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NI4OS-Europe

National Initiatives for Open Science in Europe

Deliverable D4.3
Mapping of legal, technical and procedural tools

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Abstract: This deliverable presents the analysis of legal, procedural and technical tools collected in the frame of the NI4OS-Europe WP4 and WP2 activities. The results are categorised following a clear methodology and are then mapped to stakeholder groups. Findings and next steps of work in WP4 are provided aiming at minimising the gaps in Open Science tools identified in the landscape so far, at global level and in NI4OS-Europe countries.

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The NI4OS-Europe Consortium consists of:

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02.05.2020	f	Milutin Radonjić	Internal quality check
04.05.2020	final	Eleni Toli	Final version, ready for submission

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References

[1] Project NI4OS-Europe-857645 – Annex I – Description of the Action

[2] D2.1 Stakeholder map, inventory, policy matrix (https://zenodo.org/record/3736129#.Xqq7GagzY2w)

[3] D4.1 Incentives for Supporting ORDM and FAIR (https://zenodo.org/record/3736148#.Xqq7ZagzY2w)

[4] D4.2 Data repository integration and ORDM/FAIR compliance guidelines (https://zenodo.org/record/3736150#.Xqq8GqgzY2w)

[5] Collected tools catalogue: https://docs.google.com/spreadsheets/d/1Sk8YmcUbxoMDelcyEKyXGPxDG61zEmDc/edit#gid=739815483

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List of Acronyms

EOSC	European Open Science Cloud
CRIS	Current Research Information System
ERA	European Research Area
FAIR	Findable Accessible Interoperable Reusable
FAIRsFAIR	Fostering Fair Data Practices in Europe
HPC	High-Performance Computing
OA	Open Access
OpenAIRE	Open Access Infrastructure for Research in Europe
ORDM	Open Research Data Management
OS	Open Science
PID	Persistent Identifier
PMB	Partner Member Board
RFOs	Research Funding Organisations
RoP	Rules of Participation
RPOs	Research Performing Organisations
WP	Work package

Executive summary

What is the focus of this Deliverable?

The purpose of this deliverable is to analyse and categorise contemporary existing tools covering the increased demand for providing:

- support to research funders' and institutions' policymaking and implementation activities in a standardised, yet inclusive, fashion;
- clear workflows, guidelines and training for nurturing Open Science competent researchers;
- technical solutions to address the needs for researchers to publish in FAIR and Open modes.

The aim is to understand the strengths and weaknesses in NI4OS-Europe countries and in stakeholder groups and respond, also to European and global demands, by immediately addressing identified gaps in legal, procedural and technical tools in upcoming deliverables of WP4 concerning the development of new tools.

What is next in the process to deliver the NI4OS-Europe results?

Work, analysis and findings of D4.1, D4.2 and the current deliverable, will be used by NI4OS-Europe to identify possible tools supporting ORDM and FAIR that are currently missing. Work will be concluded with the two upcoming deliverables, D4.4 and D4.5 which will develop data management and certification tools.

What are the deliverable contents?

This Deliverable describes a landscape collection of legal, procedural, technical tools performed for D4.3 and combined with data received from D2.1 survey activity. For the needs of D4.2, a first analysis of this collection preceded with a view on repositories integration in EOSC and compliance with open and FAIR principles. The sections are structured as follows.

Section 1 - Introduction, presents an overview of the work performed and sets the basis on how the deliverable should be read and perceived.

Section 2 - Methodology, presents the overall approach and the steps and work plan followed. References to previous work and links with this activity and with other work packages is provided.

Section 3 - FAIR and ORDM services and tools, reuses the responses received from D2.1 survey to give input about the services and tools used in current national research ecosystems of NI4OS-Europe partners.

Section 4 - Categorisation of tools, explains the specifics of the categorisation which was followed and informs about the main outcomes of the analysis of tools it was based upon.

Section 5 - Stakeholders, shows the uptake of tools and highlights specific needs of stakeholders in terms of Open and FAIR RDM tools. User profiles are created to showcase different ways of use of services and tools, possible modifications and adjustments of services needed for different stakeholder types, etc.

Section 6 - Conclusions and Next steps, lists major findings and makes suggestions about future work in NI4OS-Europe.

Conclusions and recommendations

This Deliverable, combined with D4.1 and D2.1, offers valuable analysis and categorization of the existing guidelines, policies, technical solutions and models addressing FAIR and open issues. This snapshot is useful in bridging the gap between specific stakeholders and user groups needs and existing tools and models. Thus, this work helps to spot inconsistencies in the current scenery, extract user requirements, and most important, design fit-for-purpose tools for both EOSC stakeholders and the EOSC-Core architecture.

1. Introduction

This deliverable is part of Work Package 4 (WP4) of NI4OS-Europe project and is only one segment of its activities that aim to provide clear pathways as well as new products that would make an easy transition to national Open Science ecosystems. WP4 is supporting this through the development of guidelines, tools and mechanisms that assist the formulation of Research Data Management (RDM) policies, ensure technical compliance of infrastructures and services in particular with the FAIR principles, define legal and ethical actions that enable open sharing of scientific data, etc. All activities are undertaken in support of and in coordination with WP2, which is bound with setting up national open science cloud initiatives. In addition, specific outcomes of WP4 are to be communicated with WP5 that is responsible for the on-boarding of repositories to EOSC for enriching them with evolving best practices. All the above are complemented by and communicated through related training activities taking place in WP6.

Work on D4.3 and the parallel analysis of tools focus on scanning the landscape to identify potential gaps in the literature and current best practices applied, either on the strategic, operational or technical level and to **create a tools catalogue** for NI4OS-Europe stakeholders to consult from. Ultimately, a major aim of this work is determined to support the production of tools that move away from duplicating efforts in areas that have already been extensively explored and/or have triggered the creation of a plethora of equivalent products.

In order to avoid misinterpretations and create a common understanding of this deliverable, it is important to state that the term "tools" is used in two ways:

a. Based on the computing definition where a tool is a software designed to implement specific functions; sometimes provided "as a service".

   Under this definition fall for example tools for Data Management Planning that provide an interface and complete functionalities that allow for the scope to be achieved[1].

b. Based on the wider definition where something facilitates usability and performance of actions.

   Guidelines, models, collections of policies or structured collections of resources also correspond to this definition[2].

Finally, the tools catalogue should not be confused with the on-boarding of services (and sometimes tools offered as services) to the EOSC catalogue. This catalogue is not a regional service catalogue to plug into the EOSC one for making on-boarding easier. Rather, it is a collection of existing instruments for Open and FAIR RDM to assist stakeholders in complying with relevant mandates at European and/or national level. Hence, the list of sources/tools is comprised of guidelines and tools that are essential building blocks of open research ecosystems touching more upon the technical side of open and FAIR implementation, while it also includes models and workflows that support policymakers, Research Performing Organisations (RPOs) and Research Funding

[1] Check for example the online DMP tool "Argos": https://argos.openaire.eu/home

[2] Check for example the "TOP Guidelines" for an approach to standardisation of journal's policies and practices with respect to data sharing: https://cos.io/top/

Organisation (RFOs) in adopting equivalent policies in their area of influence. In addition, the list contains tools and methods of immediate use by researchers to be embedded in their everyday work thus enhancing current research practices.

Though, WP4 will indeed on-board tools that will create in the course of NI4OS-Europe with the perspective of feeding them into the EOSC Architecture and EOSC-Core building blocks at large, as well as to enabling the transition to more open science ecosystems and code of conduct.

2. Methodology

In terms of the methodology followed for the completion of the deliverable, the tools catalogue was populated mostly with desk research which was later complemented by findings of the landscaping survey performed as part of the NI4OS-Europe work package dealing with the setting up of National Open Science Cloud initiatives (WP2). Moreover, landscape review took stock of preliminary work undertaken in the EOSCpilot WP3 work on policy, namely the *Open Science Monitor* and the *Policy Toolkit*, to ensure the continuation of work in the context of EOSC. The *Open Science Monitor* provides a comparison of open and FAIR principles highlighting differences and commonalities between them, thus giving great input to WP4 activities focusing on Open and FAIR RDM. The *Policy Toolkit* lists sources that are necessary for the effective operation of services that support the EOSCpilot policy (the *Open Science Monitor* being one of them) and ensures successful implementation and adoption of the EOSCpilot policy framework by its stakeholders. To meet the scope and objectives of NI4OS-Europe, the EOSCpilot toolkit was cleared up, updated, re-categorised and enriched with new sources found either directly from searching the Internet or indirectly from attending talks and presentations for Open Science and FAIR data management.

Below, the methodological steps are presented in more detail. Also, the connection with other deliverables and with the EOSC is explained.

2.1. Overview of WP4

Deliverable *D4.3 "Mapping of legal, technical and procedural tools"* is third in the sequence of deliverables produced by WP4 on ORDM standards, processes, tools and certification schemes. The ultimate goal of WP4 is the development of new tools for ORDM, which is facilitated by work preceded in *D4.1 "Incentives for supporting ORDM and FAIR"*, *D4.2 "Data repository integration and ORDM/FAIR compliance guidelines"* and concludes with the current report.

Specifically, D4.1 [3] defines the set of incentives and rewards to be promoted for adoption through the policy activities of the national open science initiatives (WP2). This work takes into consideration the successful paradigms of OpenAIRE NOADs' actions in countries that already have or are now developing national Open Science policies intending to boost the application of FAIR and open research data management standards, processes, tools and certifications in the NI4OS-Europe area of influence. Next, D4.2 [4] presents the current open and FAIR scenery, focusing on standards' integration with services to make them FAIR-aligned. Based on that, guidelines are produced to showcase how best practices can be applied for compliance to be met in the context of repositories. Also, D4.2 takes great input from the early work on. Figure 1 depicts how the development of tools draws input from deliverables D4.1, D4.2.

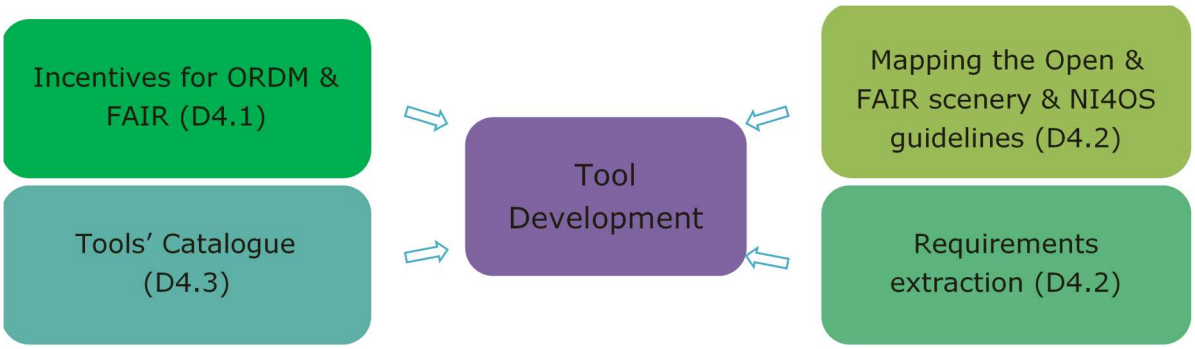


Figure 1: Tools development utilizes input from D4.1, D4.2, D4.3

Thus, the contribution of the aforementioned deliverables is significant in the preparation stage before the development of ORDM tools in WP4, as:

- D4.1 provides incentives and rewards for ORDM. The adoption of the proposed framework or particular aspects of it could be supported by a new tool.
- D4.2 produces compliance guidelines that enhance the tools catalogue as well as highlight the requirements for the new tools, such as FAIR alignment.
- D4.3 consists of a landscape review of existing tools for ORDM, thus making the identification of current gaps and immediate needs in the Open Science ecosystem more prominent.

2.2. Methodological steps

Zooming in the specifics of D4.3 work, this section describes in detail the steps undertaken to identify, select, analyse and display information about tools for Open and FAIR Research Data Management that would be beneficial to a number of EOSC stakeholders' activities.

The whole process has been divided into two stages, the preparatory stage and the core work. The preparatory phase includes all activities that allowed for better knowledge of existing solutions, independently of their purpose, targeted audience or use. It also includes the identification of stakeholders who could be the potential beneficiaries and users of the tools. In the main stage, collected information has been classified, analysed and descriptions of basic characteristics of tools have been provided. Work includes in more detail the following streams:

- **Capturing the open & FAIR scenery** (Desk research) – Preparatory stage

The first step was to understand the evolving open and FAIR scenery by looking at EOSC preparatory work through extensive desk research. Work focused on outcomes of previous projects such as EOSCpilot, but also current ones, such as FAIRsFAIR, as well as on following recent developments of global data fora such as RDA. Especially useful was the work performed by EOSCpilot, related to the Policy Toolkit, as a primary information source when starting this activity.

- **Identifying and exploring stakeholder groups and needs** – Preparatory stage

In order to determine how the tools can be used by EOSC and NI4OS-Europe stakeholders, the tools catalogue extracts information from descriptions found at providers' websites to include tags showing stakeholders as prospective users. This is then linked to the

stakeholder groups identified and used in WP2 to ensure consistency in the approach of NI4OS-Europe and of the analysis of its outcomes. Complementary to this, to further understand the needs of stakeholder groups in total, the results of D2.1 survey were re-used. Answers containing information about tools or services were isolated from the main survey spreadsheet and were examined in comparison with the general characteristics of respondents, mainly the type of stakeholder group they belong to. This activity proved to be useful for a better understanding of potential user profiles for each tool. On certain occasions, teleconferences between the WP4 team and tool developers were performed to increase comprehension in the way specific tools can be used by the team and by EOSC stakeholders.

- **Collection** – Core work

The compilation of the current collection of tools took place in iterations, which included the evaluation of available content, the identification of missing aspects, the population of the catalogue, and the re-evaluation of its content. The EOSCpilot Policy Toolkit that had been used as a starting point for the collection of related information, has been modified and put in the context of the NI4OS-Europe objectives. Following a thorough cleaning of the existing tools based on criteria such as whether they are up-to-date and functional, new tools were populated. These have been identified either through additional desk research, or by receiving input from the community (e.g. by attending talks and presentations for Open Science and FAIR data management). In addition, tools identified through the survey were then mapped with those already included in the tools catalogue for deduplication of same records. Finally, the list was re-examined in terms of granularity and inclusiveness to ensure all ORDM aspects, from legal to operational to technical, are covered.

- **Description and categorisation of tools** – Core work

In order to provide a comprehensive presentation of each tool, a set of essential attributes has been identified. Collecting the related information for each tool allows potential users to better understand its purpose and decide about its implementation. It also allowed further analysis and categorization, presented in more detail in Section 4, based on their type and use.

Table 1: Description of information collected for each tool in the tools catalogue

Name	**Name of the tool**
Description	Brief summary of the scope and the main functionalities
Published by	Name of organisation or project the tool is developed by
Type	Type of tool based on its form and scope (guidelines & policies, tool, model)
Use	Ways that the tool can be used in (certification, decision making, support)
Users	Developers or end-users as stakeholders (e.g. RPOs, RIs, etc.) or with their specific role (e.g. librarians, service managers, etc.)

Tags	Keywords that best describe the tool in terms of Open Science and its main functionalities
Research output	The type of output that it can be used on or for (e.g. publications/articles, data, software, services, workflows)
Focus	Area of ORDM focus in the NI4OS-Europe WP4
License	Information about the license of the tool so that people know how to use it
Development stage (just for tools)	Current development of the tool (concept, pilot, operational i.e. in production) and relevant dependencies (integrated tool, primary tool)
Geographic area	Geographical coverage of the content of the tool and/ or potential use by specific geographic areas
Link	URL of the tool's Homepage

The complete tools catalogue with descriptions of tools is made available as a separate file and will be also separately deposited in the NI4OS-Europe Zenodo community.

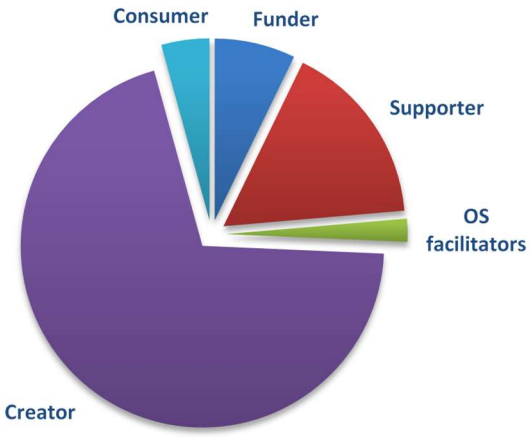
3. FAIR and ORDM services and tools

This section will reuse the responses collected from the NI4OS-Europe survey conducted for T2.1 and presented in D2.1 [2], to provide insights about the services and tools used in current national research ecosystems of NI4OS-Europe partners. The purpose of the survey was to collect information about Open Science initiatives, infrastructures, services, policies, stakeholders and topics in the 15 partner countries. Furthermore, it would offer an initial mapping of OS-related stakeholders, infrastructures, services and policies in the partner countries at the beginning of the project, to help tailor project activities.

3.1. Capturing the open & FAIR scenery (who and why)

The first step in the methodology followed to achieve the desired analysis, was to reduce the dataset size to only the required and relevant data for the context we are focusing on. This reduction in size came naturally as we created a subset of the survey questions that were considered meaningful for this analysis. Based on these questions we extracted the corresponding answers from the collected dataset. In addition, stakeholder profile, organisation and country information was used for this analysis. Data for every question was analysed and used to create a series of meaningful charts. Most data had to be cleaned and processed to create a dataset that can produce informational charts. While some data required simple text or number replacements to homogenise the collected input, other questions imposed the need to create subcategories in the collected input, to extract meaningful information. These charts point at dependencies between stakeholder types and organizational infrastructure, guidelines, policies, tools and services.

Diverging from D2.1, partial survey responses were considered and were included in this analysis to increase the volume of processed responses to some questions that would otherwise be inadequate. These responses were not considered as part of the primary dataset but were individually analysed in isolation from the rest of the dataset. We did not try to relate context-like questions and this allowed us to ignore major differences in the number of responses received for each question, which would otherwise play a significant role in the weight of the produced results. The base dataset used is depicted in Figure 2.



Stakeholder	Particip.	Part. %
Funder	42	7.2%
Supporter	96	16.4%
OS facilitators	12	2.1%
Creator	409	70.0%
Consumer	25	4.3%
Total	584	100%

Figure 2: Stakeholders' groups participation in total responses examined

Five stakeholder groups have been identified during the creation of the survey: a) Funders and policymakers, b) Supporters – the ones who support research such as repositories, research infrastructures, e-infrastructures, service providers, libraries, etc. c) OS facilitators including OS initiatives – beneficiaries representing European or national initiatives for OS, d) Creators – those who perform research, such as research performing organizations and researchers, e) Consumers – those who "consume" research, for example SMEs and citizens. These stakeholder groups are of interest for this analysis as we approached the subject of the higher-level analysis as the total area covered by NI4OS-Europe partners.

3.2. Services and tools in NI4OS-Europe countries

The following subset from the survey questions has been isolated focusing only on questions related to ORDM tools:

- Open Science related infrastructure used by your organization: [Institutional repository, …, CRIS (or CRIS-like) system]
- Where do you store code/software produced in the organization?
- Which specific service(s) does your organization provide to the research community?
- Who are your user communities?
- How do you support users who have issues or difficulties in using services?
- What is the authentication model for your service?
- List guidelines that you use or are aware of, for each of the listed areas [Data Management Plans, …, Compatibility of licences]
- List specific individual tools that you use or are aware of (or use), for each of the listed areas: [Data Management Plans, …, Compatibility of licenses]
- Which identifiers are used in your community for these digital objects?
- What kind of infrastructure would be the most useful for your research/work and how intensively would you use it?
- Apart from the services you already have, which additional services would benefit the users in your organization?
- What do you expect from EOSC?

Analysis for the Open Science-related infrastructure used by organizations shows that this question did not touch the Funders and Supporters groups as there were no inputs from these two stakeholder groups. The answers provided by the rest of the stakeholders were processed in comparison to each other for each of the infrastructures questioned. Relevant results are presented in Figures 3 to 7.

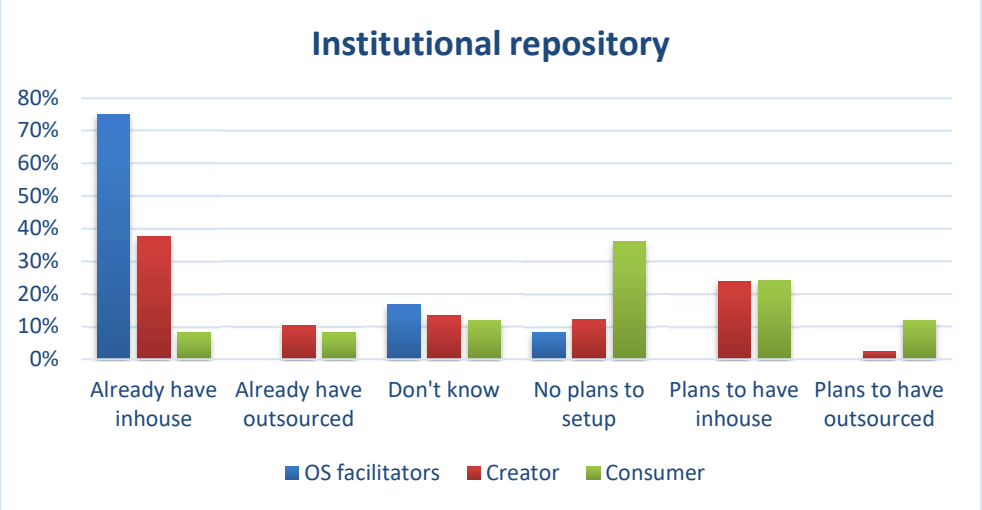


Figure 3: Open Science-related infrastructure for institutional repositories

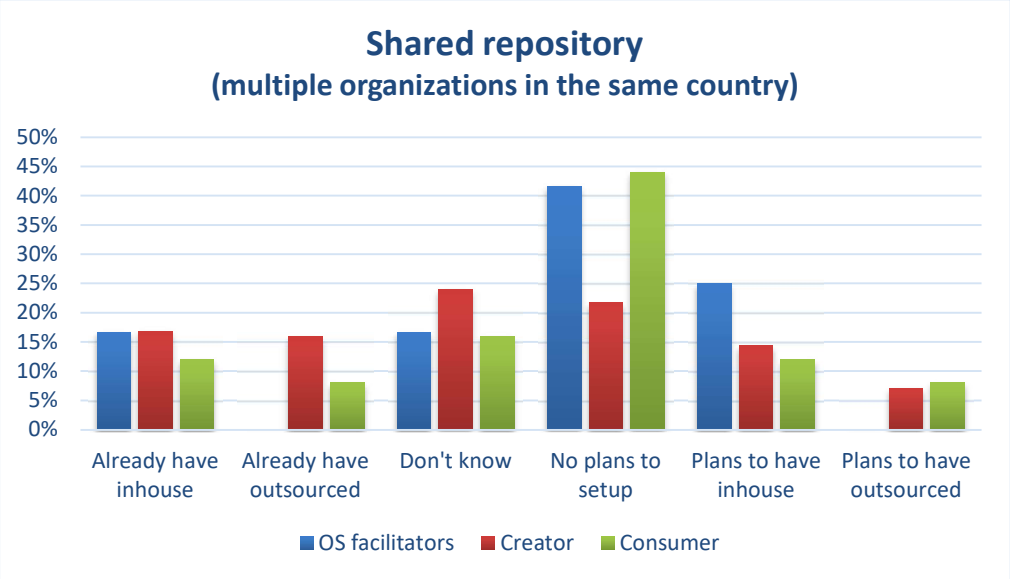


Figure 4: Open Science-related infrastructure for shared repositories

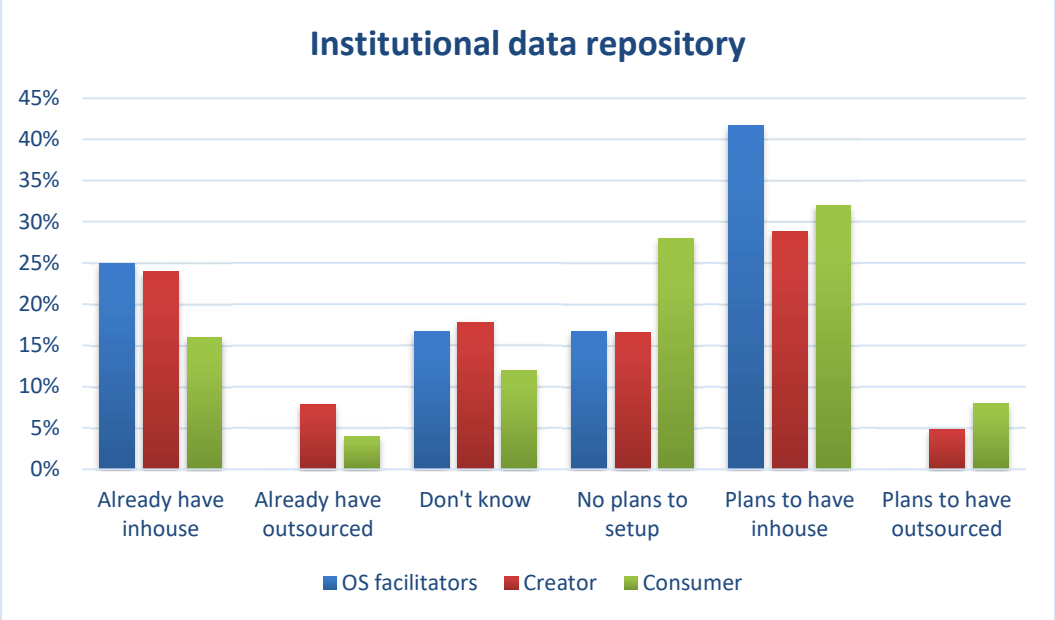


Figure 5: Open Science-related infrastructure for institutional data repositories

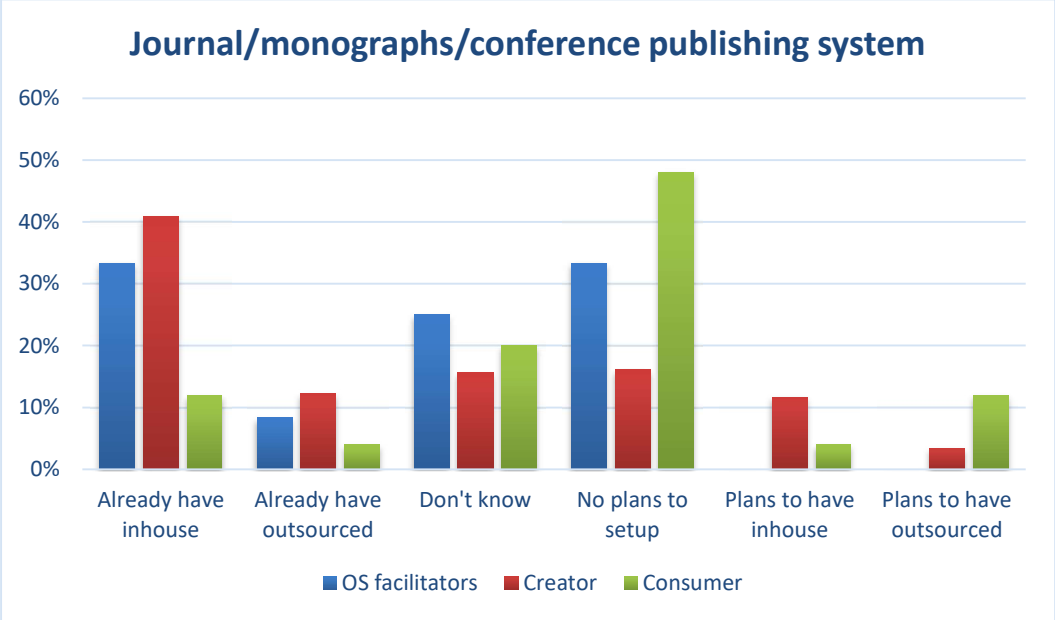


Figure 6: Open Science-related infrastructure for journal/monographs/conference publishing systems

Figures show that Institutional repositories are mostly already available among OS-facilitators and Creators, while Consumers are not particularly concerned with those. Shared repositories, as expected are not very popular, as the vast majority (41.7% OS-facilitators, 21.8% Creators, and 44.0% Consumers) have no plans of setting them up and the percentage of the ones that already use them is very low with an average of 15.2%. Data repositories show a trend to increase among stakeholders with an average of 21.6% already having in-house, while an average of 38.7% is seen as having plans to implement them in-house or to outsource them. Journal, monographs and conference publishing systems are quite popular among the OS-facilitators and Creators, while most

of Consumers (68.0%) along with 45.0% of OS-facilitators and Creators do not have knowledge of these infrastructures or have no plans of setting them up. Results for CRIS – Computational research infrastructure for science, Figure 7 shows that Consumers are either unaware of its existence or have no plans of setting up relevant infrastructure, while most stakeholders are already using it or utilizing outsourced infrastructure. There is also a high percentage of unaware stakeholders, 38.0% average from all groups, and others with no plans of utilizing such infrastructure, 31.0% average.

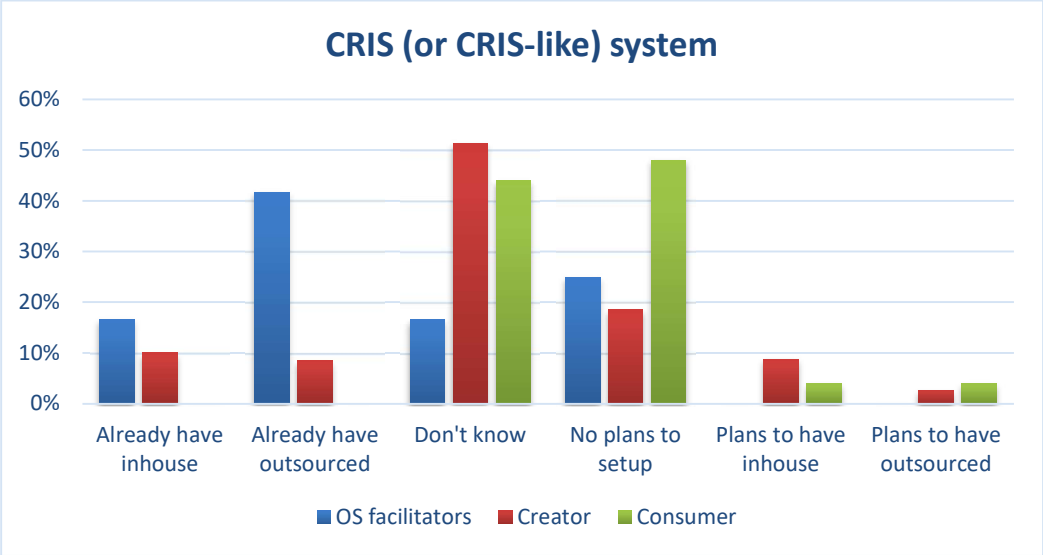


Figure 7: Open Science-related infrastructure for CRIS (or CRIS-like) systems

Figure 8 is also related to infrastructure and very indicative of the current status, as it shows a clear preference for storing code/software produced for the organization in personal computers. It should be noted that this question allowed multiple answers per stakeholder, so the results shown are calculated per answer from the total stakeholders that chose that storage solution.

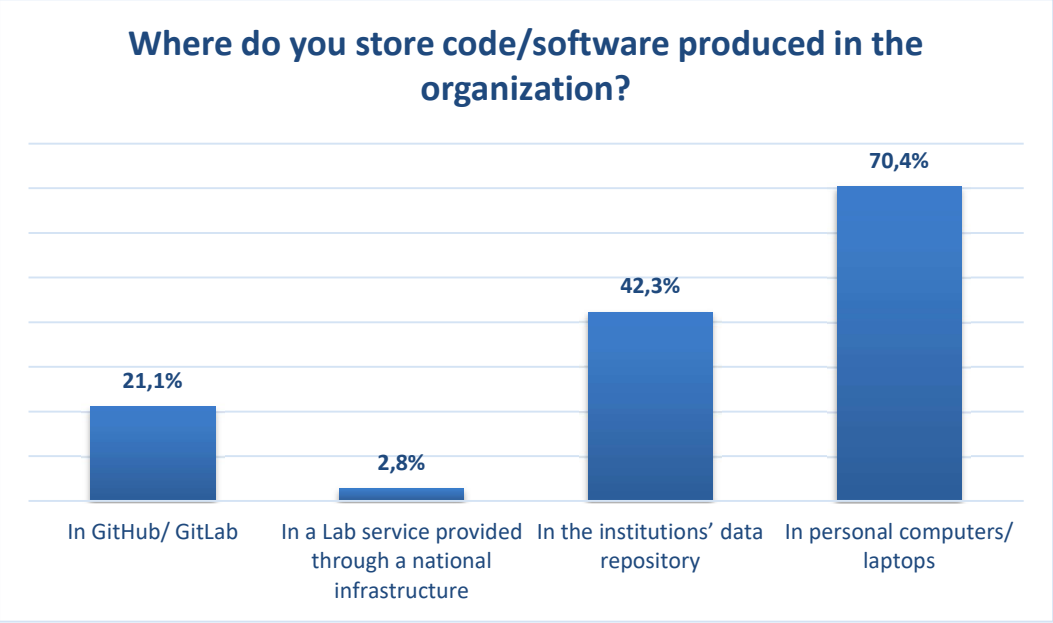


Figure 8: Storage for code/software produced in the organization

Most of the questioned stakeholders provide data infrastructures which store and manage research data as a service, as seen in Figure 9. This, along with the ones providing high-bandwidth networks and high-performance computing implies the use and maintenance of related infrastructure (on-premises or cloud). In addition, a high percentage offer data storage and management of related services, which is in agreement with current research trends, supports the trend in identified needs as derived from **Error! Reference source not found.** As expected, the stakeholders with service offerings come from the groups of Supporters and OS-facilitators.

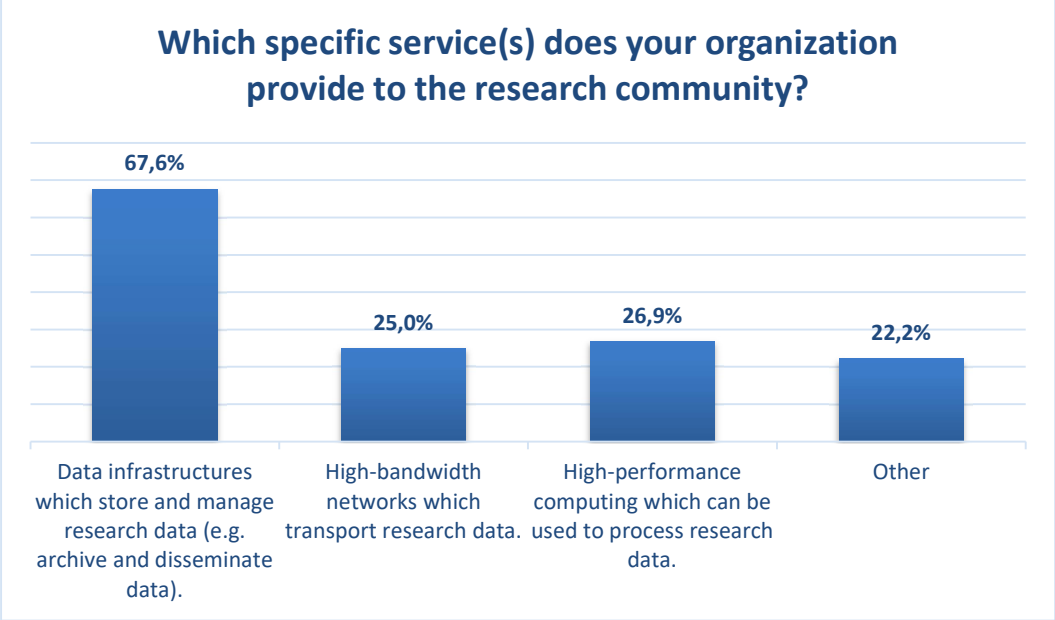


Figure 9: Specific service(s) provided by an organization to the research community

User-support is usually related to services provided by stakeholders, since it is inevitably required, and it is also usually related to dedicated infrastructure and/or tools. When stakeholders from Supporters and OS-facilitators that provide services, were asked about the way they support their users, most revealed the engagement of dedicated teams and helpdesks available during working hours. The results show a very low availability of 24/7 support, which can be probably understood by the low availability rate required for the applications (or requests) using these services. Again, for this question it should be noted that it allowed multiple answers per stakeholder, so the results shown are calculated per answer from the total stakeholders that chose that support option.

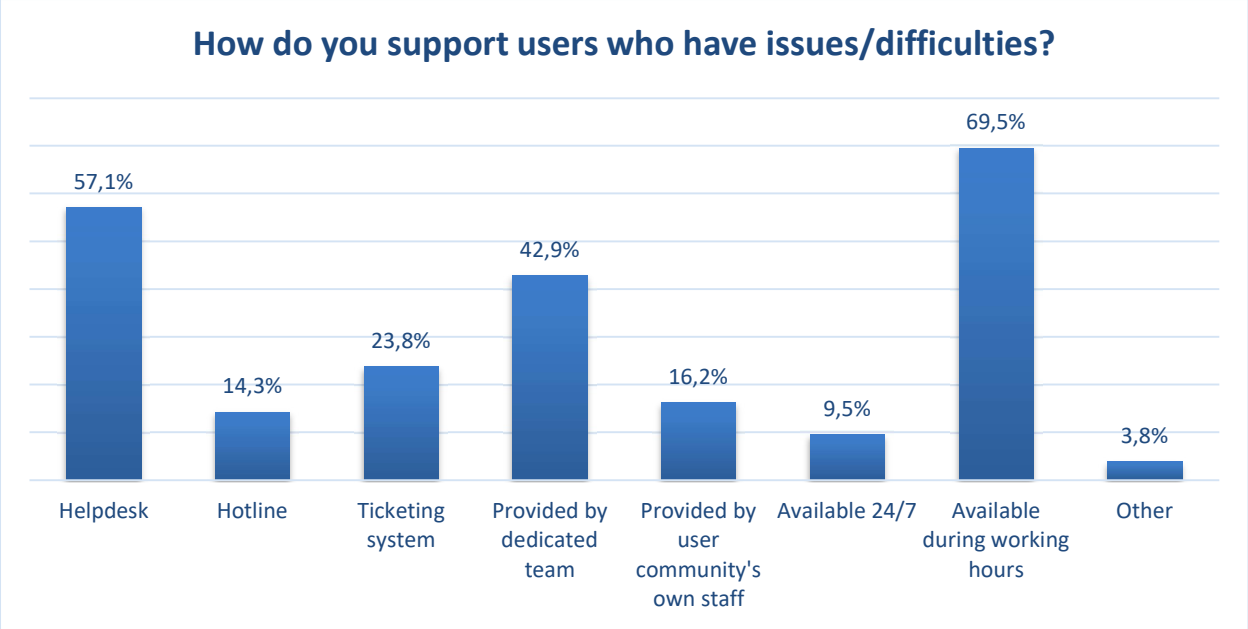


Figure 10: User-support trends among stakeholders

The graph in Figure 10 is relevant for conclusions about the tools used by the stakeholders providing services. The graph in Figure 11 provides a picture of the authentication models used by service providers to authenticate users for their service offerings. It is evident that in the absence of proven and certified infrastructure offering open-source re-usable and shared authentication models 54.63% of service providers chose to operate with a local authentication mechanism.

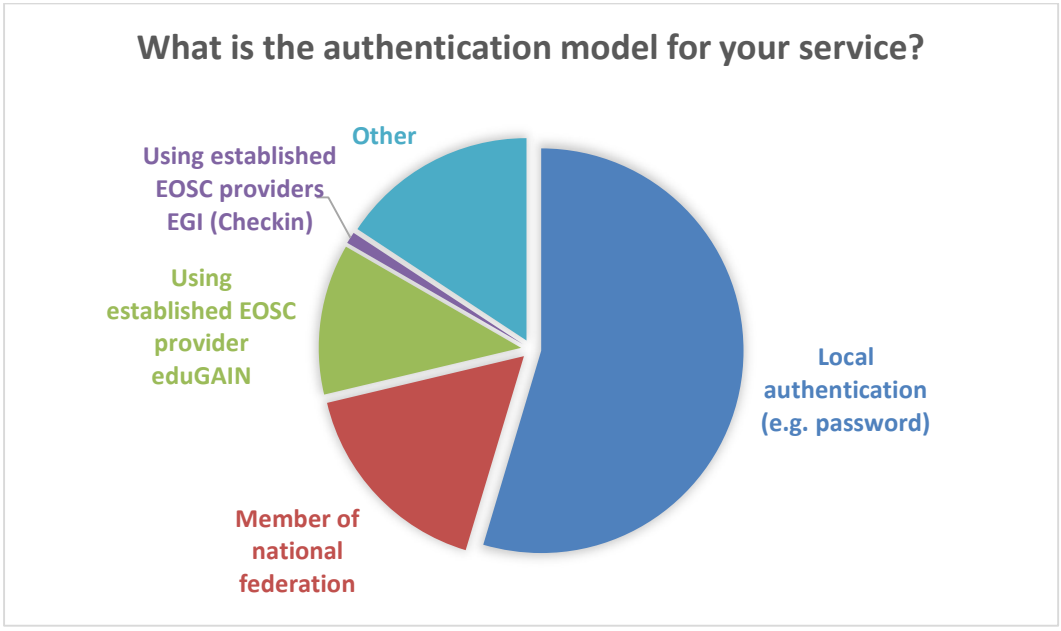


Figure 11: Authentication models used by service providers

Error! Reference source not found. is very indicative of the tools used among the stakeholders and particularly those also involved with offering services (Supporters, OS-facilitators). This question allowed multiple answers per stakeholder, so the average

results shown are calculated per answer from the total stakeholders that chose the particular tool option. Also, the "Not Aware" columns are the ones that answered with a single answer, and the total average in each category is weighted on the total answers from each stakeholder group.

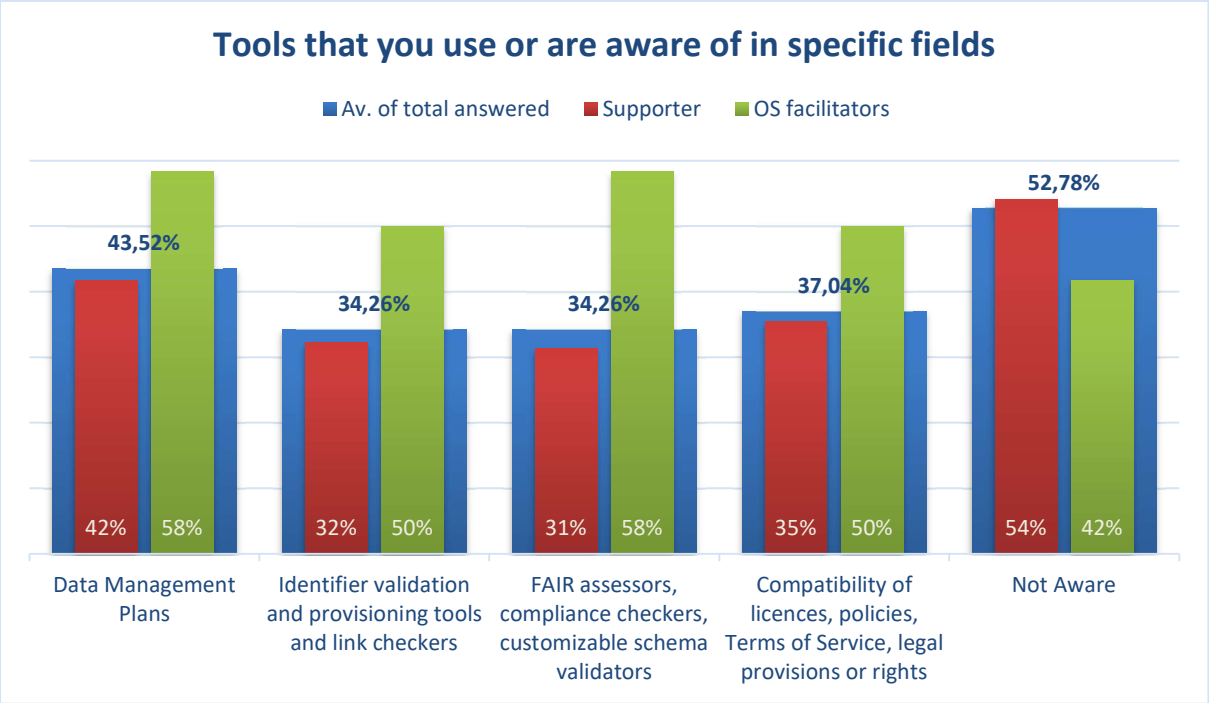


Figure 12: Tools used by stakeholders providing services

Interestingly, almost 53% of stakeholders answered that they are unaware of the tools used in their fields, which is probably associated with the role of the person answering in the organization. The choices for the rest of tool categories are very indicative in showing a trend towards the engagement with tools promoting and/or supporting OS and FAIR. At least the knowledge levels for these categories seems to follow the current developments in OS and FAIR data with the OS-facilitators being far ahead, as it would be expected. A similar picture can be seen in Figure 13, where guidelines are the subject of interest instead of tools. In this graph we can see a greater awareness of the subject and better knowledge about the guidelines for the questioned categories, as the responses came from the Creators group, thus indicating a penetration to current OS developments. It could be assumed that it also indicates the start of a movement sparked by the European OS initiatives.

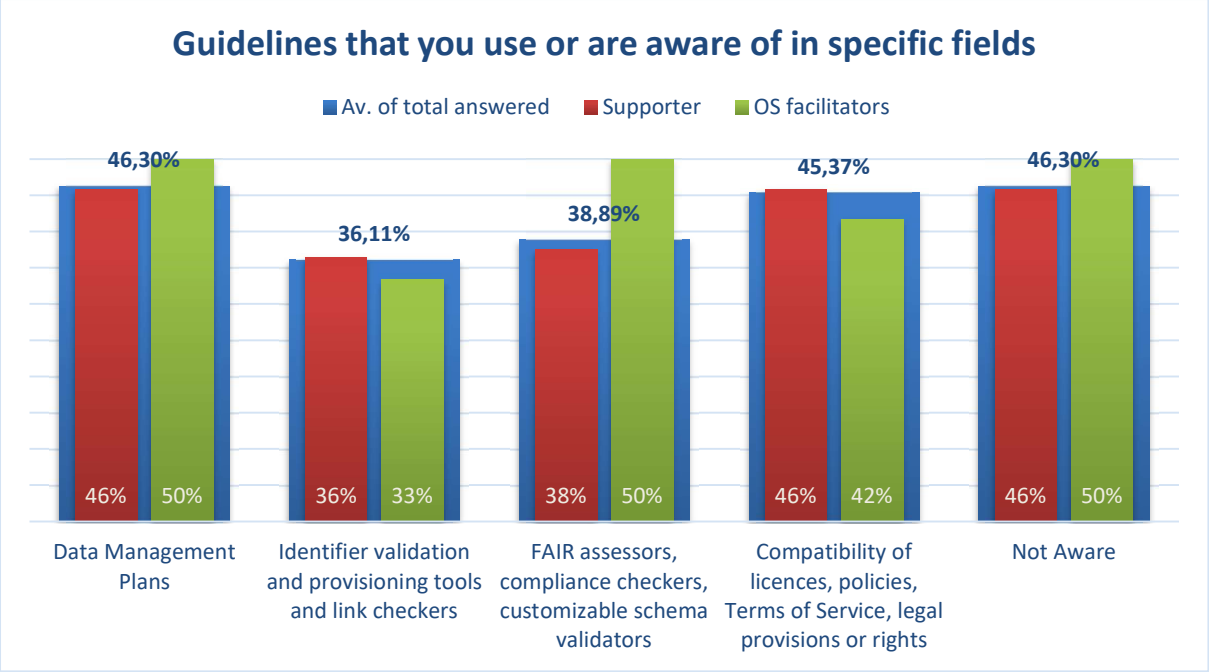


Figure 13: Guidelines used by stakeholders providing services

The next two figures (Figure 14 and Figure 15) can be another indicator of the OS movement reaching the stakeholders. The majority of stakeholders (90%) indicated that they are already using identifiers for digital objects, or are at least aware of their use, thus having identified objects uniquely and permanently through their lifetime. This is solving one of the concerns when aiming at providing re-usable objects.

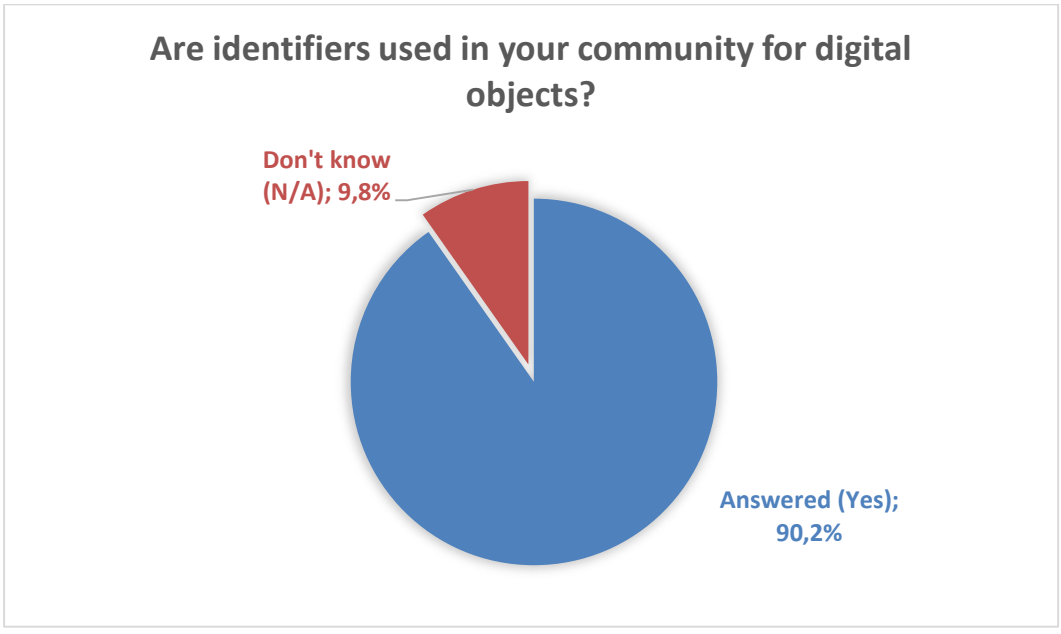


Figure 14: Use of identifiers for digital objects in stakeholder's community

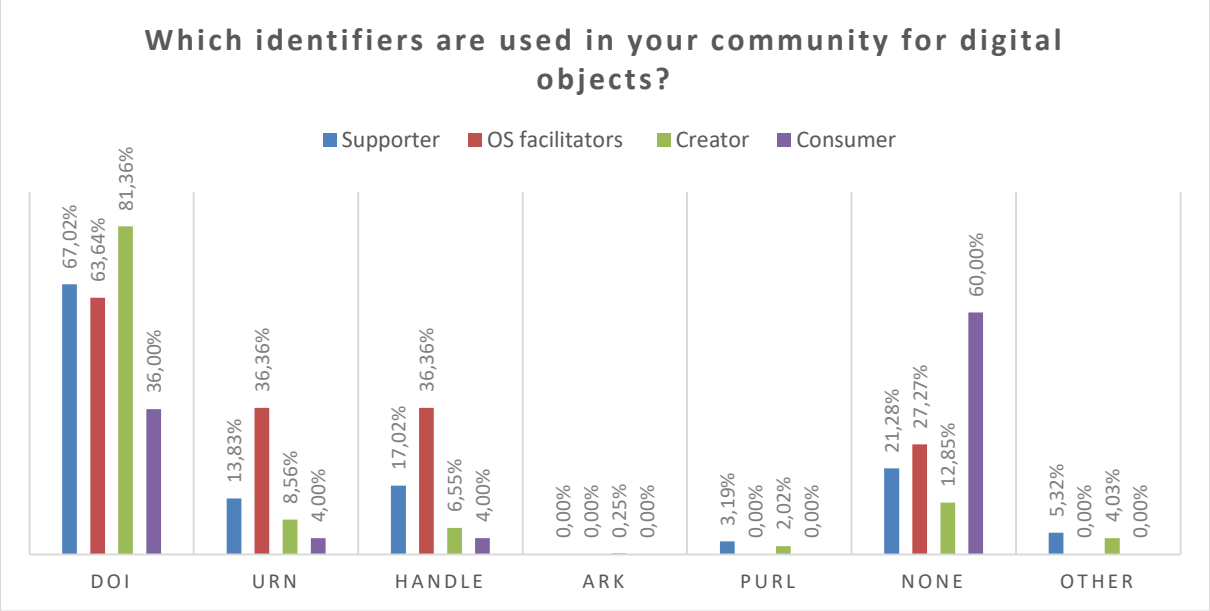


Figure 15: Specific identifiers used for digital objects in stakeholder's community

In support of Figure 14, Figure 15 clearly shows the use of some types of identifiers by all stakeholder groups except Funders who were not asked to answer this question. As expected, Consumers have not been using identifiers at the highest rate, indicating that the OS initiatives have not reached them yet, or that they are currently using a way to circumvent the use of identifiers.

4. Categorisation of tools

The categorisation of the analysed tools (as "instruments") was derived from analysing their type and use as seen in the tools catalogue [5]. The tools are then analysed according to whether the approach they follow is on a strategic, operational or technical level and are further explained in terms of their relation to Open and FAIR RDM coverage within the research and data management lifecycle.

Each category in terms of the use of the tools (certification, decision making, support) is analysed and presented according to the tools that it is populated with. The first level in each category[3] defines the scope that the tools serve, while sub-levels focus on the different use of the tools based on their end product and/or the stakeholder group using them. More about stakeholders use and needs for ORDM tools will be presented in Section 5. It should be noted that a tool may belong to more than one subcategory.

This activity resulted in the following:

- Categories in terms of the **type** of tools:
  a. *Guidelines & Policies* are essentially documents in the form of checklists, templates or collections of resources[4] with the main purpose to guide users' actions.
  b. *Models* refer to the standardized description and depiction of which certain actions should take into consideration.
  c. *Tools* here denote the practical use of software designed and run to implement specific functions.
- Categories in terms of the **use** of the tools:
  - *Certification* provides a layer of validation as it implies that a set of criteria has been defined and that compliance with them can be checked through a (self-)assessment process.
  - *Decision making* refers to the methodology and workflows in place for users to consult before making important decisions about their actions.
  - *Support* is inclusive to all users focusing on facilitating respective stages and actions around ORDM or FAIR.

Table 2: Categorization of the collected tools

		Certification	Decision making	Support
a. Guidelines & Policies				
b. Models				
c. Tools	For endusers (ready to use – "real" tools)			
	For developers			

[3] For example, in 4.1 Certification first level is 4.1.1 Guidelines and policies.
[4] Sometimes those collections are referred as "toolkit".

Analysis of the tools within each category takes into consideration the type of research output(s) being addressed by the tools. An overview of the types of research outputs and their coverage in the landscape collection of tools can be viewed below.

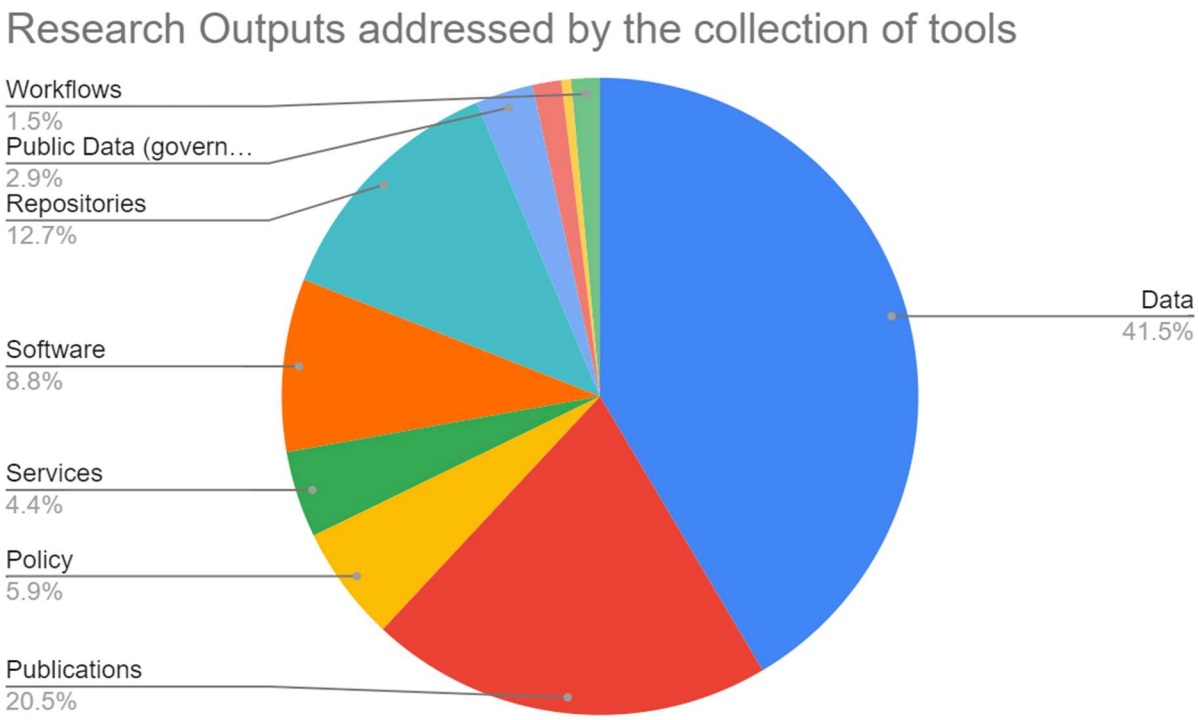


Figure 16: Research Outputs addressed by the tools landscape collection

Also, the tools in each category are explained according to their focus in strategic, operational and technical aspects of Open and FAIR RDM. The following pie shows detailed steps about the focus of the tools included in the landscape collection:

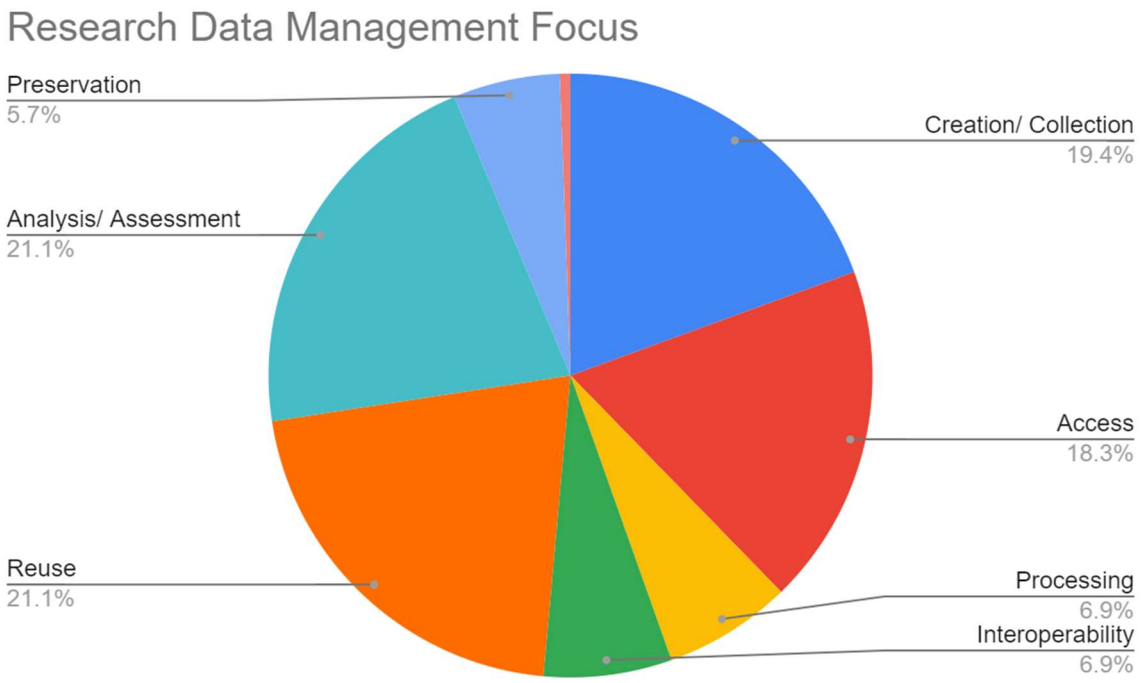


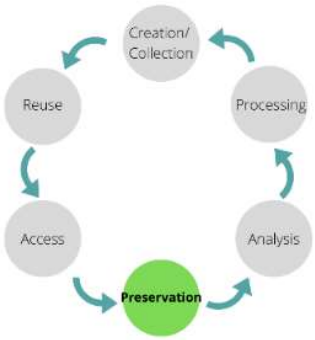
Figure 17: Open and FAIR RDM focus of the tools in the landscape collection

4.1. Certification

Certification provides a layer of validation as it implies that a set of criteria has been established and that compliance with them can be verified through an assessment or a self-assessment process. Below, the use of the tools in this category is explained with respect to their relation to Open and FAIR research and their coverage of data management needs.

4.1.1. Guidelines & Policies

This category contains **guidelines, recommendations and requirements** produced in order to be used for audits that aim at **certifying specific ORDM mechanisms**.



The landscape review showed that the maturity is used in certification schemes to ensure **trustworthiness** in operation or content preservation in **digital repositories**. The examples for this include the TRAC criteria and checklist[5] or the CoreTrustSeal[6] certification. Past attempts include the Nestor Catalogue of Criteria for Trusted Digital Repositories[7]. They all follow a self-assessment approach for they can be performed by subjects inside the organisation.

[5] https://public.ccsds.org/pubs/652x0m1.pdf
[6] https://www.coretrustseal.org/
[7] https://files.dnb.de/nestor/materialien/nestor_mat_08-eng.pdf

The CoreTrustSeal was recently updated to better reflect FAIR principles; it offers the community of peers to review the outcomes of self-assessments before repositories are certified. Of course, there are ISO standards that could be used to tackle issues that have to do with trustworthiness and **sustainability**. Their acquisition is based on a formal peer-review by accredited ISO experts.

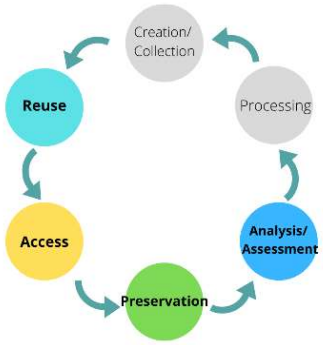
4.1.2. Models

The Models category was in general more difficult to populate as it faces similarities with other categories, since **models are closely related to both guidelines and policies**, for which they **provide more standardized approaches**. They are also closely related to tools, as **models are often used as conceptual foundations for implementation of tools**.

Collection of the landscape lists here The Carpentries[8] for their methodology to **create and teach courses** on data management and software development that has been incorporated in a training programme. This programme, among other things, certifies **instructors** on thematic areas supported/ covered by the organisation.

4.1.3. Tools

This category lists tools that have been **developed to perform assessments that are based on pre-defined criteria** and at the end provide some sort of **validation through their outcomes**. Here, the certified outcomes vary from **being assigned badges or given seals of approval to enabling key aspects of ORDM** to be achieved after undergoing through the assessment process.



To this end, the landscape collection includes the Open Data Certificate[9] which assesses and assigns **badges** declaring levels of **openness of public datasets**. Similarly, to understand the levels of **openness of research** performed in an institution, Curate Science[10] created badges corresponding to transparency and credibility criteria.

The needs for **machine-readable licenses** and **digital objects PIDs** are addressed by Creative Commons[11] and DOI[12]/Datacite[13] services respectively. The prior certifies that licenses are machine-readable while the latter ensures discoverability of digital objects in the short and long term.

[8] https://carpentries.org/
[9] https://certificates.theodi.org/en/
[10] https://curatescience.org/app/home
[11] https://creativecommons.org/
[12] https://www.doi.org/
[13] https://datacite.org/

Finally, OpenAIRE Repository Validator[14] enables **interoperability of digital repositories and CRIS systems**. The validation process checks metadata requirements that affect interoperability and identifies the areas to be corrected by the repository manager.

4.2. Decision making

4.2.1. Guidelines & Policies

The focus of this category is on resources that in some way **guide decision making of stakeholders**, being that directly by providing a clear pathway or indirectly by informing about useful concepts that could be utilized for initiating such a process. Here, **important EU documents are mentioned along with model policies and procedures** reflecting their **adoption and implementation by stakeholders**.

For that, the list includes **Open Science policies** already enforced at European level as well as **model policies** and **resources** that assist **awareness-raising** and **policymaking** on the different aspects of Open Science.

Key European policies for Open Science are:

- Recommendation on access to and preservation of Scientific Information[15] setting the framework of how **openness and FAIRness** of scientific information should be integrated into national research ecosystems.
- European Charter for Access to Research Infrastructures[16] ensuring modes of access are in place along with data management plans and training on the development and use of **services**.
- Plan S[17] for **open access publications** and scientific journals transformative agreements.

An **overview of complementary policies** that influence the European Open Science ecosystem can be found at the EOSCpilot project's *D3.1 "Policy Landscape Review"*[18].

Model policy templates were developed to foster policymaking and adoption at national and institutional levels in a more consistent way. LEARN Toolkit of Best Practice for Research Data Management[19] focuses on RDM providing insight for both policy development and training. OpenAIRE

[14] https://www.openaire.eu/validator/
[15] https://ec.europa.eu/digital-single-market/en/news/recommendation-access-and-preservation-scientific-information
[16] https://ec.europa.eu/research/infrastructures/pdf/2016_charterforaccessto-ris.pdf
[17] https://www.coalition-s.org/addendum-to-the-coalition-s-guidance-on-the-implementation-of-plan-s/principles-and-implementation/
[18] https://eoscpilot.eu/sites/default/files/eoscpilot-d3.1.pdf
[19] http://learn-rdm.eu/wp-content/uploads/RDMToolkit.pdf

model policies and checklists[20] is a follow-up to LEARN and other similar outcomes, such as PASTEUR4OA[21] or RECODE project[22].

OpenAIRE takes stock from those attempts to combine **open access and RDM** in updated model policy templates for RFOs and RPOs. Following the same philosophy, Science Europe has created the Practical Guide to the International Alignment of Research Data Management[23] to provide a more standardized way of creating **DMP templates**.

Zooming in the **Intellectual Property Rights and Management**, there are existing efforts to facilitate the **adoption of IP policies** as well as information tailored to **knowledge transfer and commercialization** approaches in Universities. The World Intellectual Property Organisation provides guidance on those matters through **model policies and checklists** included in their IP Policies Toolkit for Universities[24], asset maps and **model agreements** provided in an IP commercialization tool for Universities[25].

Moreover, there are **specialised resources** addressing and assisting compliance with specific processes in Open and FAIR research lifecycles and policy documents, such as regarding **licensing** or **monitoring of research artefacts**. Hence, this sub-category includes the Choose an **open-source license** guide[26] driving researchers' and developers' decisions about the license that best fits their software distribution needs. For **legal issues in RDM**, the RDA & CODATA Legal Interoperability of Research Data: Principles And Implementation Guidelines[27] offers great guidance. In addition, specific **criteria that evaluate openness** are addressed by "HowOpenIsIt? A Guide for Evaluating the Openness of Journals"[28] and "HowOpenIsIt? Guide to Research Funder Policies"[29], which provide a standardised approach to **measuring openness of publishers and funders policies**, respectively.

Additionally, collection of resources for Open Science that are provided in the form of **supporting to researchers' activities material** plays an important role for **how Open Science is perceived** by the academic and research communities and for **how it integrates with existing research and support workflows**. All relevant organisations and initiatives provide some kind of support by collecting and sharing resources that are important and enhance their strategic scope, actions and needs of their target audience or users. Indicatively, equivalent efforts aiming at spreading awareness and familiarisation of stakeholders with Open Science principles and best practices, collectively or individually, are:

- **Open Science**

[20] https://www.openaire.eu/toolkit-for-policy-makers-on-open-science-and-open-access
[21] http://www.pasteur4oa.eu/resources
[22] https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=9958
[23] https://www.scienceeurope.org/media/jezkhnoo/se_rdm_practical_guide_final.pdf
[24] https://www.wipo.int/about-ip/en/universities_research/ip_policies/index.html#toolkit
[25] https://www.wipo.int/about-ip/en/universities_research/ip_knowledgetransfer/index.html#toolkit
[26] https://choosealicense.com/
[27] https://www.rd-alliance.org/rda-codata-legal-interoperability-research-data-principles-and-implementation-guidelines-now
[28] https://sparcopen.org/our-work/howopenisit/
[29] http://www.orfg.org/policy-development-guide

OpenAIRE Open Science Primers[30] and Rainbow of Open Science Practices[31] which reflect on Open Access and RDM topics, including **tools and resources** essential in a research workflow.

- **Open Access**

  A useful **use case** for RPOs who are interested to **develop a unified strategy** and implementation action plan for Open Access is The Pathways to Open Access[32].

- **Peer-review**

  OpenUP Hub[33] for providing a rich collection of peer-review resources and tools of benefit to all stakeholders.

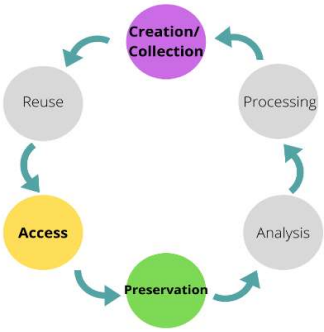
In this gradual transition to Open Science, **engagement activities** ensure its uptake along with nurturing a much-needed/desired **cultural change** in the way research is performed, shared and assessed. Of the resources that guide institutions on how to perform engagement activities based on a set of administrative and operational criteria is the Engaging Researchers with Data Management: The Cookbook[34]. Also, LIBER Open Science Roadmap[35] provides great insight into engagement and advocacy activities to be performed exclusively from academic and research libraries in Europe.

Furthermore, landscape review recorded guidelines and resources which focus on **designing and scaling public services** for **Open Data services** and **Social Data services** as highlighted in the ODI Checklist: How to design to scale[36] and the Data and Public Services Business Case Canvas[37] and the CESSDA Guide for Developing National Data Service Plans[38].

4.2.2. Models

This category is populated with resources that present **modelized workflows and/or documents that assist decision making in a concerted way** thus, ultimately, enhancing support provided for given actions of implementation. The resources span from **conceptual models** to **operational frameworks** that ensure consistency and completeness of the given action.

[30] https://www.openaire.eu/os-primers
[31] https://zenodo.org/record/1147025#.XqI3wcgzY2w
[32] https://escholarship.org/uc/item/5gc4r5mg#main
[33] https://www.openuphub.eu/
[34] https://www.openbookpublishers.com/product/1080
[35] https://libereurope.eu/blog/2018/07/03/liber-launches-open-science-roadmap/
[36] https://theodi.org/article/scaling-data-enabled-projects-a-checklist/#1557752072029-30a3367f-5b34
[37] http://theodi.org/wp-content/uploads/2019/07/ODI-Data-Public-Services-Business-Case-Canvas-2019-05.pdf
[38] https://www.cessda.eu/Tools-Services/For-Service-Providers/Guide-for-Developing-National-Data-Service-Plans



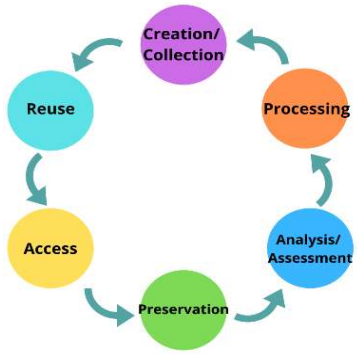
From the full list of the landscape collection, the models that fit here are relevant to **FAIRness** and **preservation** of data as well as to **policymaking** procedures. Regarding FAIR principles, FORCE11 Decision Trees[39] target FAIRness by design, meaning that they provide the technical framework that would ease **machine-actionability** even of policies. Other resources in this direction are PASTEUR4OA, RECODE project or LEARN Toolkit of Best Practice for Research Data Management specifically for RDM policy development and training.

The latter may be achieved, especially for assessment purposes, when the policies are complemented by checklists such as OpenAIRE's policy checklists that assess organisations' **adoption readiness** levels.

Also, driven by work in the area of repositories trustworthiness, the CESSDA SaW Capability Development Model (CESSDA-CDM)[40] focuses on preservation to communicate key elements for proper permanent storage and retention in data archives and repositories. To assist funders in creating **discipline-specific DMPs**, Science Europe has created the Framework for Discipline-specific Research Data Management[41].

4.2.3. Tools

The focus of this category is on **software applications and small databases** that **assist decision making around core Open and FAIR RDM activities**, such as for costing RDM or for DMPs production, finding publication venues for research artefacts and assigning licenses, etc. Collection also identified **tools with a more strategic approach** concerning policy, assessment and monitoring activities.



Open and FAIR RDM has been at the epicentre of discussions for the past years as stakeholders work on understanding how specific steps of a research lifecycle can become more machine-readable and machine-actionable in light of the FAIR principles. Those discussions have led to new research on technical specifications and standards that could support a FAIR ecosystem. Hence, new tools are being designed and existing tools are now updated to conform to new global practices and standards.

Focusing more on RDM, there is the need to **estimate costs** associated with certain steps of the research lifecycle. For that, there are tools that provide detailed information about costs for **publishing papers**, like the APCDOI[42], about ensuring **curation of data**, like

[39] https://www.force11.org/group/scholarly-commons-working-group/wp3decision-trees
[40] https://www.cessda.eu/Tools-Services/For-Service-Providers/CESSDA-CDM
[41] https://www.scienceeurope.org/our-resources/guidance-document-presenting-a-framework-for-discipline-specific-research-data-management/
[42] https://github.com/ryregier/APCDOI

the Curation Costs Exchange[43], and others that help with **costing IP** related fees for application and renewal processes, like the IP Costing tool[44].

Additionally, to enable **discoverability of research artefacts**, various types of registries have been realised. In particular, OpenDOAR[45] is used for **papers** and Re3data[46] for **data.** There are also registries for key enablers of FAIR data, such as FAIRsharing Standards[47] for **standards** and Protocols.io[48] for **protocols** where researchers can browse and find respective content for their research data management needs.

Regarding **re-usability**, several tools guide through the selection of **licenses** for research artefacts such as the European Language Resources Association License Wizard[49]. Yet, some tools **combine and compare** information from two or more types of licenses, like the JLA – Joinup Licensing Assistant[50] and the License Compatibility Matrix[51].

Apart from the ORDM orientation, the landscape collection covers tools that **assess digital infrastructures and ecosystems**, **manage organisational policies** and **monitor** the current state of Open Science and Open Data. The Data Asset Framework – DAF[52] and the Collaborative Assessment of Research Data Infrastructure and Objectives – CARDIO[53] have both greatly contributed to **self-assessment** of organisations' **data assets** resulting to the development and/or improvement of their research data services. Data Ecosystem Mapping[54] is equivalent to the aforementioned self-assessment but for **open data**. Furthermore, the Digital Repository Audit Method Based On Risk Assessment – DRAMBORA[55] expands to **risk assessment** of **repositories.**

As for ORDM policies, B2SAFE – Data Manager Policy Tool[56] supports better **management of data policies** by data managers.

Finally, some tools measure specific aspects of **Open Science** and **Open Data** in an attempt to draw the current state of strengths and weaknesses in those areas. Particularly, Monitor UK[57] measures **expenditure in APCs** while Open Data Barometer[58] and Global Open Data Index – GODI[59] focus on showcasing **open data practices uptake**.

[43] https://www.curationexchange.org/about
[44] http://www.latinamerica-ipr-helpdesk.eu/services/ip-cost-tool
[45] https://v2.sherpa.ac.uk/opendoar/
[46] https://www.re3data.org/
[47] https://fairsharing.org/standards/
[48] https://www.protocols.io/
[49] http://wizard.elra.info/
[50] https://joinup.ec.europa.eu/solution/joinup-licensing-assistant/joinup-licensing-assistant-jla
[51] https://services.openminted.eu/support/licenseCompatibilityMatrix
[52] https://data-audit.eu/
[53] http://www.dcc.ac.uk/resources/tools/cardio
[54] https://theodi.org/article/data-ecosystem-mapping-tool/
[55] http://www.repositoryaudit.eu/
[56] https://eudat.eu/news/a-new-feature-for-b2safe-the-data-policy-manager-dpm-tool
[57] https://www.jisc.ac.uk/monitor-uk
[58] https://opendatabarometer.org/?_year=2017&indicator=ODB
[59] https://index.okfn.org/

4.3. Support

4.3.1. Guidelines & Policies

This category contains **resources and strategic or policy documents** produced to **support scholarly communication, build capacity on and/or enable compliance with ORDM activities**. Among other things, here, landscape review covers research papers, training material and collections of advocacy resources.

Overall, regarding **policies**, the landscape showed that there is great provision towards all stakeholders ORDM activities to be supported and for compliance to be met at all levels.

The list of policy documents varies from guides that support description of data according to **DMP policy requirements**, like the "H2020 Online Manual Data Management"[60] or the "Guidelines on the Implementation of Open Access to Scientific Publications and Research Data in Projects"[61], to **reports guiding RDM activities**, like the "Practical Guide to the International Alignment of Research Data Management"[62] and **use cases** like the Managing and sharing data: best practice for researchers[63] and "The realities of Research Data Management"[64]. For **legal issues in RDM**, the RDA & CODATA "Legal Interoperability of Research Data: Principles And Implementation Guidelines"[65] offers great guidance. Furthermore, it includes resources that support **policymaking**, such as the "Transparency and Openness Promotion Guidelines"[66] for **publishers' data policies**, OpenAIRE model policies and checklists for **Open Science policies** of organisations and funders, the LEARN Toolkit of Best Practice for Research Data Management dedicated to the development of **institutional RDM policies** and the IP Policies Toolkit for Universities[67] for **IP policymaking**. Other examples that are useful in supporting **policy compliance** are the "HowOpenIsIt? A Guide for Evaluating the Openness of Journals" and the "HowOpenIsIt? Guide to Research Funder Policies". Also, first deliverable of NI4OS-Europe WP4 on "Data repository integration and ORDM/FAIR compliance guidelines"[68] provide great input to a collection of guidelines for ORDM.

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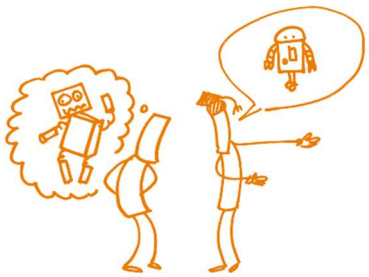
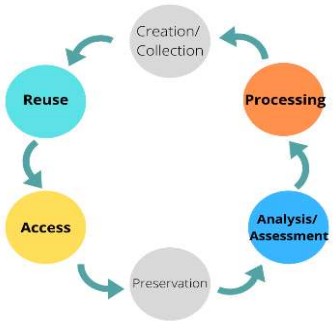
[60] https://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/open-access-data-management/data-management_en.htm
[61] https://erc.europa.eu/content/guidelines-implementation-open-access-scientific-publications-and-research-data-projects
[62] https://www.scienceeurope.org/media/jezkhnoo/se_rdm_practical_guide_final.pdf
[63] https://ukdataservice.ac.uk/media/622417/managingsharing.pdf
[64] https://www.oclc.org/research/publications/2017/oclcresearch-research-data-management.html
[65] https://www.rd-alliance.org/rda-codata-legal-interoperability-research-data-principles-and-implementation-guidelines-now
[66] https://cos.io/top/
[67] https://www.wipo.int/about-ip/en/universities_research/ip_policies/index.html#toolkit
[68] https://zenodo.org/record/3736150#.Xqnp6KgzY2w

Focusing on **open data**, the ODI Checklist: How to design to scale[69] and Data and Public Services Business Case Canvas provide methodologies that assist decisions related to designing and managing **public services**.

Moreover, in support of open practices and FAIRness of digital objects, the landscape collection contains guides that provide a great base for and contributes to a common understanding of the concepts of:



- **Open Science practices** through the OpenAIRE Open Science Primers, the Rainbow of Open Science Practices[70] and the LIBER Open Science Roadmap[71].
- **Domain and generic RDM** following great examples, like the CESSDA Data Management Expert Guide[72] for social data management or the Research Data Management Toolkit[73] for generic support.
- **FAIR principles** via the original paper of FAIR Guiding Principles for scientific data management and stewardship[74] which thoroughly explains the concept of **FAIR digital objects**. Another useful resource is the recent publication of FAIRsFAIR report on FAIRness of services[75] which shows how **FAIR enabling services** can be realised.



The landscaping also captured a great interest in **measuring FAIRness of data**. "How FAIR are your data?" checklist[76] guides researchers' decisions on that matter. Other approaches in that direction are the A design framework and exemplar metrics for FAIRness[77] and the FAIR-TLC: Metrics to Assess Value of Biomedical Digital Repositories: Response to RFI NOT-OD-16-133[78].

Complementary, the Metrics Toolkit[79] for **alternative metrics** to Open Science guides assessments of **research impact** according to policy conditions.

Additionally, landscape identified guidelines that enable implementation of ORDM concepts, like the OpenAIRE Guidelines for **interoperability** between archives/ repositories and the selection of **PID systems** as shown in "Persistent identifiers: Consolidated assertions"[80]. Other resources useful for researchers ORDM practices

[69] https://theodi.org/article/scaling-data-enabled-projects-a-checklist/
[70] https://zenodo.org/record/1147025#.XihqisgzZPZ
[71] https://libereurope.eu/blog/2018/07/03/liber-launches-open-science-roadmap/
[72] https://www.cessda.eu/Training/Training-Resources/Library/Data-Management-Expert-Guide
[73] https://rdmtoolkit.jisc.ac.uk/
[74] https://www.nature.com/articles/sdata201618
[75] https://zenodo.org/record/3688762#.Xqq0QqgzY2x
[76] https://zenodo.org/record/1065991#.XqN-XGgzY2w
[77] https://www.biorxiv.org/content/10.1101/225490v3
[78] https://zenodo.org/record/203295#.XqOFCmgzY2z
[79] https://www.metrics-toolkit.org/
[80] https://www.rd-alliance.org/system/files/PID-report_v6.1_2017-12-13_final.pdf

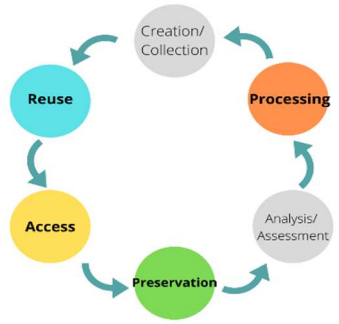
concern the processes of **licensing** and **cleaning data**. For the former, there are guides with steps on to license data, like "How do I license my research data?"[81], Choose an open source license guide[82] for software distribution needs and others aiming at assigning licenses to repositories, like "Making your repository Open"[83]; a good example driving cleaning data process is the "How to clean your data"[84].

Finally, the landscape of this category is highly populated with resources that share **collections of useful information** that guide ORDM practices including in the areas of:

- **Review and assessment** through the OpenUP Hub collection of resources.
- **Copyright** as appears in The Copyright Term and the Public Domain in the United States[85] which provides **access to public domain works**.
- **Training** for **materials and tools** essential for **building capacity** and **familiarising** stakeholders with ORDM concepts and/or with the use of specialised tools. Here, the FOSTER Open Science Resources[86] is included along with CESSDA Training[87], SSHOC Training Toolkit[88] and ELIXIR's TeSS Training Portal[89] that provide a tailored to **domain** view in ORDM training.

4.3.2. Models

This category includes resources produced following a **standardized methodology** to more effectively support policymaking and the development of new resources, methodologies, standards and tools, hence they capture, among other things, **technical specifications and conceptual models for Open Science**.



In policymaking, this is possible with **model templates** for **Open Science policies** that facilitate the compliance of stakeholders with European conditions. Among such attempts are the OpenAIRE model policies and templates[90] that combine major principles such as Open Access, RDM and FAIR data, Open Source software, etc.

Some templates are tailored to specific issues that are directly or indirectly related to Open Science policies. Such examples are "IP Policies Toolkit for Universities"[91] and "IP

[81] https://www.openaire.eu/how-do-i-license-my-research-data
[82] https://choosealicense.com/
[83] https://www.openaire.eu/making-your-repository-open
[84] http://accelerate.theodi.org/#/id/589215ccb61c46e176e7f092
[85] https://copyright.cornell.edu/publicdomain
[86] https://www.fosteropenscience.eu/resources
[87] https://www.cessda.eu/Training
[88] https://training-toolkit.sshopencloud.eu/
[89] https://tess.elixir-europe.org/about
[90] https://www.openaire.eu/toolkit-for-policy-makers-on-open-science-and-open-access
[91] https://www.wipo.int/about-ip/en/universities_research/ip_policies/index.html#toolkit

commercialization tool for Universities"[92] for **Intellectual Property Rights policies,** and "Preservation Policy Template"[93] for long-term **preservation of data**. Also, some focus only on **service policies**, such as "OpenDOAR Policy Tool"[94] for **repositories policies** development.

At the same time, RDA Machine Actionable Policy Templates[95] and the Open Science Policy Registry[96] list requirements and metadata for policy management, task automation and assessment thus enabling **machine actionability of data policies**. Complementary, there are **model descriptions of policies** that facilitate the development of policy registries, like the CERIF Description of an OA Policy[97].

Moreover, the RDA Common Standard for maDMPs[98] ensures a unified description of **DMPs** globally and enables **interoperability** between tools that are developed according to the standard. Science Europe supports funders' policymaking by providing a Framework for Discipline-specific Research Data Management[99].

Delving into ORDM activities, the Open Citations[100] offers a data model for capturing **citations** while the FAIR Data Maturity Model[101] assists **FAIRness of data**. The ADA-M Automatable Discovery and Access Matrix[102] is one of the efforts to describe meta-models and enhance **discovery** and **data sharing**. Also, the ODI Data Ethics Canvas provides a framework to ensure **ethical management of data**.

Finally, landscape collection captured CESSDA SaW Capability Development Model – CESSDA-CDM for it assists effective **preservation** in social data services.

4.3.3. Tools

This category lists tools that either provide **dedicated support or can be used in support of specific actions and on different concepts of RDM and Open Science**. Here, tools reflect on policymaking and monitoring to training and ethical data management, sharing and planning.

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92 https://www.wipo.int/about-ip/en/universities_research/ip_knowledgetransfer/index.html#toolkit
93 http://www.dcc.ac.uk/sites/default/files/documents/Preservation%20policy%20template.pdf
94 https://v2.sherpa.ac.uk/opendoar/policytool/
95 https://www.rd-alliance.org/group/practical-policy-wg/outcomes/practical-policy
96 https://www.eoscpilot.eu/content/d37-updates-policy-supporting-services
97 https://www.sciencedirect.com/science/article/pii/S1877050917303022
98 https://www.rd-alliance.org/group/dmp-common-standards-wg/outcomes/rda-dmp-common-standard-machine-actionable-data-management
99 https://www.scienceeurope.org/our-resources/guidance-document-presenting-a-framework-for-discipline-specific-research-data-management/
100 https://opencitations.net/
101 https://www.rd-alliance.org/group/fair-data-maturity-model-wg/outcomes/fair-data-maturity-model-specification-and-guidelines
102 https://github.com/ga4gh/ADA-M

Starting from **designing** and **managing data activities**, the RDMO – Research Data Management Organiser[103] and Data Wiz[104] offer support through their platforms to prepare research data according to the whole research data lifecycle by organising RDM activities and accomplishing tasks associated with each step of the lifecycle.

Other tools recorded in the landscape collection show tailored support on certain steps of the lifecycle, like for **data sharing** through the B2DROP collaborative tool[105] or for **data processing** and **data analysis** through OpenRefine[106], ResearchObject.org[107] and RStudio[108] or more specialised for **data anonymization** such as Amnesia[109] and Data Anonymization Tool – ARX[110] and **vocabularies** management like the CESSDA Vocabulary Service[111]. Here, legal tools support actions related to **copyright**, **IPR** and **open data**. Specifically, The copyright term calculator[112] and the Public Domain Calculator[113] both showing when and if a work is in the **public domain**. The downsides are that the prior is US-based and hence not applicable to the EU copyright law and jurisdiction, while the latter focuses only on the scientific field of Digital Cultural Heritage. Moreover, WIPO IPR Case Studies Wizard[114] promotes good practices for **IP exploitation** while License selector[115] and Open Data Commons[116] offer support in **licensing data**.

Many tools help the **discovery of research artefacts** and **supporting research material**. These are about **finding publications and data** like B2FIND[117], Open Science Framework – OSF and OpenAIRE Explore[118], finding policies and standards thus facilitating FAIR practices through FAIRsharing Policies[119], ROARMAP[120] and FAIRsharing Standards. Also, Bip!Finder[121] offers a discovery portal for researchers to search within the filtered content based on short-term and long-term **impact** metrics. Protocols.io[122] offers a registry for storage and discovery of protocols. Research infrastructures have developed

[103] https://rdmorganiser.github.io/en/
[104] https://datawiz.leibniz-psychology.org/DataWiz/?datawiz_locale=en
[105] https://www.eudat.eu/services/b2drop
[106] https://openrefine.org/
[107] http://www.researchobject.org/
[108] https://rstudio.com/
[109] https://amnesia.openaire.eu/
[110] https://arx.deidentifier.org/
[111] https://vocabularies.cessda.eu/#!discover
[112] http://www.publicdomainsherpa.com/calculator.html
[113] https://archive.outofcopyright.eu/calculator.html
[114] https://www.wipo.int/ipadvantage/en/
[115] https://eudat.eu/services/userdoc/license-selector
[116] https://www.opendatacommons.org/
[117] https://www.eudat.eu/services/b2find
[118] https://explore.openaire.eu/
[119] https://fairsharing.org/policies/
[120] https://roarmap.eprints.org/
[121] https://bip.imsi.athenarc.gr/
[122] https://www.protocols.io/

platforms to store and preserve their data, such as CESSDA data catalogue[123] the social sciences, and others for **software resources** like ELIXIR Tools Platform[124]. On the other hand, the DTL FAIR Data Tools[125] support **FAIR data management processes**. To complement that, some tools allow to **self-assess FAIRness of data** such as the Self-Assessment Tool to Improve the FAIRness of Your Dataset – SATIFYD[126] or the FAIR Maturity Evaluator[127].

Other tools that provide greater visibility to scientific content are OpenAccessButton[128], Unpaywall[129], CORE[130] and Kopernio[131] plugins for opening **access to paywalled content**.

Aforementioned activities reflecting the research data lifecycle are then be **documented** in tools that support the process of **writing DMPs.** In that respect, the landscape showed that there is a pool of options for researchers to choose from: starting with the ancestor in this category, DMPOnline[132], to new tools that apply the RDA Common Standard for DMPs providing machine actionable solutions, including ARGOS[133], EasyDMP[134], DMP OPIDoR[135], Data Stewardship Wizard[136]. Since the purpose of this collection is not an exhaustive research on DMP tools, the list is not extensive rather it is indicative of current trends and approaches at a national, institutional and project level. These tools differ based on the scope and users' community they serve.

From a technical viewpoint, there are tools, sometimes offered as services, that are used to strengthen Open Science practices and help build local Open Science ecosystems. Among them are **archives and repositories software** such as DSpace[137], CKAN[138] and DataVerse Network[139] that offer information system capabilities for **storage and distribution** of scientific content. More specialised tools that ensure persistency of content are **PID providers and resolvers**, like DOI and DataCite, are widely used by the Open Science community. In terms of FAIRifyed tools, the SmartAPI[140] applies FAIR principles to **APIs**.

From a strategic viewpoint, landscape review captures **assessment** tools that either support **Open Science services** to be realised and enhanced or support **monitoring** of **Open Science uptake and impact**. Tools about the former are The Data Asset

[123] https://datacatalogue.cessda.eu/
[124] https://elixir-europe.org/platforms/tools
[125] ttps://www.dtls.nl/fair-data/find-fair-data-tools/
[126] https://satifyd.dans.knaw.nl/
[127] https://fairsharing.github.io/FAIR-Evaluator-FrontEnd/#!/
[128] https://openaccessbutton.org/
[129] https://unpaywall.org/
[130] https://core.ac.uk/
[131] https://kopernio.com/
[132] https://dmponline.dcc.ac.uk/
[133] https://argos.openaire.eu/
[134] https://eudat.eu/catalogue/easyDMP
[135] https://dmp.opidor.fr/
[136] https://ds-wizard.org/
[137] https://duraspace.org/dspace/
[138] https://ckan.org/
[139] https://dataverse.org/
[140] https://smart-api.info/

Framework – DAF and the Collaborative Assessment of Research Data Infrastructure and Objectives – CARDIO, both being about **self-assessment** of organisations' **data assets** that drive the development and/or improvement of research data services. Data Ecosystem Mapping[141] is equivalent to the aforementioned self-assessment but for **open data**. Furthermore, the Digital Repository Audit Method Based on Risk Assessment – DRAMBORA expands, among other things, to **repositories risk assessment**. Additionally, landscape review unravelled a great variety of tools developed to monitor and assess the Open Science and Open Data environment. For a **full view** to how Open Data and Open Science are perceived in Europe, there are tools such as the Global Open Access Index – GODI, the Open Data Monitor[142] and Open Science Monitor[143]. Other attempts get into the details of certain Open Science aspects, like with Monitor Local[144] which focuses on **monitoring open access activity** of researchers. JISC's suite of monitoring tools and services about policies are widely used for they support researchers to **comply with given policies**: SHERPA Juliet v2[145] informs about **funders policies** regarding publishing an archiving scientific content in other platforms, while SHERPA RoMEO[146] offers the same information but for **publishers' policies**. SHERPA FACT[147] is a compliance tool that helps researchers to select journals that comply with funders requirements. Also, the Top Factor[148] tool helps in assessing the application of TOP Guidelines in publishers' data policies.

Other tools such as the B2SAFE – Data Manager Policy Tool helps the internal process of **managing data policies** in an organisation or a project.

Finally, in support of **advocacy**, tools such as The Publishing Trap (boardgame) provide an alternative approach to communicating to researchers and research communities vital Open Science aspects such as best practices for **publishing** research artefacts. Concerning **capacity building** activities, tools like MANTRA[149] and the Open Science MOOC[150] provide a selection of modules for **training** researchers and/or cultivating trainers on how to follow and apply Open Science in practice. Also, there are tailored training courses that guide researchers on how to use important services, such as the online Lectures on PCT at the EPO[151] for **patents** applications.

[141] https://theodi.org/article/data-ecosystem-mapping-tool/
[142] https://opendatamonitor.eu/frontend/web/index.php?r=dashboard%2Findex
[143] https://ec.europa.eu/info/research-and-innovation/strategy/goals-research-and-innovation-policy/open-science/open-science-monitor_en
[144] https://monitor.jisc.ac.uk/local/about/
[145] https://v2.sherpa.ac.uk/
[146] https://v2.sherpa.ac.uk/romeo/
[147] https://v2.sherpa.ac.uk/fact/
[148] https://www.topfactor.org/
[149] https://mantra.edina.ac.uk/
[150] https://opensciencemooc.eu/
[151] https://e-courses.epo.org/mod/pageextended/view.php?id=4944

5. Stakeholders

Based on the landscaping activity pertaining to the tools collection, this section focuses on the four main stakeholder categories of **RPOs**, **RFOs**, **researchers** and **service providers** to:

a. communicate the target users/audience of the tools according to the type and use of the tools (Section 4);
b. provide an overview of the uptake of certain tools per stakeholder by using data from the survey performed in WP2 (D2.1);
c. identify any gaps and needs for new tools to be designed by combining data from the tools landscape and the survey. Shortages are clearly explained in the conclusions (Section 6).

It should be noted that stakeholders are addressed differently in the survey where the focal point is on how research is utilised by them. For that, survey maps together many stakeholder categories to form four amplified categories based on who funds, supports, consumes and facilitates research conduct[152]. Hence, subsections 5.1 and 5.2 analyse stakeholders' data differently, but their combined result is cleaned and ascribed with both approaches.

5.1.Identifying stakeholder groups & needs

For this analysis, the identified stakeholder groups are the ones described in section 3.2 of this deliverable, namely Funders, Supporters, OS-facilitators, Creators and Consumers. Service providers come from Supporters and OS-facilitators groups while Creators and Consumers are mostly the services consumers.

Concerning infrastructure, the needs of stakeholders in total are identified in the graph shown in Figure 18.

[152] Please also see D2.1 pages 14-15

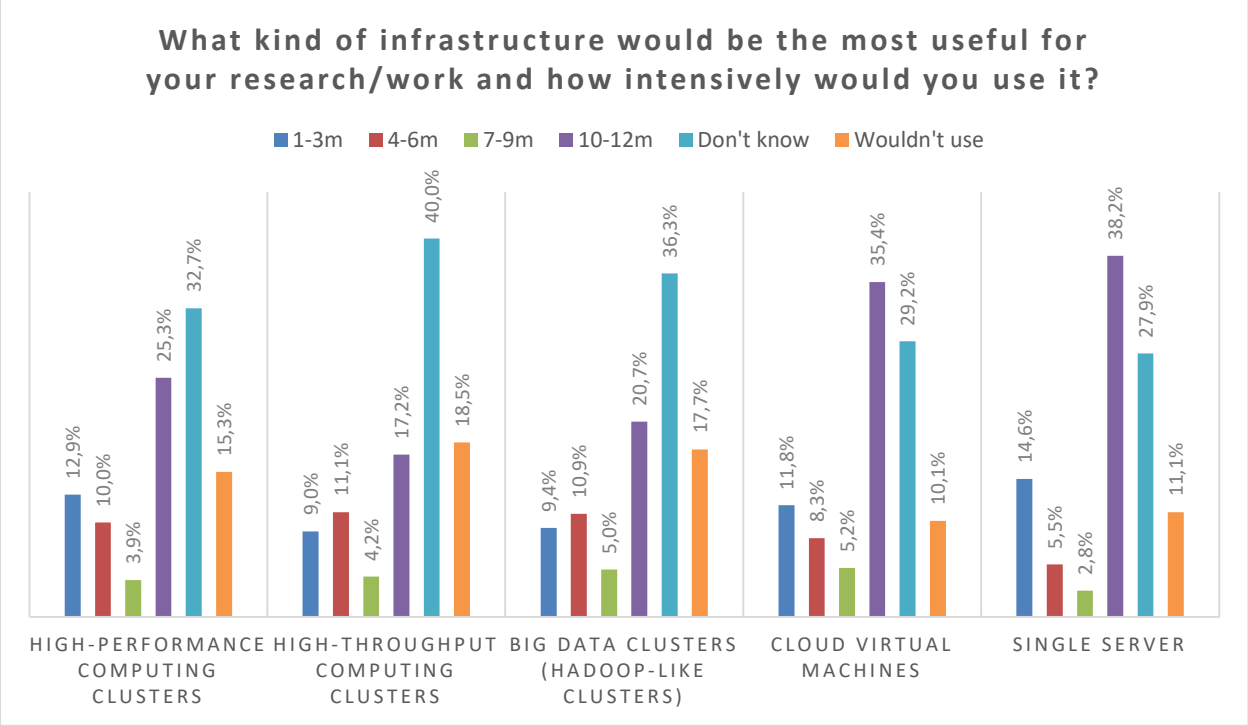

Figure 18: Useful infrastructure used by stakeholders for research/work

A clear trend towards cloud virtual machines and high-performance virtual cluster can be seen for the longer-term (10-12 months) usage needs of all stakeholders, while the classic on-premises single server machines remain useful and needed for all types of stakeholders. It should be noted that all stakeholder groups except Funders, for obvious reasons, provided input in this question reaching 92.8% participation for this answer. However, Figure 18 also indicates a high percentage of stakeholders unaware of the infrastructure or its usage, which when put together with the ones who are negative regarding the use of these infrastructures, becomes very high with an average sum of 47.7% for the two options for all infrastructure choices. If the more dedicated high-throughput computing clusters are also counted towards the current trends, the graph shows increased needs for cloud computing infrastructure following the current research technology advancements.

An interesting part of the identified stakeholders' needs are the answers to the question "*What do you expect from EOSC?*", where only 42% of the survey participants answered. For the individual stakeholder groups, the lowest participation was noticed in the Creators with only 39% of them answering. Consumers' focus was on technology-related improvements, with indicative answers being: "*Collaborate and share information quicker and more easily with partnership organizations*" and "*Further development of ICT technologies in our country*". Funders provided a more theoretical, close to definition approach in their answers with this one as an indicative:

> *EOSC is foreseen to be the key enabler for data-driven research. EOSC will facilitate the employment of open science practices by all the stakeholders promoting new ways of cooperating and conducting research. Services provided by EOSC will ensure that all publications and research data from publicly funded projects will be openly available*

> *and curated according to FAIR principles. It is expected to serve so as a portal that offers open, easy and reliable access to research data and publications as well as a toolbox for the implementation of open science principles by the research community.*

Creators seem to be more concerned with the technical aspects as benefits of EOSC, indicating the need to have FAIR data, free re-usable services and thematic services, increased research content visibility, better collaboration among researchers and desiring even High-Performance Computing services. Supporting and indicative comments are: "*To provide multiple free services for Electrical Engineering research, as well as access to repositories and open platforms for our research community and students.*", "*Our expectations are related to FAIR data in archaeology. EOSC should enable access to information about excavations (current on shortly after being performed) and finds.*" and

> *Unification of the computing infrastructure, modernization, upgrading facilities, educate and train more specialists in High-Performance Computing, Big Data, Data Science. Europe must be competitive in supercomputing power intellectual and technical access to modern HPC infrastructure.*

OS-facilitators pinpoint the need for research support by enabling the easy discovery of free services and data through a central access point. Some indicative comments are: "*Greater discoverability of services and content; focus on interoperability; a curated and up-to-date catalogue of services*", "*To ensure that relevant data would be findable, accessible and interoperable for all scientists, by creating a platform and set of services for different user needs*" and "*One single access point to European resources, tools, and e-infrastructure, which are mostly free of charge*".

Supporters' comments were the most representative of all other groups' comments, aggregating all other identified needs, while also adding the needs for a central point for training and an open market for services. Most indicative answers drawn are: "*Single point of access to national and international R&E services and resources. Training and support for various user communities. Awareness-raising for the importance of open data and open scientific results.*", "*Open market for public services, no competition with commercial providers.*" and "*Developing open science, formulating policies about OS, training researchers, …*".

In parallel to this question, it may be interesting if one would also look stakeholder groups expectations in contrast with the question "How likely is it that your organization will contribute to EOSC?", to understand how willing and in what ways the various stakeholder groups are in supporting EOSC, and thus contributing in their identified needs in practice. Figure 19, attempts to draw a picture of this, based on stakeholders' input.

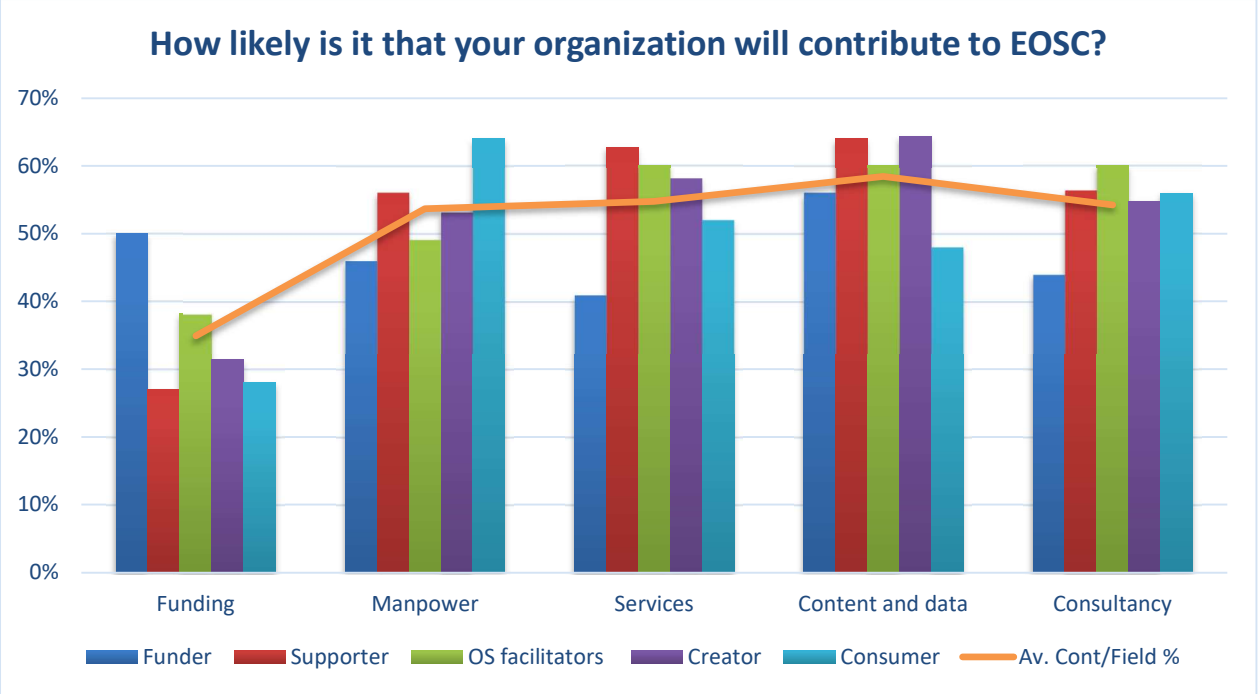

Figure 19: Stakeholders' willingness to contribute to EOSC

The responses indicate a nice uniformity among the different stakeholder groups which could be very promising for supporting the future of EOSC if proven in practice. As one would expect, Funders would be more willing to fund initiatives, while the rest of stakeholders would be willing to support EOSC with manpower, services, content/data and consultancy. In total, Services and content/data are the most popular resources stakeholders would contribute to EOSC.

More specific needs were identified from the stakeholders from their input to the question "Apart from the services you already have, which additional services would benefit the users in your organization?" 259 answers (44,0%) were collected for this question in a free text form, where one was free to provide text input according to their needs. These answers were screened, and a frequency-based answer grouping was created per stakeholder group. Common services/tools desired among all stakeholder groups in addition to their currently available are, in order of preference based on the frequency of appearance in their answers: a) publishing platforms, b) data repository software, c) data anonymization tools, d) DMP tools, e) VPN service. On top of these common requests, Consumers also asked for video streaming services, Creators asked for re-use of very expensive research equipment, High-performance computing services, data translation services, IT support services, workshops, training and datasets from various disciplines. Funders additionally asked for plagiarism identification tools. Supporters asked for training services, CRIS (Current Research Information) System, AAI, data visualization services, High-performance computing services, and together with OS-facilitators asked for FAIRness assessment tools.

Table 3 summarizes and matches stakeholder groups and their needs (at a high-level), as they were identified through this analysis.

Table 3: Summary of OS stakeholder groups and identified needs.

Stakeholders/ Needs	Funders	Supporters	OS-facilitators	Creators	Consumers
virtual machines	X	X	X	X	X
high-performance virtual cluster	X	X	X	X	X
single server	X	X	X	X	X
high-throughput computing clusters	X	X	X	X	X
Discipline specific services	-	X	-	X	X
FAIR datasets	-	X	-	X	X
Single point of access	X	X	X	X	X
publishing platforms	X	X	X	X	X
data repository software	X	X	X	X	X
data anonymization tools	X	X	X	X	X
DMP tools	X	X	X	X	X
VPN service	X	X	X	X	X
Expensive equipment re-use	-	-	-	X	-
IT support services	-	-	X	X	-
Training	-	X	-	X	-
plagiarism identification	X	-	-	-	-

FAIRness assessment tools	-	X	X	-	-
AAI	-	X	-	-	-
CRIS	-	X	-	-	-

5.2. Type and use of tools by stakeholders

The focus here is on the tools collected during the landscape activity combined with tools identified in the survey. Services that are part of digital and data infrastructures, such as AAI or VMs that are included in survey data, have been excluded from this analysis. Review of those tools per stakeholder groups provided great insight about their uptake and utility. The following figures show the type of tools available per stakeholder group as well as how the tools can be used by them. Depending on the research activities performed by stakeholders at the strategic, operational or technical level, and on how the outputs of the research conduct are utilized by them, some stakeholders expect to be provided with adequate supporting resources. Also, the research activities that stakeholders are involved in determine types of used resources and tools. For example, those that fund research, i.e. research funders, in their everyday work need resources about decision making, hence they could use more guidelines & policies resources. Whereas those that perform or consume research, i.e. RPOs and researchers, would mainly need tools to support and accommodate their research needs. Similarly, service providers who build and enhance national and organization data ecosystems in support of their service development and operation needs, may more frequently use Tools like software applications, methods, etc., than other stakeholders.

Research Funding Organisations

The analysis showed that, between the three types of tools in the collection, guidelines & policies is highly populated (more than half of the total collection). One third of the items in the collection are tools, while models appear to have a much smaller presence. Moreover, the collection of RFOs tools are to be used mostly in support of RDM and decision-making activities and less in certification.

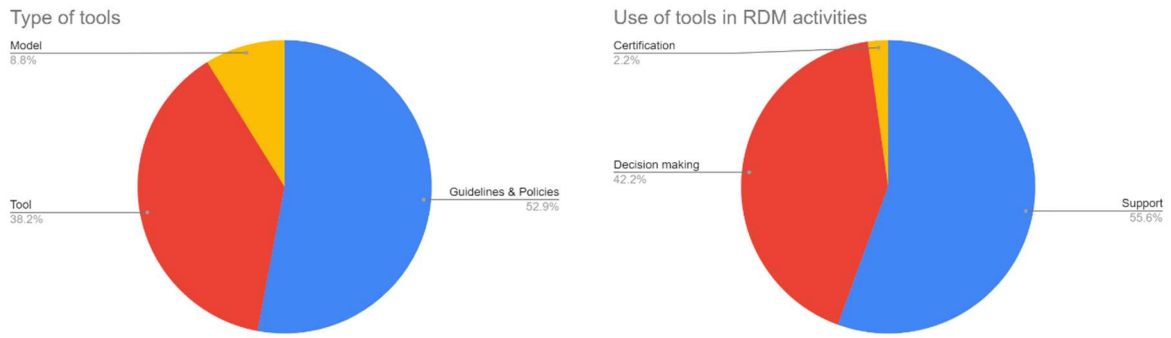

Figure 20: Tools addressed for use by RFOs

Research Performing Organisations

Here, analysis showed that the instruments RPOs are interested in reflects more on Guidelines & Policies and Tools than on Models and that these tools are used mainly to support RPOs research and decision making and less to provide a certification to their activities.

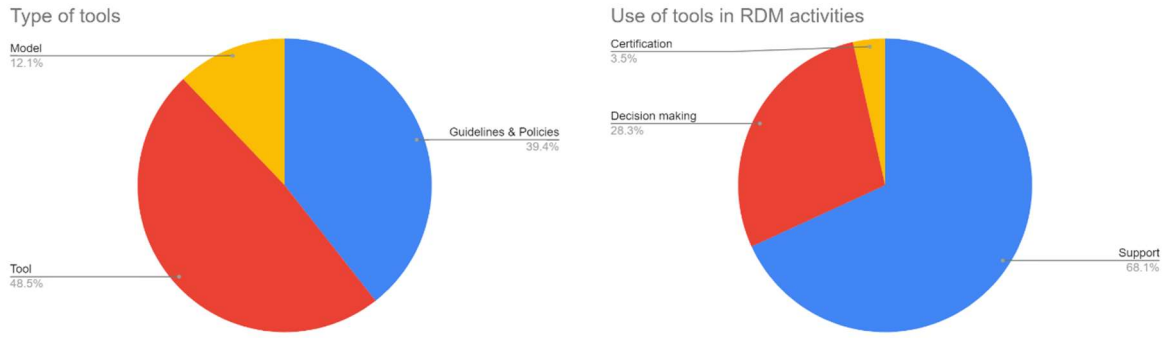

Figure 21: Tools addressed for use by RPOs

Researchers

For researchers, the key instruments seem to be mostly Tools and Guidelines & Policies, while Models are much less in use. Examining for which purpose researchers use these tools and resources, we see that it is mainly to support their RDM activities, but also to drive their research conduct. As it was the case with the RPOs in general, also the researchers are less interested using the tools for certification purposes.

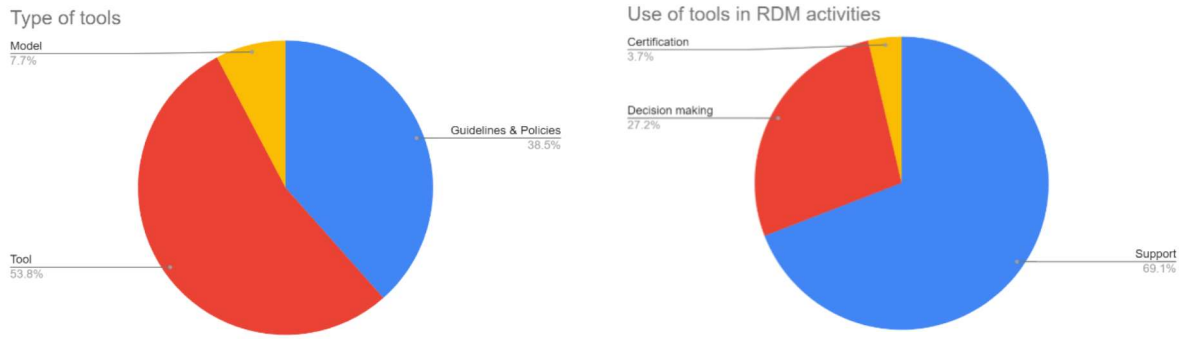

Figure 22: Tools addressed for use by researchers

Service Providers

Service provider instruments are mainly Guidelines & Policies (about half of the total collection). They are followed by Tools which constitute about 33% of the answers. It is worth mentioning that although the use of Models represents the 14.9% of the answers, in the Service Providers category have been identified more Models than in other categories. Service providers can use these tools to support the development of their services, maintenance of their activities, and to decide on how to proceed with building data services and to certify them.

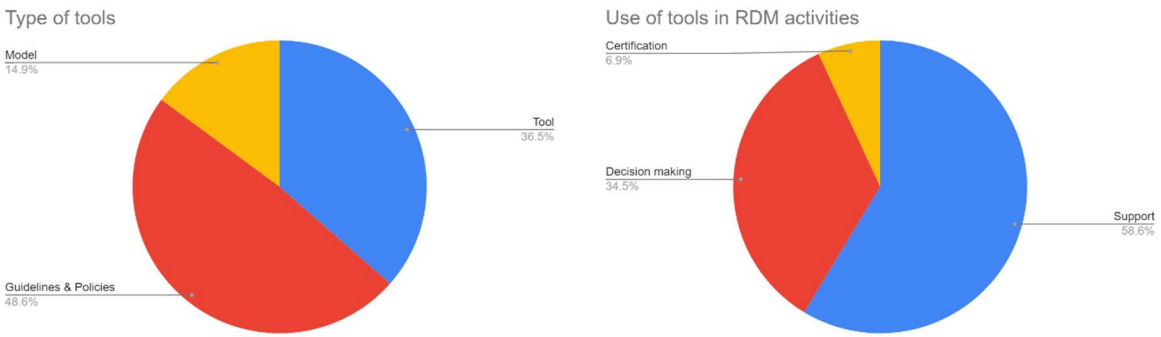

Figure 23: Tools addressed for use by service providers

6. Conclusions & Next steps

This is the part where the main results of observations during T4.3 activity are discussed along with the needs that are currently not covered by the global community. That will define our next steps and steer the priorities for developing tools (T4.4 and 4.5) that are closer or tailored to current demands of both the EOSC ecosystem (this could be the development of a service/tool that is essential for EOSC-Core operations but is not there yet) and researchers or other stakeholders in their open and FAIR research endeavours.

Overall, the analysis highlighted that there is good provision for tools and services for Open and FAIR Research Data Management at all levels:

- **Strategic**, driving development and improvement of processes concerning the structure, architecture and management of data, services and operations, e.g. with model policy templates or assessments/audits.
- **Operational**, covering from essentials to specifics of undertaken activities and ensuring their successful implementation, also in compliance with standard practices, e.g. with software applications, training resources, use cases etc.
- **Technical,** contributing to the development or integration of software and best practices for the realisation, enhancement and maintenance of systems and services, e.g. with PIDs or smartAPIs.

Currently, trends concentrate on developing tools to address documentation requirements in RDM and others to measure levels of data FAIRness. DMP tools grow due to demanding RDM conditions set by the EU, national funders or institutions and research communities. Hence, apart from generic approaches such as DMPonline and ARGOS DMP tools, there are efforts by national bodies and research communities to develop tools that meet their requirements, like the French example of DMP OPIDoR which was developed by CNRS (French National Centre for Scientific Research) and the Data Stewardship Wizard for the Life Sciences. It should be noted that most of the aforementioned tools are in the process of applying the RDA DMP Common Standard for machine actionable DMPs to their model.

Also, implementation of FAIR principles has led to standardisation and testing of FAIR metrics (A design framework and exemplar metrics for FAIRness; FAIR-TLC: Metrics to Assess Value of Biomedical Digital Repositories) including production of methodologies for their assessment (FAIR Data Maturity Model) and even creation of self-evaluation tools (FAIR Maturity Evaluator, SATIFYD), addressing not only data but repositories, services and other research outputs.

Additionally, there is maturity in certifications for repositories with CoreTrustSeal leading the way to FAIR-aligned data repositories and OpenAIRE ensuring interoperability and findability for repositories, including literature repositories, in the EOSC.

The Open Science community is supporting the transition to the new model of conducting and disseminating research and EOSC through advocacy, and training. There is both great expertise and comprehensive material for those matters. However, there are currently no training resources for IPR in Open Science.

Also, in terms of Open Science policy adoption and its implementation, there is useful material produced in line with European policy recommendations and directives. OpenAIRE NOADs are mobilised to ensure compliance with policy conditions and produce or make use of model policy documents and checklists in consultations with key stakeholders. This

model will be expanded in the NI4OS-Europe countries within the context of WP2 activities. More information about the policy landscape in the region is made and will be continuously enriched through WP2 streams.

Additional observations at a smaller scale which emerge from the analysis of data from both the WP2 survey and landscaping activity of this deliverable are the following:

- Some of the tools are manually curated therefore creating the need for more automated processes to be realised, eg FAIRSharing registries.
- There are not many legal tools in the Open Science area as opposed to the public sector. Additionally, copyright tools for public domain works, such as the Public Domain Calculators by Europeana, could be broadened to all domains.
- The survey highlighted the need for digital services to support data-intensive research in the EOSC, i.e. VMs, computing, HPC etc.

More about the findings from the perspective of NI4OS-Europe project and EOSC:

- WP4 could expand to working closely with the INFRAEOSC-5 projects, also in the frame of the EOSC task forces, to facilitate the development of practical tools for key EOSC procedural issues such as that of the Rules of Participation (RoPs), for example by delivering a tool that certifies EOSC compatible services.
- There have been attempts to develop tools for machine-readable policies, but this is yet to be implemented; WP4 could take this opportunity and produce such a tool for EOSC taking into consideration EOSCpilot work on policy supporting services.
- This work needs to be continued and expanded to other regions to get the greater picture.
- This work could be combined with similar EOSC clusters work to give a vertical hue to current approach undertaken, which touches less upon domain-specific RDM, by providing insight on domain-specific tools which would highlight more Open Science elements such as methodologies, standards etc. For example, ELIXIR CONVERGE could provide more input on the Life Sciences, SSHOC on the Social Sciences etc.

Finally, to ensure the continuation of the work presented in this deliverable for the greater benefit of communication with stakeholders and support in the EOSC, it is proposed to create a wiki for the implemented and supported instruments. The wiki will include the list of tools that have been identified in this deliverable, could be available from the EOSC portal and modifiable by everyone. Projects having similar landscape reviews in their workplans could openly reuse, update or adapt the produced list of tools.

