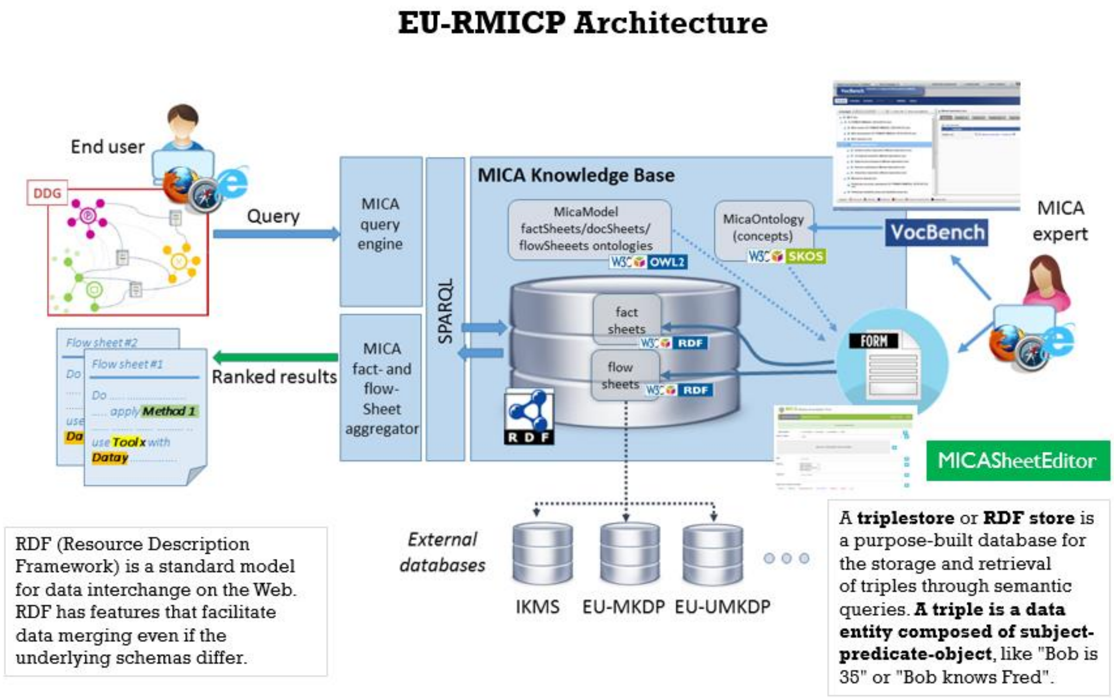

Figure 20. The MICA Expert System. General architecture of the EU-Raw Materials Intelligence Capacity Platform (after Ph. Genoud, LIG, modified). Extract from Cassard and Tertre (2017).

Note that in this context, JRC (as a MICA full partner) can have a full access (i) to the MICA Sheet Editor which allows managing the different types of sheets (linkedSheets, docSheets, factSheets and flowSheets (creation, update, deletion), to annotate them over the ontologies, to link them between themselves or with data sources… and (ii) to the ontology editor (VocBench – see Figure 20) which allows editing the ontologies, modifying both perimeter and granularity and characterizing the relationships between the different concepts.

EU-RMICP databases (triple store and relational) and relation with interfaces

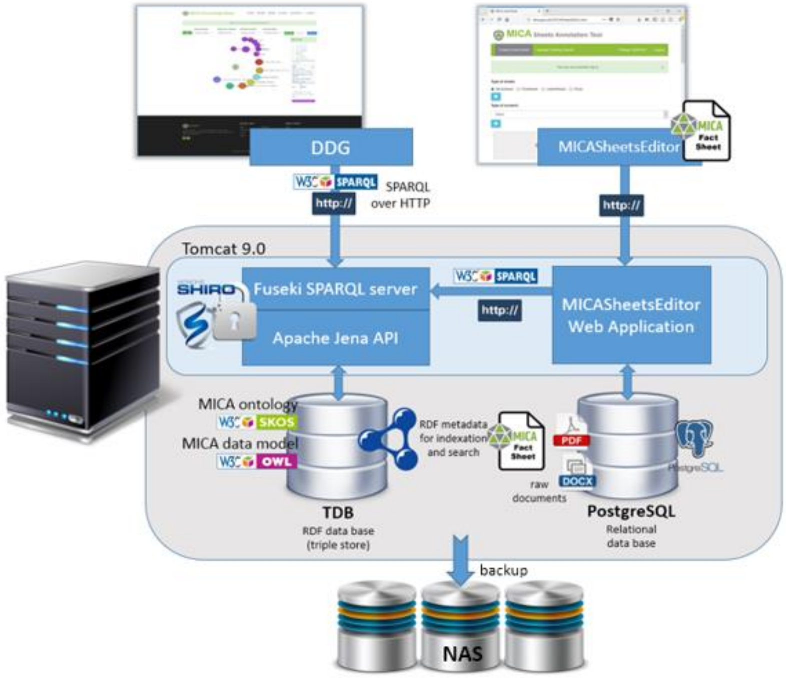

Figure 21. The EU-RMICP databases and the relations with interfaces.

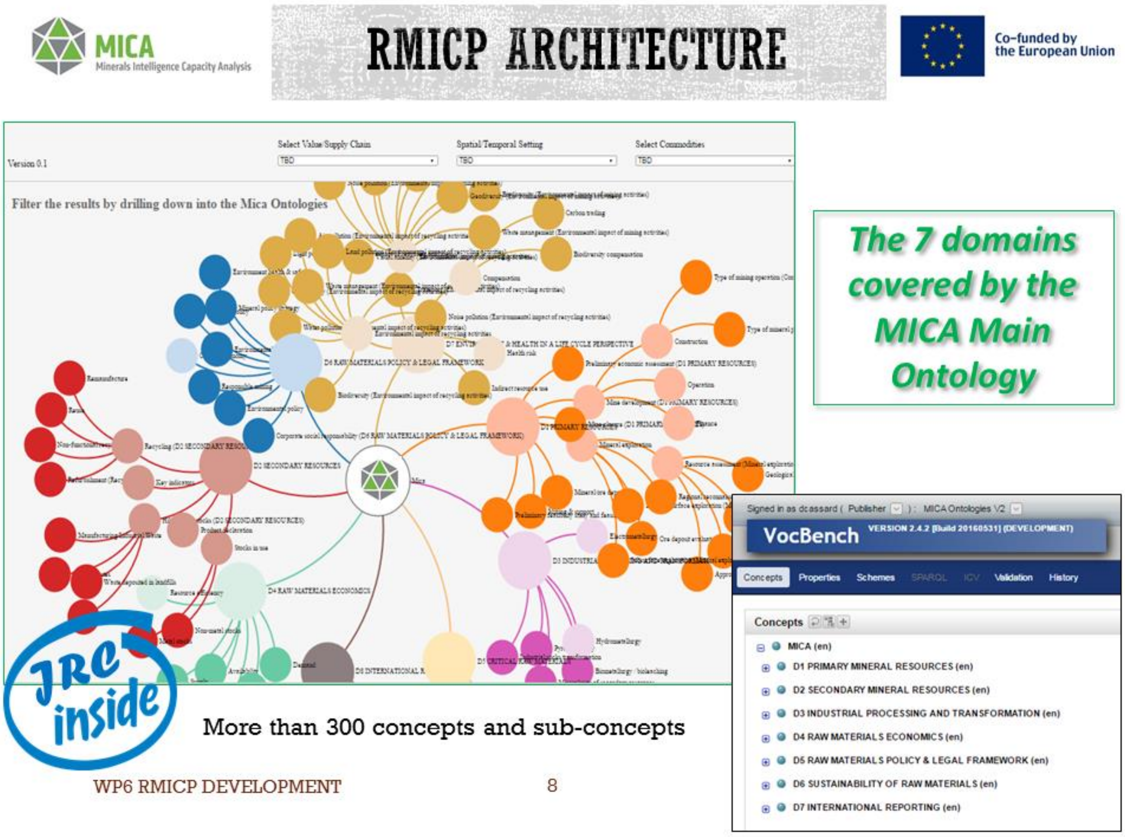

Figure 22. The MICA Main ontology and the 7 domains covered with more than 300 concepts and sub-concepts. The Dynamic Decision Graph (DDG) allows navigating the ontology and selecting concepts of interest. Extract from Cassard and Tertre (2017).

9 CONCLUSION

From this assessment of existing Knowledge Data Platforms (KDPs) and their content and RMIS needs in terms of data, information and knowledge as they emerge from the publication entitled ‘Raw Materials Information System (RMIS): Towards v2.0 – An interim progress report & roadmap (Manfredi et al., 2017), several actions can be undertaken.

It is particularly interesting to note here that, thanks to the synergies existing with ongoing European projects, notably SCRREEN and ORAMA, certain developments should be able to be launched more easily than initially planned.

This does not mean that for some specific tasks the solution on how to proceed to transfer data toward the RMIS is already perfectly identified at this stage. This report tried to evaluate the possible solutions and to compare them, in terms of ease of implementation, maintenance and sustainability and therefore cost.

Table 2 is an attempt to summarize the recommendations made regarding the transfer of part(s) of data and information, aggregated data and knowledge stored in KDPs to the RMIS 2.0.

DIKW	Detailed type	Type of transfer	RMIS' target	Synergy with
D, I	Structured data. Primary resources (Mineral4EU, EURare, SCRREEN)	▶ WFS + ETL (not recommended) ▶ API based on ERML-Lite (recommended).	ScoreBoard	-
D, I	Structured data. Secondary resources – Mining wastes (Minerals4EU, ProSUM)	▶ WFS + ETL (not recommended) ▶ API based on ERML-Lite (recommended).	ScoreBoard	-
D, I	Structured data. Secondary resources - Urban mine (ProSUM)	▶ API 'ProSUM e-Stat' ▶ Pre-computed views	Scoreboard, MSA	SCRREEN
D, I	Structured data. Aggregated data (e-Minerals Yearbook)	▶ API 'e-MY' ▶ Pre-computed views	ScoreBoard, MSA, CRM, Trade	ORAMA
K	Knowledge from Knowledge Bases (all platforms)	▶ API 'OpenSearch'	RMIS Search Capability	SCRREEN
W	Methods & Tools. Ontology-based MICA Expert System	▶ Connection via newly developed sheets	RMIS Search Capability Decision-aid system	SCRREEN

*DIKW refers to Data, Information, Knowledge, and Wisdom (or intelligence).

Table 2. Summary of recommendations.

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