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D.9.4 INNOVATION AGENDA

Lead Author: Sophia Sotiropoulou

With contributions from: Demetrios Anglos, Marta Castillejo, Anthony Corns, Adam Gibson, Maria Makridaki, Polonca Ropret, Mary Teehan, Michal Vopálenský

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Abstract

Innovation constitutes the goal and at the same time the medium for achieving all E-RIHS strategic objectives and therefore the Innovation Agenda addresses all research actions and services, training and communication as well as collaborations with other RIs and Industry (in the broad sense), in the Heritage domain. The 'Innovation Agenda' represents the main action plan that reflects the priorities set in key areas and provides those mechanisms and structures necessary to enable innovation in any specific identified direction. The document reviews mechanisms, internal rules and procedures concerning the E-RIHS Innovation Strategy and discusses issues related to formulating, managing and keeping up-to-date the Innovation Agenda. A systematic approach in monitoring innovation, defining metrics and indicators (KPI's), will provide a reliable assessment of the innovation impact to Excellence, Synergies and Co-creation, Users and public engagement and the Sustainability of E-RIHS ERIC as a leader in the global HS landscape.

This document is Deliverable 9.4, elaborated in the context of E-RIHS PP, WP-09, Task 9.2, 'Exploitation of E-RIHS capacities: innovation, transfer of knowledge and marketing'. The analysis for this task was based on extensive qualitative and quantitative research and builds upon Deliverable 9.2 '*Analysis of The Innovation Background*'.

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This document reflects the state of advancement of the preparatory work at the time of its delivery. As such, its content may be subject to further evolution.

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Authors (Partner)	Sophia Sotiropoulou, Mary Teehan, Maria Makridaki, Anthony Corns, Michal Vopálenský, Demetrios Anglos, Marta Castillejo, Polonca Ropret, Matija Strlic			
Responsible Author	Name	Sophia Sotiropoulou	Email	sophiaso@iesl.forth.gr
	Partner	FORTH	Phone	+30 2810 391813

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Abbreviations

BoF Birds of a Feather
CESSDA Consortium of European Social Science Data Archives
CLO Central Liaison Office
CPD Continuing Professional Development
EC European Commission
ERIC European Research Infrastructure Consortium
EOSC European Open Science Cloud
ESS The European Social Survey
FAIR Findable, Accessible, Interoperable, and Reusable
GRI Global Research Infrastructure
HR Human resources
HS Heritage Science
INNO WG Working Group on Innovation
IPR Intellectual Property Rights
IPRMP IPR Management Plan
JRA Joint Research Activities
KPI Key Performance Indicator
KT Knowledge Transfer
OECD Organisation for Economic Co-operation and Development
RDA Research Data Alliance
RI Research Infrastructure
RRI Responsible Research and Innovation
SHARE Survey of Health, Ageing and Retirement in Europe
SRIA Strategic Research and Innovation Agenda (SRIA)
SSHOC Social Sciences & Humanities Open Cloud
TNA Trans-National Access
TT Technology Transfer
TTO Technology Transfer Office
VRE Virtual Research Environment

Narrative (technical) description

1 EXECUTIVE SUMMARY

The goal of E-RIHS, the European Research Infrastructure for Heritage Science (HS), is to grow and strengthen a creative, Europe-wide framework for supporting frontier research in heritage science. It will do so by offering access to expertise, data and technologies through a standardized approach based on different modes of services organized in four platforms:

- ARCHLAB (access to heritage archives and collections);
- DIGILAB (remote access to data and tools for heritage research);
- FIXLAB (access to large-scale facilities and advanced laboratories;
- MOLAB (collections of mobile instruments enabling in-situ diagnostics).

The success and long-term sustainability of E-RIHS will rely on its capacity and means to foster scientific excellence and equally to identify, promote and exploit its innovation potential. This will enable the development of next-generation instruments, methods and knowledge management tools capable of advancing or even radically redefining the state of the art across the RI.

Innovation Strategy

The *Innovation Strategy* constitutes the framework of principles guiding E-RIHS to be a leading innovator. It takes into account the overall mission of E-RIHS and interfaces strongly with the scientific vision and excellence strategy aiming to address grand challenges in key areas of HS. This will ensure that E-RIHS becomes not only the recognised hub of research excellence in HS, but also a sector-specific innovation incubator.

Innovation Agenda

The Strategy is to be implemented through a dynamic *Innovation Agenda*, the main action plan that reflects the priorities set in key areas and provides those mechanisms and structures necessary to enable innovation in any specific identified direction.

Setting up all the mechanisms and internal rules and procedures concerning the Innovation Strategy is the first step towards enabling and exploiting innovation. A most important factor when formulating an Innovation Agenda though, is its proper management. The innovation ecosystem constantly changes and new challenges and opportunities emerge. Strong leadership is required, not only to ensure that all steps and procedures are followed, but also to assess and revise the Agenda when needed.

A number of key actions integrate into the E-RIHS Innovation Agenda including:

Monitoring of Innovation – Introducing the concept of Innovation Radar we set up mechanisms to: a) monitor existing and emerging or disruptive technologies throughout E-RIHS (and beyond), b) evaluate their potential for generating impact, c) locate exploitation opportunities, and d) advise on key areas for development.

However, for E-RIHS, innovation applies not only to cutting edge technologies and instrumentation development but is also relevant to a variety of procedures and a broad field of application areas. Diverse types of innovation arise in investigation or conservation methodologies and are equally important to user servicing, to data management and handling as well as to education and training activities. This diversity requires a systematic approach in defining metrics or Key Performance Indicators (KPIs) that would provide

a reliable assessment of the innovation impact and contribute to enhancing E-RIHS' potential for producing further innovations with impact in various fields and research communities.

Managing Innovation – Mechanisms and tools will be enabled to: a) detect emerging opportunities in terms of financing innovation, collaboration opportunities, smart specialization, funding schemes encouraging synergies between stakeholders etc., and b) promote and facilitate the dissemination of innovation (e.g. novel scientific knowledge, exploitable research outcomes etc.) emerging from E-RIHS. Synergies will be established with the appropriate stakeholders at regional, national and European level, in order to create standard communication and dissemination channels.

Considering the multi-actor nature of E-RIHS (providers, users, support scientists/engineers), it is important to work towards a well-defined and balanced Intellectual Property Rights (IPR) support system, adjustable to the different types of innovation envisaged in E-RIHS so as to promote creativity and innovation exploiting the broad knowledge basis in the E-RIHS ecosystem. Importantly, all the above relate to the existing national and EU legal and administrative framework for granting and protecting IP rights.

Exploitation and Dissemination– Defining a strategy for exploiting innovation across E-RIHS and for adopting optimal routes for exploitation (services, licensing, spin-off creation, joint ventures, sales).

Technology Transfer (TT) – is the process of converting scientific findings into useful products or services for society. E-RIHS should encourage a culture that supports innovation exploitation and, under certain conditions, commercialization. In this respect, a technology transfer methodology is to be developed based on networking among Technology Transfer Offices (TTO's) in the various National Hubs. The importance of building networks in the TT and licensing community is critical. By working through networks, innovators exchange ideas and experiences, forming best practices that become performance standards for both individuals and their institutions.

Education and Training – E-RIHS is operating on the basis of the innovative concept of inter/trans - disciplinary and cross-sectoral integration of heritage-related research activities. Future developments aiming at strengthening and capitalizing on this innovation will rely on the E-RIHS Academy, its major goals being: a) to formulate a Continuing Professional Development (CPD) system for HS, and b) to create the next generation of heritage scientists acting as access providers. The E-RIHS Academy will develop a range of training channels suited to the different training aims and appropriate for addressing the specific needs of the different research communities. User and provider training courses will be designed separately but towards the same goal, the creation of a culture of co-operation, co-interpretation of results and co-creation of new knowledge expanding the innovation potential. The E-RIHS Academy will also function as the connective tissue and the interface among well-established education programs and short term specialized seminars or summer schools developed at partner's national level.

Collaborations and Interoperability – Openness in collaborations within E-RIHS, across the user communities and furthermore across to industrial partners is fundamental for defining new challenges and opportunities and for enhancing innovation. E-RIHS will pursue interoperability through appropriate measures and actions aiming to simplify procedures and encourage collaborations fostering innovation among its users, providers, industry, and other stakeholders related to HS. Some of the key actions to be implemented by E-RIHS towards this direction include widening and upscaling communication and dissemination channels among stakeholders, and setting up of mechanisms enabling easy and immediate knowledge exchange and technology transfer activities. In parallel, specific actions are already developing concerning the design and implementation of DIGILAB as the main gate and a Virtual Research Environment (VRE) for discovering and providing access to HS knowledge (research data and procedures) as well as to advanced services including

software tools and methods for data handling, processing and management enabling interoperability at both encoding and semantic level.

2 E-RIHS Excellence and Innovation

2.1 E-RIHS overview

E-RIHS, the *European Research Infrastructure for Heritage Science*, represents a major initiative towards an advanced concept for a pan-European Research Infrastructure capable of delivering top-level cross-disciplinary services to users and promoting innovation in Heritage Science (HS)[1,2,3,4]. Via the integration of world-leading European resources, E-RIHS aims at creating an organisation with a clear identity and a strong cohesive role within the global HS community.

The mission of E-RIHS is to ambitiously stretch the boundaries and the impact of HS. It will develop the most comprehensive and advanced scientific and technological capabilities that will enable researchers, organizations and industry to develop skills, knowledge and innovation to enhance the appreciation and preservation of heritage. Emphasis will be placed on promoting a culture of cross-disciplinary collaboration and training throughout its members.

E-RIHS will deliver integrated access to expertise, data and technologies through a standardized approach. It will promote best practice and advance methods for the specific needs of heritage assets, whether material or digital. This will be implemented on the basis of different modes of access:

- ARCHLAB - access to heritage archives and collections;
- DIGILAB -remote access to data and tools for heritage research;
- FIXLAB - access to large-scale facilities and advanced laboratories;
- MOLAB - collections of mobile instruments enabling in-situ diagnostics.

The success and long-term sustainability of E-RIHS will rely on its capacity and means to foster scientific excellence and equally to identify, promote and exploit its innovation potential and smart specialization of its facilities. This will enable the development of next generation instruments, methods and knowledge management tools capable of advancing or even radically redefining the state of the art across the RI.

2.2 E-RIHS as an innovation ecosystem

As already analyzed in D9.2[5], the interweaving of research with innovation is a fundamental structural principle for the effective operation of RIs and their enabling role for convergence of researchers, funding institutions, industry and even governments. In this context, ERICs possess a strong potential for promoting innovation in the EU.

[1] http://www.e-rihs.eu/
[2] E-RIHS flyer
[3] E-RIHS overview for SAB
[4] http://www.e-rihs.eu/wp-content/uploads/2016/04/E-RIHS-in-one-page-2017.10.02.pdf
[5] E-RIHS PP Deliverable D9.2, “Analysis of the Innovation Background”

The vision of E-RIHS ERIC is to become the globally recognised hub of research excellence for all heritage investigations, not just HS. In this sense, E-RIHS constitutes a platform for interdisciplinary partnership with the aim to address major scientific and technical challenges in HS, often beyond the realm of pure science and technology. It allows access to state-of-the-art equipment and facilities, top-level expertise, data, archives and collections, in an innovative way. E-RIHS is open to collaboration with other RIs seeking to exchange best practices and take advantage of innovations deriving from other scientific fields: Furthermore, E-RIHS encourages and facilitates innovation through different types of collaboration and strategic partnerships (e.g. among providers, between providers and users, with industry, at global, EU or regional levels). A major ambition of E-RIHS is to promote a culture of innovation in every research activity, in the access services provided and also at the management level, exploring new models for maximising the impact of HS research on development and socio-economic growth based on the sustainable use of cultural heritage.

2.3 Innovation in Heritage Science

Innovation, as more generally defined in the "Oslo Manual" for Innovation of the Organisation for Economic Co-operation and Development (OECD)[6], ***goes far beyond R&D:*** *It goes far beyond the confines of research labs to users, suppliers and consumers everywhere – in government, business and non-profit organisations, across borders, across sectors, and across institutions.* According to the same manual, four types of innovation can be defined: **product** innovation, **process** innovation, **marketing** innovation and **organisational** innovation.

These four types of innovation can be found in the Cultural Heritage domain[7] and therein HS can have key contributions. For example, the E-RIHS Trans-National Access (TNA) catalogue of services[8] encompasses a multitude of cutting-edge tools dedicated to provide unique services to diverse user communities at several levels including:

- Instruments and workstations;
- Techniques and methodologies;
- Integrated multi-technique methods;
- Interdisciplinary approaches for data processing and interpretation.

An innovative concept in itself, E-RIHS offers access to large-scale and medium-scale analytical facilities (FIXLAB), to an impressive array of advanced mobile analytical instrumentation (MOLAB), as well as to invaluable scientific datasets archived in knowledge repositories of prestigious European museums, galleries and research institutions(ARCHLAB). In addition, it combines these services with unique expertise in designing or optimising sophisticated scientific investigations and proper approaches for analysis and interpretation, specific to the targeted object or material, revealing their complex microstructure and chemical composition, giving essential and invaluable insights into historical technologies, materials, alteration and degradation phenomena or authenticity. E-RIHS aims at growing opportunities for innovation by exploiting the prolific interaction and collaboration between providers and users through the provided TNA services, building also strong links with industrial partners and the broader heritage industry. Significant innovations developed so far in the E-RIHS organizations have emerged over the past decade through a

[6] https://www.oecd.org/innovation/

[7] http://www.innovatorsinculturalheritage.eu/launch

[8] E-RIHS PP Deliverable D8.3, "TNA catalogue of services"

number of RI-level projects supported by the EC, such as EU-Artech, CHARISMA, IPERION-CH[9], ARIADNE or PARTHENOS. As recorded in the E-RIHS PP-9.2 Innovation Survey (see D9.2, [5]) most of these innovations fall under the Use-led and Research-based Innovation cases, even though occasionally Technology transfer and Spill-overs have been achieved. A general overview would classify these innovations in different types as shown in Figure 1.

Obviously, given the present experience, many more innovations can be developed through E-RIHS in additional areas producing, for example, non-economic, non-technological and social innovations. It is noted that the overall positive outlook has sparked great interest towards the development of key RIs for serving various heritage research communities and this is the reason ESFRI has introduced a number of pan-European RIs in the SSH domain (DARIAH, CLARIN, ESS, SHARE and CESSDA), with E-RIHS being the latest addition in the 2016 Roadmap.[10]

Beyond the direct impacts related to increasing the quality and efficiency of scientific production in HS, E-RIHS activities are expected to provide further impacts benefitting the scientific community, sector operators and the public at large. Thus, Europeans, more broadly, and public services more specifically, will benefit from better access to non-technical knowledge, improved awareness and increased understanding of artistic and cultural assets. Finally, implementing various types of innovations in heritage institutions can enhance the access of citizens to culture, strengthen its message to society and generate positive impact on cultural tourism.

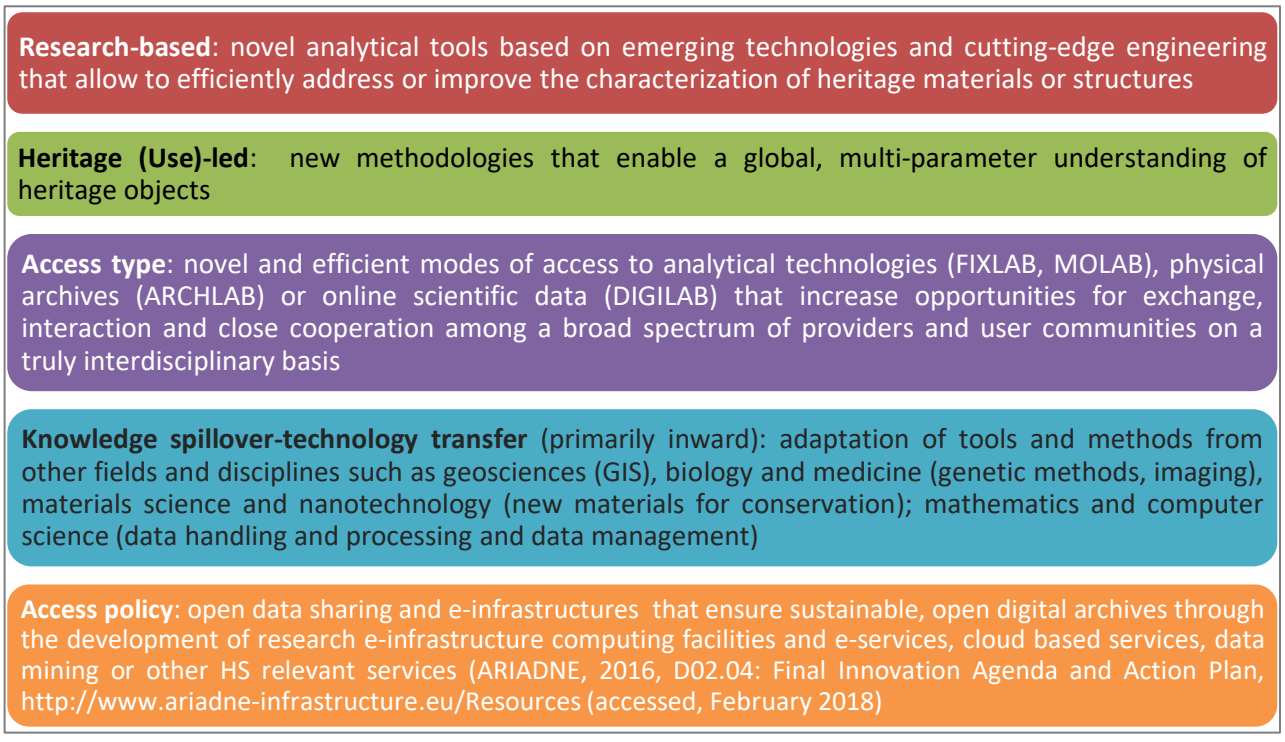

Figure 1 Types of Innovation relevant to Heritage Science

The strategic role of E-RIHS in promoting HS as an innovation enabling actor in heritage industry exceeds the European borders and shows a clear potential for global impact. E-RIHS, through its international co-

[9] https://zenodo.org/record/3592059 M. Kowalska, P. Targowski, Success stories: Impact of 15 years of European Research Infrastructure Projects on Heritage Science, Dec 23, 2019, version 2.71

[10] ESFRI Roadmap 2016

operation strategy, aims to play a connecting role in the global community of HS, fostering a trans-disciplinary culture of exchange and cooperation,[11].

2.4 Motivation for innovation

Innovation goals need to be truly inspiring and should foresee a desirable future status for E-RIHS, consistent with its Vision as described in D.9.1[12]. The elements motivating researchers to innovate derive from the needs to address specific or broader goals. These can be purely scientific, motivated by specific needs, or in the context of pursuing wider global and social challenges.

Considering specific challenges in HS, these emerge from the need to:

- advance our scientific understanding of Heritage and this way contribute to its interpretation and/or conservation;
- perform advanced analyses for obtaining materials composition (e.g. trace elements, spatial distribution) or understanding processes (e.g. ageing);
- perform efficient diagnostic tests and analyses in situ (at monuments, archaeological or historical sites);
- perform conservation treatments via methods that minimize risks and ensure a safely reversible intervention;
- handle and interpret complex or large sets of data in specific domains such as paleontology, archaeogenetics;
- understand interdisciplinary aspects of CH and promote HS as a cross-disciplinary approach to research questions related to the history, interpretation, appreciation, and preservation of Heritage;
- address questions of broader significance concerning material culture, the society and economy of ancient communities and civilisations.

Challenges covering a much broader scope may relate, for example, to:

- preventive and sustainable conservation
- climate change and its impact on CH[13]
- natural or human-caused disasters affecting heritage

Grand Challenges included in the UN 2030 Agenda for Sustainable Development[14], adopted in 2015, provide a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which constitute an urgent call for action by all countries - developed and developing ones- in a global partnership. New realities are reshaping innovation, and E-RIHS should re-examine whether its science, technology and innovation (STI) policies remain purposeful in driving sustainability. And, in a broader context, if they are supporting growing demands on innovation that is capable of addressing a wide range of social and global challenges, as reflected in the SDGs. The focus on the SDGs highlights the importance of linking innovation more closely to people's needs.[15]

[11] http://www.e-rihs.eu/e-rihs-as-a-global-research-infrastructure/

[12] E-RIHS PP D9.1 First version of the E-RIHS scientific vision

[13] Joint Programme Initiative on Cultural Heritage and Global Change, Strategic Research and Innovation Agenda 2020.

[14] https://sustainabledevelopment.un.org/post2015/transformingourworld

[15] OECD (2018),OECD Science, Technology and Innovation Outlook 2018: Adapting to Technological and Societal Disruption, OECD Publishing, Paris. https://doi.org/10.1787/sti_in_outlook-2018-en

The UN SDGs will be used as a broader guiding framework for setting E-RIHS's Innovation priorities (see Table 1). More specifically, HS research interfacing with cultural industries into heritage management and heritage conservation responds to pressing global challenges impacting on European science and society. HS research for better understanding and efficient conservation of heritage has the potential to lead to innovations that can benefit other scientific fields and industries as HS benefits from innovation in other fields. More importantly, HS contributes to social cohesion and the well-being of citizens through studies of our past. Strategically important areas that present relevance and economical and/or societal impact are tourism, employment and education.

The scientific and innovation strategy of E-RHIS is aiming to act as the central HS innovation radar in order to create the mechanisms and progressively establish within E-RIHS the framework of a sector-specific innovation incubator to meet the needs of the several HS user communities. Such a strategy requires constant awareness and monitoring mechanisms for the periodic assessment, review or resetting of priorities and action plans to foster innovation in all scientific and exploratory process, services and management levels stressing the technological interoperability and convergence of methods through the definition of best practices.

Table 1 E-RIHS Challenges vs Grand Challenges

Grand Challenges are E-RIHS Challenges		
1 SDG	Disasters, wars	Natural disasters, as earthquakes, volcanos, flood and others can heavily affect the historical sites, collections in museums, artwork in galleries, books in libraries etc. Military or even urban conflicts may have similar effects. There exist several challenges for HS in this regard including, for example: - developing techniques for fast digital mapping of archeological sites and architectural structures; - thorough documentation linked to high resolution 3D digitisation of objects and artworks (murals, paintings, statues...). New methods will be developed that will allow fast digitization needed for recovery of the damaged sites pieces, or at least their conservation in the 3D virtual form.
2 HS	Digitization of historical manuscripts and books	A specific topic relates to historical manuscripts and books as they can be very fragile and often need particular and very well defined storage conditions. Even listing them can be a dangerous operation. Modern imaging methods allow inks, such as gall ink which contains iron, to be distinguished from the substrate (paper, parchment...). Eventually, it may be possible to scan a closed book and then read its contents through post-processing algorithms without opening it.
3 HS	Modern GIS methods for mapping and on-site detection	Many archeological sites are not evident when observed from the ground. Yet several interesting ones have been discovered by observing vegetation patterns or other signs via aerial photography and satellite imaging. It is foreseen that new methods will be developed for analysis of satellite images allowing further identification of promising areas. Additionally, there are many archeological sites covered by forests (Guatemala, Mexico, Indonesia...) or under the sea. Again, future aerial or satellite mapping and advanced analysis may help in their identification, mapping and excavation. Many places are known of ancient or medieval populations or routes and many excavations have been undertaken therein. However, hidden artifacts remain. Advances in electronics and mobile diagnostic instrumentation will allow their discovery thanks to much greater sensitivity and portability. Modern and advanced radio-methods will make it possible to map and virtually reconstruct subterranean structures of ancient constructions.
4 SDG	Climate change	Climate change can dramatically influence monuments, buildings, facades, murals etc. In addition, changes in chemical composition of the rain can slowly, yet heavily damage the

		calcite constructions and buildings. Increased exposure to UV light can affect murals and paintings. Temperature and humidity can result in favourable conditions for growth of mould, bacteria and vegetation on heritage buildings and accelerate their erosion. In this context: - new conservation methods will have to be developed to ensure stable behavior of the objects in spite of changing environmental conditions. - new methods of providing suitable microclimate will be needed for conserving facades and murals that cannot be moved.
5 SDG	Over-tourism	Increase of tourism activities is a serious problem in natural reservations as well as culture heritage sites. The challenge here is how to re-distribute the load from the crowds of tourists and yet offer visitors a rewarding experience. A partial answer to this question could be found in point 6, below.
6 HS/ SDG	Interactivity / hands-on experience	The modern world is getting faster and people are focusing more and more on the experiences. HS, or more specifically, applied heritage science, can offer many solutions: - virtual models of the archeological sites accessible and browsable via smartphones, - virtual reality tours through ancient cities and sites, - 3D models of inaccessible places (undersea, tropical forest), - with 3D printing, exact copies of artifacts can relatively easily be made by mapping the real object. Visitors can then touch the identical copies and even try to use them (medieval tools etc.).
7 HS	Introducing good practice to new sites / facilities	New sites, museums and galleries are being opened around the world, and it is important to ensure that best practices developed elsewhere are used in new sites. Defining best practice in remote areas or in developing countries given financial constraints is challenging. There are opportunities for countries and institutions with a strong track record of excellent curatorial practice such as those in the EU to work closely with regions that are new to protection of heritage or have particular financial limitations.
8 HS	Mobile instruments	Advances in electronics (as well as micromechanics, photonics, etc.) allow miniaturization as well as a dramatic increase in computing power leading, for example, to modern mobile phones that have significantly higher computational power than standard desktop computers ten years ago. HS is one of the disciplines that can benefit most from these advances which offer the capacity to facilitate the use and optimize the performance of analytical instruments on site (MOLAB model). A good example is the XRF hand-held instruments that are rapidly entering a domain that has been dominated by desktop devices, and making the method much more attractive to restorers and archaeologists. This challenge will certainly lead to innovations consisting of developing high quality mobile devices that will facilitate field work.
9 HS/ SDG	Digital Transformation and remote access to Facilities after COVID-19 pandemic impact	The COVID_19 pandemic has created a new reality and completely transformed the usual ways of operation. The pandemic was a means to confirm that unforeseen conditions can have a severe impact on day-to-day business and alternatives should be found and established in order to efficiently handle unexpected situations. A great challenge for E-RIHS is to establish certain pathways, processes and adequate infrastructure that are efficient in terms of achieving research objectives and at the same time safe for researchers so that limitations and obstacles as the ones introduced by the pandemic can be mitigated. Therefore, digital transformation will be fully promoted and supported through E-RIHS as well as new technologies will be deployed to enable remote access to facilities, labs and sites. Alternative ways for communication and collaboration, video-conferencing applications, virtual meetings and other types of remote working/learning/collaboration platforms not requesting physical presence will be explored so as to minimize travel requirements. Innovations deriving through E-RIHS could be effectively considered and their outcomes could be integrated with inventive settings to enrich storytelling and virtual tours of museums,

		galleries and heritage sites, recently adopted by Museums and Sites to engage their visitors and raise income even when they are physically closed.[16]
10 SDG	Internet of Things	More efficient and cheaper connectivity coupled with advances in electronics, opens new options in (online) data collection. The prevailing trend in this respect is Internet of Things (IoT), i.e. the network of physical devices embedded with electronics, software, sensors, actuators and connectivity, which enables these "things" to connect, collect and exchange data. IoT has also quickly found its place in cultural heritage applications. The development of deployment in this area is yet to be expected, not only for monitoring environmental parameters for heritage sites/objects, but also collecting data on object changes, behaviour of visitors and other direct and indirect effects on monuments and individual artifacts. Another promising trend, Crowdsourcing, as an innovative method for engaging citizen in science has been recently explored in HS.[17] Measurements of colour and area were chosen because of the possibility of producing them with smartphone cameras. The quality of measurements was evaluated experimentally by comparing data contributed by anonymous visitors in heritage sites with reference measurements of known accuracy and precision. The results demonstrated that it is possible to extract colorimetric and area measurements from images contributed by citizen scientists who use their own smartphones, and to quantify their precision and accuracy. The error associated with these measurements is sufficiently small to allow for some useful applications.
11 HS/ SDG	Big Data	IoT deployment, modern instrumentation and digitization, all lead to the production of large volumes of science and research data. This requires innovative approaches to storage and archiving and offers new possibilities for their processing, analysis and extraction. Data warehouses with data marts are already commonly deployed in commercial areas, and data mining is used to gain new knowledge from these raw data. These techniques are also used in the field of scientific data and it is therefore appropriate to think about and develop them in the field of HS. Software applications and statistical or neural-network-based processing methods, developed for specific applications in disciplines that are regularly tackling Big Data handling, processing and management issues, will be included in the catalogue of advanced services provided via DIGILAB TNA platform.
12 HS/ SDG	Open Data	Nowadays there are also changes in science that should be reflected in individual disciplines, including HS. The relationship between society and science is continually changing and science and its strategic development have become part of wider political concepts. In the last decade we can therefore meet the concept of Open Science as a systematic change in the modus of operandi of research activities affecting the research cycle and all of its stakeholders. Although there are many Open Science trends, open access is the most discussed and elaborated one. Open research data in this context is data (statistics, results of experiments, measurements, observations, survey results, interview recordings and images) in digital form allowing users to freely access, mine, exploit, reproduce and disseminate data. Consequently, one of the supporting innovation trends is therefore the development of methodological procedures and technical means to access, mine, exploit, reproduce and disseminate data acquired and generated within research activities in the field of HS.
13 HS/ SDG	Connections through Heritage Science	Developing new knowledge through HS to deepen our understanding of past connections, for example, shared histories and mobility of populations. In a geo-political landscape where divisions grow, heritage may be a positive factor and nurture cultural well-being. Innovation in communication and access to Heritage knowledge may contribute in changing our understanding of heritage as a reflection of a country's history needing to reflect all citizens. There is a need to improve understanding and interpretation of controversial topics such as slavery, colonialisation, racism, genocide. There is also increasing pressure on museums to return objects to their original countries. It might be a certain pathway where innovations

[16] Van Eyck from home, Virtual tour, https://vaneyck2020.be/en/van-eyck-from-home/

[17] R. Brigham, J. Grau-Bové, A. Rudnicka, M. Cassar, M. Strlic, Crowdsourcing as an Analytical Method: Metrology of Smartphone Measurements in Heritage Science, *Angew. Chem. Int. Ed.* **2018**, *57*, 7423, doi:10.1002/anie.201801743

		through HS can contribute by making for example replica objects and virtual displays, whereas more voices for example from African/colonial views need to be included in the HS landscape.[18]

3 E-RIHS – Strategic Research and Innovation Agenda (SRIA)

The Innovation Strategy takes into account the overall mission of E-RIHS that reflects Europe's vision for HS and interfaces strongly with the scientific vision and excellence strategy with the aim to address grand challenges in key areas of HS. It will consist of a carefully designed framework of principles aiming to transform E-RIHS to a leading innovator in the HS domain. This will ensure that E-RIHS becomes not only a recognised hub of research excellence, but also an innovation incubator in HS.

3.1 Strategic objectives of E-RIHS SRIA

Among the strategic research objectives of E-RIHS, certain ones are identified as headlines in the Innovation Agenda, see Figure 2.

Figure 2 Headlines in the Innovation Agenda of E-RIHS

The **E-RIHS Strategic Research and Innovation Agenda** (SRIA) is impregnated with fundamental goals set since the early development phases (supported by the EC FP5, FP6, FP7 and H-2020) of what has nowadays come to be the E-RIHS consortium. It is progressively built around several interrelated priorities for action, which together underpin a strategic approach to the ERIC sustainability, promoting innovation.

[18] https://www.theguardian.com/uk-news/2020/jun/08/who-was-edward-colston-and-why-was-his-bristol-statue-toppled-slave-trader-black-lives-matter-protests This article is about a statue of a slave trader and philanthropist, which was removed by protesters in the UK. It was damaged and thrown in the sea, and then recovered to be displayed in a museum.

More specifically, the E-RIHS SRIA is focusing on analyzing the existing innovation potential and supporting the development of sustainable products or services of real added value that directly respond to the CH users' needs or cover identified gaps in the already provided catalogue of services as can be seen in Figure 3.

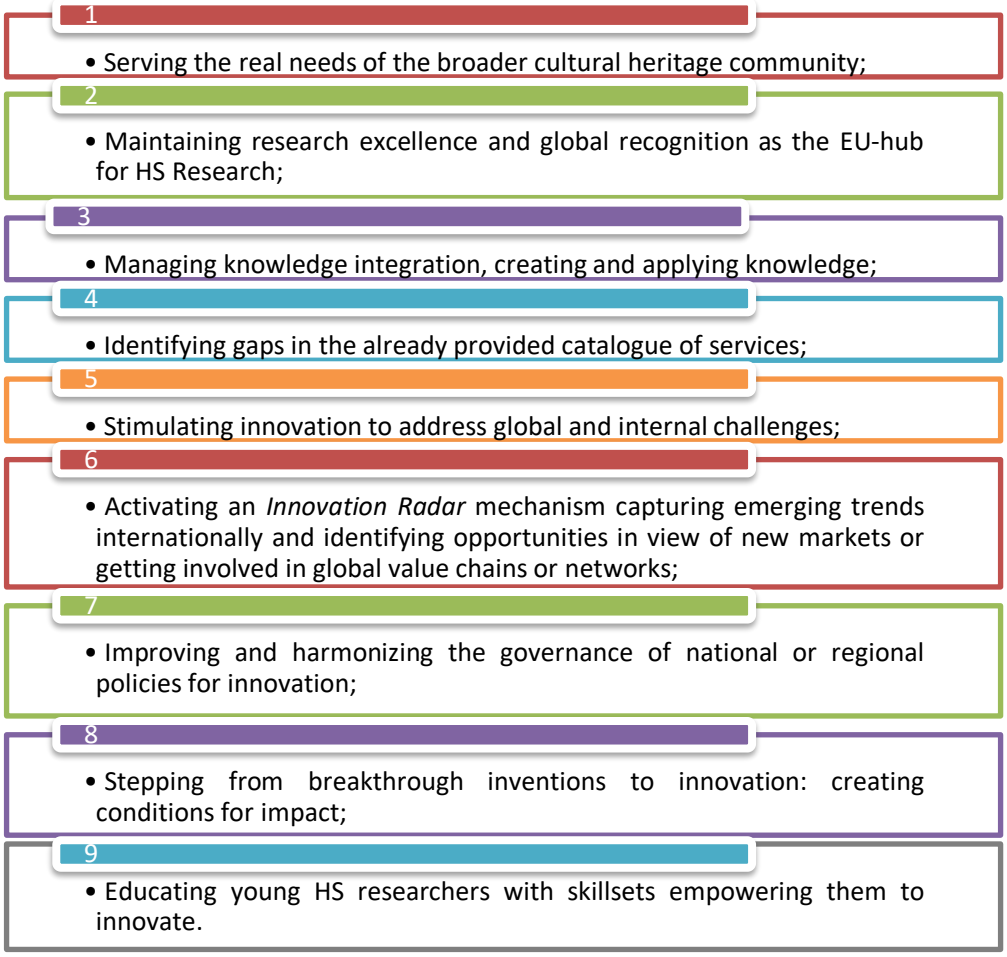

Figure 3 E-RIHS SRIA vital steps

The E-RIHS Innovation Agenda will constitute a dynamic roadmap with periodic revisions and regular updates based on established procedures and a process chain relying on co-operation and interoperability, as presented in Figure 4. During the design phase the main priorities, specific features and the structure of E-RIHS are taken into consideration so as to conclude to the key actions to enhance and promote innovation outcomes responding to **Heritage Science Research needs,** but, more generally, **aligning relevant research areas** to **Heritage communities' needs**.

The Innovation policy followed by E-RIHS is based on several fundamental enabling principles as shown in Figure 5 (left). It should be highlighted that E-RIHS will endeavor to be the first operational RRI (Responsible Research and Innovation) ERIC. It will work towards aligning providers, users, industry and society in research

outcomes[19] so as to line up its outcomes with the values of society encouraging providers and users to be conscious of RRI principles and key pillars, Figure 5 (right). E-RIHS is expected to become a wide umbrella connecting different aspects of the relationship between R&I and society such as public engagement, open access, gender equality, science education, ethics, and governance.

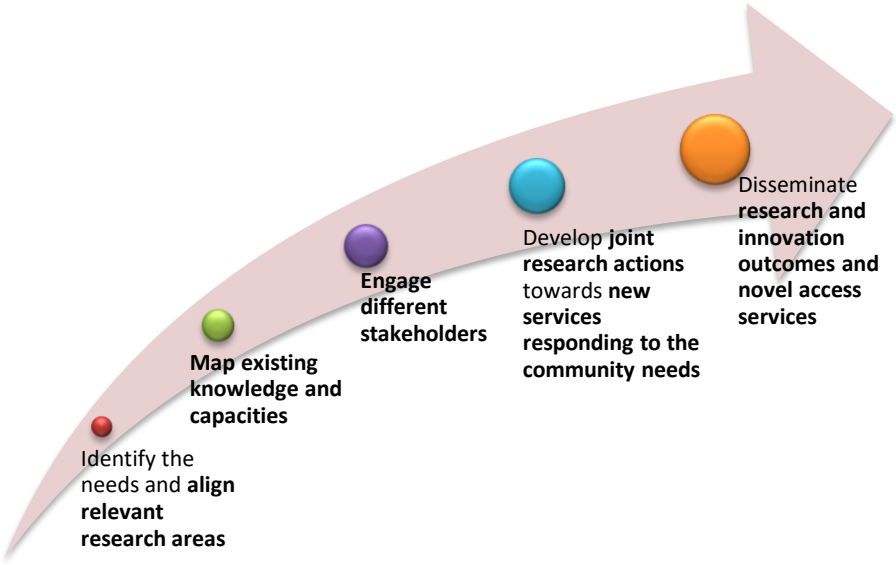

Figure 4 E-RIHS Innovation Agenda relying on the dynamic output of a well-defined process chain comprised of strongly connected links and interoperable units

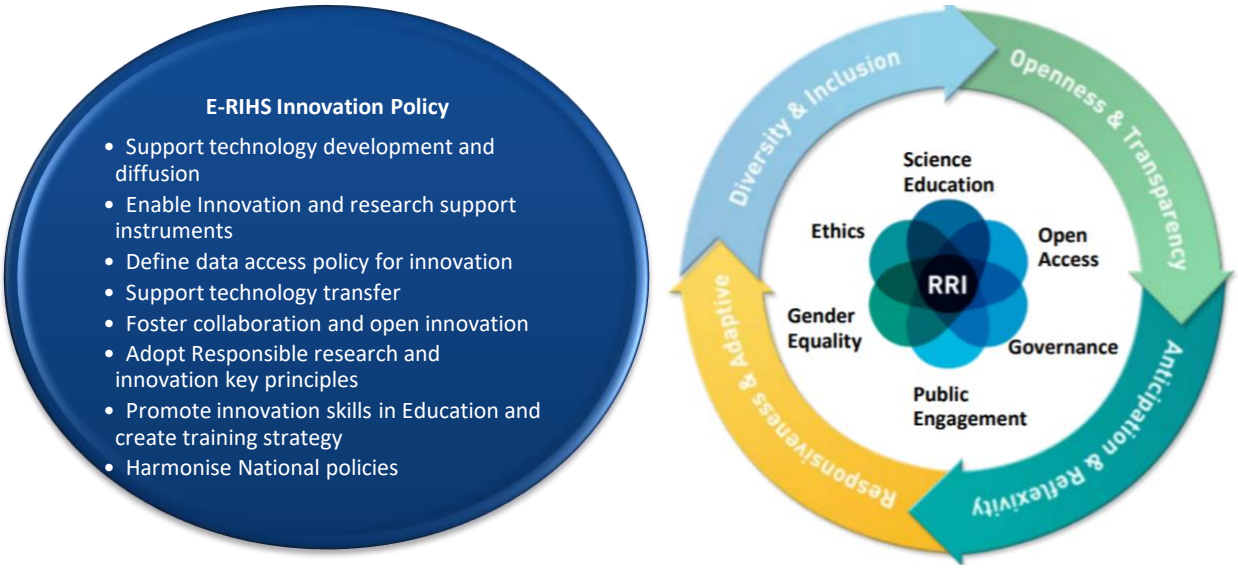

Figure 5 Fundamental principles of E-RIHS innovation policy (left). Schematic of the RRI Process requirements (right).[20]

[19] Kupper, J. F. H., Klaassen, P., Rijnen, M. C. J. A., Vermeulen, S., & Broerse, J. E. W. (2015). *Report on the quality criteria of Good Practice Standards in RRI*. Athena Institute VU, https://www.rri-tools.eu/documents/10184/16301/RRI+Tools.+A+practical+guide+to+Responsible+Research+and+Innovation.+Key+Lessons+from+RRI+Tools ; OSFair2017 Workshop | Why is responsible research & innovation important? https://www.slideshare.net/OSFair/osfair2017-workshop-why-is-responsible-research-innovation-important?from_action=save

[20] https://www.rri-tools.eu/documents/10184/107098/D1.3_QualityCriteriaGoodPracticeStandards.pdf/ca4efe26-6fb2-4990-8dde-fe3b4aed1676

The careful handling of the intellectual property rights (IPR) deriving from E-RIHS is an aspect of major importance for the E-RIHS Innovation Agenda. IPR is generally a complex topic, but depending on the field, there exist several specificities that need to be taken into account. In the HS domain, IPR is particularly complex. This stems from the diversity of content associated with either archaeological research, scientific investigations and conservation, and also due to the overlap between the commercial and non-commercial sectors within the cultural industry. The specificities, historical context and recent evolution in the field of HS have been extensively reported in Deliverable D4.4. In this context, E-RIHS is setting up an appropriate IPR management framework with a special emphasis on issues related to open science and open innovation. Technology transfer consultants and IPR experts will set the basic principles and guidelines that need to be followed so as to ensure optimal protection of IP that will allow efficient and unobstructed exploitation of research outcomes.

3.2 Innovation Agenda essentials

The Strategy is to be implemented through a dynamic Innovation Agenda, see Figure 4, the main action plan that reflects the priorities set in key areas and provides those mechanisms and structures necessary to enable innovation in any specific direction of growth, inscribed in the E-RIHS excellence landscape, [21] as indicatively mapped via the E-RIHS PP 9.2 Innovation Survey[5] addressing new methodologies, new or adapted instrumentation, data management, user facilitation or new services.

Setting up all the mechanisms and internal rules and procedures concerning the innovation strategy is the first step towards enabling and exploiting innovation. The most important aspect when creating an Innovation Agenda though, is the management of the agenda itself. The innovation ecosystem evolves constantly and new challenges and opportunities emerge. Strong leadership is required not only to ensure that all steps and procedures are followed but also to assess and revise the innovation agenda when needed.

3.3 Innovation Challenges

Benefits emerging from the innovation developed in E-RIHS, and more widely the socio-economic impact associated with that, are recognized as a fundamental return deriving from the use of the RI. Therefore, the structure and systematic updating of the innovation agenda will be based on the continuous process of adapting and upgrading the four TNA platforms separately but also as communicating vessels in all.

This dynamic character and management of the innovation agenda will rely on the convolution **of different functions and aims.** The ESFRI Scripta Volume II "Long-Term Sustainability of Research Infrastructures"[22], presents important recommendations for achieving long-term RI sustainability. Many of these are directed towards the EU member state governments and/or or national authorities and funding bodies, therefore, only those concerning the RIs are listed below:

- Establishing and maintaining excellence throughout the entire lifecycle of the ERIC by all appropriate means, by securing adequate framework conditions, by pursuing excellent in-house scientific research and by developing new technology for users;
- Meeting the current needs of E-RHIS users (including analysis and understanding of users' requirements and expectations) and the broader cultural heritage community;
- Anticipating future users' needs and expectations;

[21] E-RIHS PP Deliverable D9.3 "Scientific Strategy"

[22] https://www.esfri.eu/latest-esfri-news/esfri-scripta-volume-ii-long-term-sustainability-research-infrastructures-report , Published by Dipartimento di Fisica - Università degli Studi di Milano, October 2017, ISBN PDF: 978-88-901562-8-1

- Targeting new scientific communities of users;
- Attracting users from the private sector;
- Transferring knowledge, technology and adapting methods from other disciplines to HS applications;
- Keeping pace with relevant scientific developments and cutting-edge technologies, all in consultation with E-RIHS user communities, so as to be in a position to provide state-of-the-art instrumentation and services (outcomes of WP9 in the area of innovation and technology readiness provides a base for the appropriate treatment of this recommendation in the business plan);
- With contributions from the EC and national authorities, E-RIHS will develop or continue to support mechanisms for funding transnational access, recognizing that openness of the RI is a driver to achieve and sustain scientific excellence and achieve innovation.

Specific plans of the Innovation Agenda will include:

- Modernization with novel instruments and prototypes
- Revitalization of facilities with significant reforms (e.g. AGLAE recent reform[23])
- New methodologies and new applications (co-creation with users)
- Innovative combination or cross-analytical use of different methods
- Novel approaches on knowledge exchange and expertise building through training and education
- Promotion of remote access to facilities (FIXLAB)
- Developments of DIGILAB towards a VRE reality based on FAIR implementation, repository multi-domain/multilingual interoperability aligned with EOSC standards and guidelines[24]
- Active dissemination through appropriate communication channels aiming to reach all relevant stakeholders
- Effective management aiming to ensure long-term sustainability
- Establishment of monitoring mechanisms to enable technology transfer and interoperability
- Explore pathways for effective collaboration with Industry
- Strategic plan and initiatives towards Globalisation in HS

Specific topics and thematic areas of the Innovation Agenda focus on the following:

- Detailed knowledge of material composition for any heritage object is an important prerequisite for interpretation or for undertaking conservation procedures. A single technique cannot provide all the necessary information, so usually complementary examination / analysis methods are combined. Such a wealth of heterogeneous data (actors, analysis protocols, instruments, data formats) recorded on the same heritage object brings with it the need for interoperable integration of these datasets, otherwise both exchange and data processing will remain inefficient. The development of appropriate and shared procedures and tools for managing large amounts of related heterogeneous data remains a critical issue thus far for an efficient development of HS research.
- Recognizing the central role of knowledge integration, Innovation related to the DIGILAB infrastructure, content, services to enable discovery/findability, access and re-use of data and training modules will constitute a major but ever-evolving capital of the Innovation agenda. The expected, through DIGILAB, alignment on the use of HS digital data, identified as a major need due to the high "diversity" within E-RIHS, will enable better communication and knowledge transfer with the information and communication technologies (ICT) sector. This will benefit SMEs, public bodies and

[23] https://c2rmf.fr/analyser/un-laboratoire-de-haute-technologie-pour-les-collections-des-musees/aglae

[24] EOSC-hub Technical specifications and interoperability guidelines, https://www.eosc-hub.eu/technical-documentation#overlay-context=

citizens as well. A step forward to the Communication of HS knowledge to interested bodies and citizens is the creation of a Digital Hub for Research and Cooperation in Heritage Science, acting as an access point for information, services, good practices, training and virtual meetings for stakeholders to discuss topics of interest. It will link to related initiatives, such as the NET-Heritage initiative.[25,26]

- Virtual access via DIGILAB will enable a wider access to research and innovation services, across disciplinary and geographical boundaries. Better integration of physical (FIXLAB, MOLAB) and digital access services, specific for different research fields, such archaeological science will strengthen cooperation among archeologists and heritage scientists
- Targeting specific sectors, as paleontology and paleoanthropology and specificity of paleo materials in relation to art and archaeological materials will make it possible to extend the range of application of instruments in E-RIHS TNA platforms through specific instrumental and methodological adaptations.
- Integration of MOLAB Access services to integrated methodologies dedicated to support built heritage conservation projects.
- Using HS as a bridge between STEM (Science, Technology, Engineering and Mathematics) and AHSS (Arts, Humanities and Social Sciences), and enabling access of citizens to outcomes.

3.4 Access and Innovation

The Trans-National Access (TNA) platforms are built as nodes for co-creation. The ***culture of co-creation in TNA Platforms creates enormous potential for innovation;*** as the interaction of the provider (internal researcher) with the user (external researcher) is based on close collaboration, confidence and open exchange. It is a fertile field for the generation of ideas, for co-creation of knowledge or co-development of next-generation methods or tools for the advancement of the latest technology in the field of HS. The network of E-RIHS TNAs supports a wide variety of research, including focused research on specialised case studies and extending to large-scale and longer-term collaborative projects through interdisciplinary, combined access to the four platforms (E-RIHS ARCHLAB, E-RIHS DIGILAB, E-RIHS FIXLAB, E-RIHS MOLAB), as presented in Figure 6. Applicants submit their proposals for access through a common entry point assisted by advanced, specialised help-desk services. Proposals are evaluated by independent international peer review panels based on excellence.

Systematic exploration of the innovation potential within the E-RIHS ecosystem of capabilities and resources and joint research activities (JRA) constitute the driving force for innovation resulting in prototype analytical devices, new methods, or new services, and the exploitation of innovation products feeds the continuous expansion of the catalogue of Transnational Access (TNA) services. It is worthy to note that EU-ARTECH (2006-2009) MOLAB TNA offered 6 services, provided by two institutes, while in the context of IPERION-HS (2020-2023) MOLAB TNA numbers 48 services provided by 14 Institutions. Such expansion would have not been possible without the interaction and openness established among researchers within the consortium, among partners, access providers and users.

[25] NET-HERITAGE (European Network on Research Programme Applied to the Protection of Tangible Cultural Heritage), 7th FP 2007/2013 Granted Project GA No. 219301, http://www.netheritage.eu/

[26] E-RIHS PP Deliverable D.10.2 “Heritage Hub online“

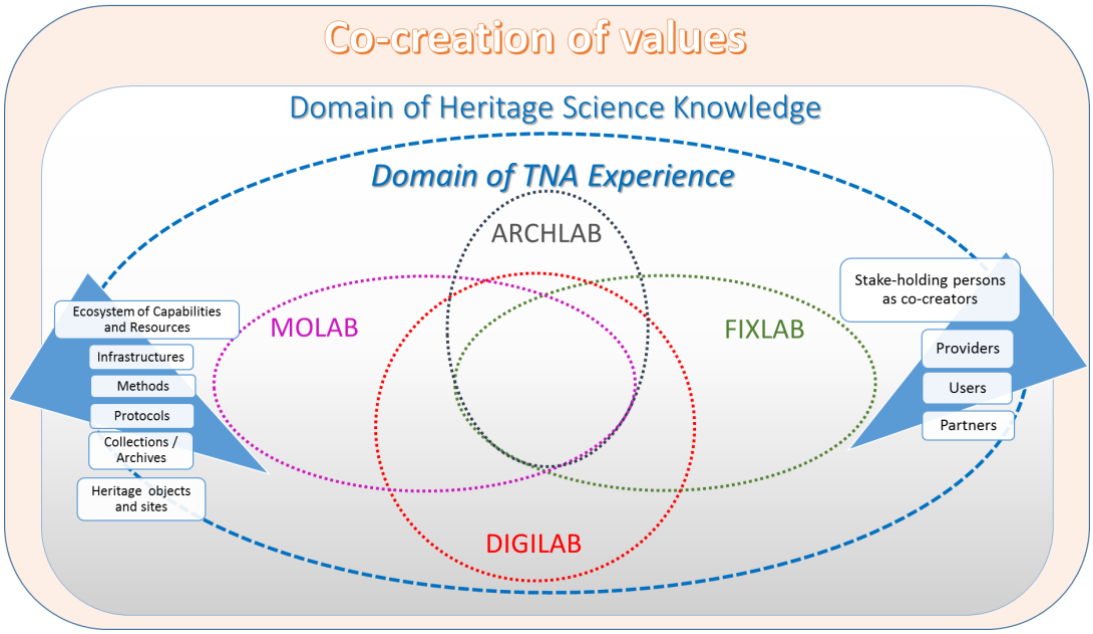

Figure 6 Schematic explaining interactions in the context of TNA activities among actors in different domains of HS Knowledge through the four integrated access platforms in E-RIHS.

E-RIHS has designed the integration of the four TNA platforms, both at management and operational levels based on the close co-operation of the central hub and the access boards. Among the measures taken, are the synchronization of calls opening and deadlines, the homogenization of application forms based on appropriate common templates, the alignment of informative technical datasheets for the catalogue of available services, including typical applications, training material and digital scientific resources available for users/potential applicants.

A central unified entry point of access to partner facilities and their resources, the user interface will consist of an interactive / visual dynamic tool for mapping the provided services, the access providers and research areas and be supported by an active expert help desk to assure the welcoming and a user-profile-based guidance and efficient assistance in the navigation into the provided services and the preparation of the proposal, when necessary, in particular for new users.

The management of E-RIHS Access services gives emphasis on the monitoring and continuous evaluation of the services outreach on the basis of scientific excellence and impact to users' communities. Access project highlights referring to services enabling novel applications are actively advertised communicating the results obtained and further stimulating the interest of experienced and new potential users for submitting new proposals. A key reference document, entitled "*Success stories: Impact of 15 years of European Research Infrastructure Projects on Heritage Science*"[9], constitutes an innovation repository for the E-RIHS TNA domain, including a compilation of a wide set of successful results achieved by European Research Infrastructure Projects on Heritage Science (EU-ARTECH, CHARISMA, IPERION CH), namely TNA activities related to the "iconic" object or providing new results with high impact to the CH community (Figure 7), or new instruments developed or significantly improved to be added in the TNA catalogue of services (Figure 8). It demonstrates the depth of knowledge and the extent of applications of available through the TNA services and preludes the potential future expansion of E-RIHS ERIC services and impact in the Heritage sector at global scale.

Figure 7 The " SUNMIX" MOLAB project, 2016, Examination of "The vase with Sunflowers" by Vincent Van Gogh in the Van Gogh Museum in Amsterdam with FTIR, Raman, and OCT analysis. Lead user: Koen Janssens, Univ. of Antwerp. Press release: https://www.vangoghmuseum.nl/en/about/news-and-press/press-releases/van-gogh-museum-to-keep-sunflowers-in-amsterdam

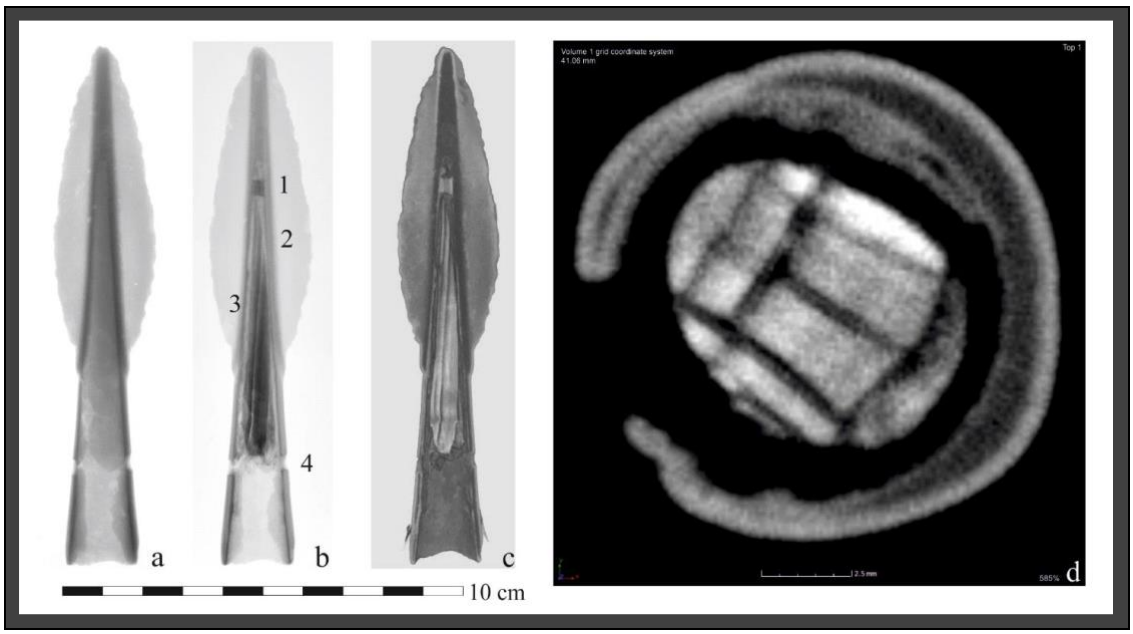

Figure 8 Bimodal (neutron and X-ray) imaging at the RAD neutron facility of BNC (Budapest Neutron Centre). X-ray and neutron imaging of the full Kikinda bronze spearhead from the Hungarian National Museum, Department of Archaeology, Prehistoric Collection: (a) X-ray radiography (b) neutron radiography, (c) neutron tomography and (d) a slice from the neutron tomography.[27]

[27] Figure 3 in: J. Gábor Tarbay, B. Maróti, Z. Kis, 'Introducing the spear project: The tale of the Late Bronze Age spearhead with wooden shaft from the Marshland of Kikinda, Serbia',Journa of Archaeological Science Reports 21 (2018) 268-274. © 2018 Elsevier Ltd. All rights reserved.

A unique example at international level of HS-TNA node fostering innovation based on co-creation is the SOLEIL-IPANEMA case (Figure 9). SOLEIL is a national synchrotron facility operating at global scale, whereas IPANEMA is a research platform focused on the study of ancient samples and artefacts. IPANEMA facilitates the access of HS users to all synchrotron beamlines at SOLEIL and other European large-scale facilities by easing contacts between specialists, co-preparing research proposals, providing technical support, developing research methodologies in imaging and data analysis, organising scientific events and training courses, enabling collaborations with industry etc.

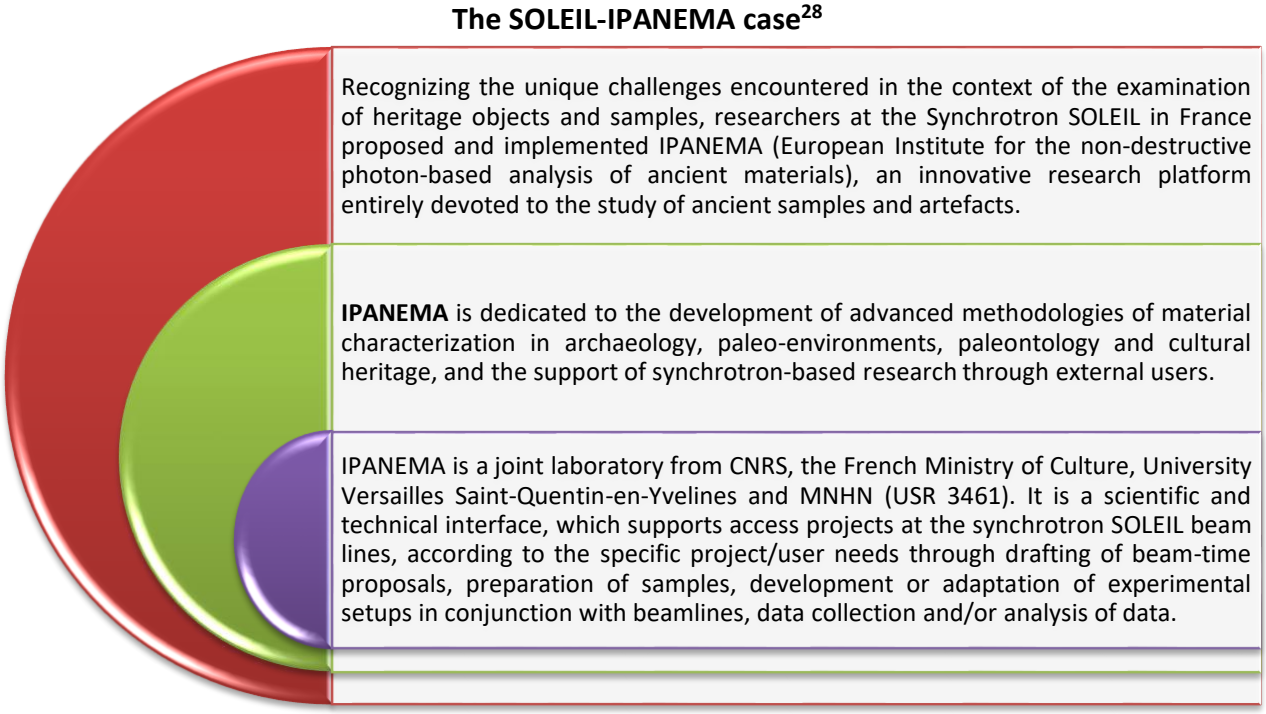

Figure 9 IPANEMA – The Ancient Materials Research Platform at Synchrotron SOLEIL

The **DIGILAB platform** will constitute a new arena of innovation for E-RIHS concerning the development, integration and access provision, not only to data repositories and expert knowledge but also to digital methodologies, technologies (Artificial Intelligence, Semantic Web, Big Data, Natural Language Processing), open tools, algorithms and models for scientific data analysis, processing, data mining and integration, knowledge representation and reasoning, visualization and interpretation, etc.[29]

The E-RIHS community domain experts, providers and users have not sufficiently explored up to now the routes of data analytics and engineering. Proper exploitation of the latter is expected to produce new knowledge and holds immense potential for innovation in HS. Engaging new actors, highly competent in Digital technologies, with the E-RIHS innovation ecosystem will open new domains of co-creation. Knowledge, data and approaches stemming from the co-operation of Physical Scientists, Humanities scholars and Data Scientists will lead to a new age of HS, transforming the practice of research and enabling open science. The development of DIGILAB assisted with enablers such as Standards, Protocols, Application Programming Interfaces (API's), Unique, Persistent and Pervasive Identifiers (UPPI's), Ontologies, will provide a fully operational Innovative Virtual Lab and Access Platform.

[28] http://ipanema.cnrs.fr/

[29] OECD (2020), The Digitalisation of Science, Technology and Innovation: Key Developments and Policies, OECD Publishing, Paris, https://doi.org/10.1787/b9e4a2c0-en.

3.5 Managing Innovation

In order to manage innovation in E-RIHS, structured procedures and mechanisms need to be established in order to:

a) detect emerging opportunities in terms of financing innovation, collaborations and funding schemes encouraging synergies between stakeholders,

b) enable the dissemination of innovation (e.g. novel scientific knowledge, exploitable research outcomes, etc.) coming from E-RIHS. Synergies should be made with appropriate stakeholders at regional, national and European level in order to create standard communication and dissemination channels.

Considering the multi-actor nature of E-RIHS (providers, users, support scientists/engineers) it is important to work towards a well-defined and balanced Intellectual Property Rights (IPR) support system, adjustable to the different types of innovations envisaged in E-RIHS so as to promote creativity and innovation exploiting the broad knowledge basis in the E-RIHS ecosystem. Importantly, all the above relate to the existing national and EU legal and administrative frameworks for granting and protecting IPR.

The management of innovation will be based on the *Pentathlon model,* Figure 10*,* which identifies five key elements for optimum performance as follows:

- A pool of ideas generation in response to problems and challenges.
- A process for selection and prioritization of ideas with incomplete information.
- Strong project management skills to move an idea through implementation to market in an environment of given high uncertainty.
- An innovation strategy to identify where innovation is needed most, in order to guide and influence ideas selection and implementation.
- An enterprise culture – of people and organisations – that can manage the tension between taking risks and the business imperative to minimise failure as products and services near market.

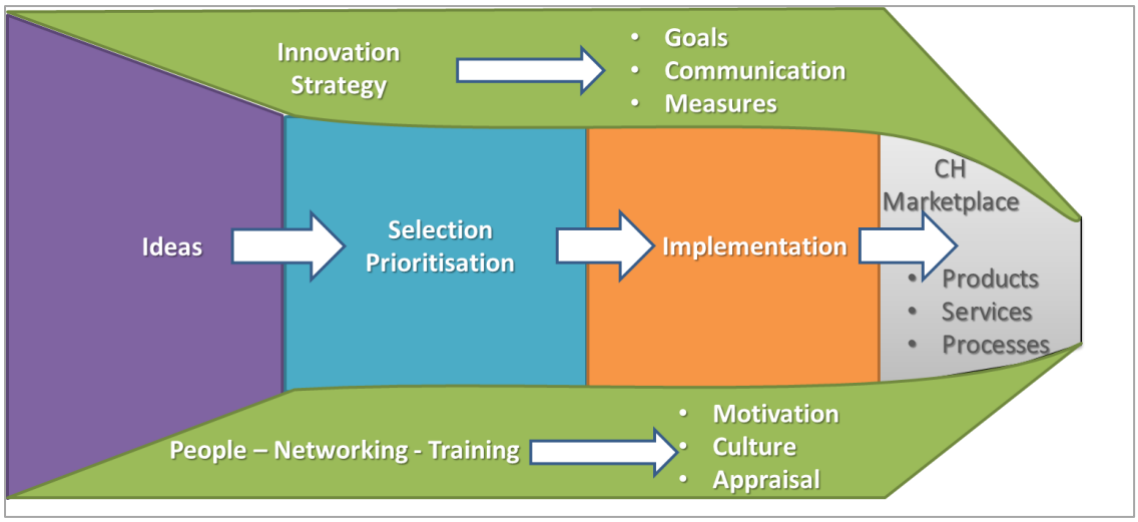

Figure 10 Sketch of innovation chain evolution following the Pentathlon model (Goffin and Mitchell, 2005[30])

The first and second steps are generally related to the work of individual research centers and labs, members of the RI. Project management skills, efficient innovation strategy and entrepreneurial culture will be needed

[30] Goffin, K. and Mitchell, R. (2005). Innovation management: strategy and implementation using the pentathlon framework. Basingstoke: Palgrave Macmillan.

for the innovation to become an integral part of the operations of the research infrastructure and that output of the research capitalize activities and resources.

Critical elements for successfully managing innovation include:

Leadership: The innovation ecosystem evolves constantly so new challenges and opportunities emerge. Strong leadership is required not only to ensure that all steps and procedures are followed but also to assess and revise the innovation agenda when needed. Therefore, the innovation strategy needs to be adaptive and to evolve over time permitting adjustments to the desired goals/targets, but also following refocus on internal and external challenges.[31,32]

Partnerships: Synergies are necessary for ensuring the efficiency of the RI and these will be sought in the TNA Platforms, National Hubs and other stakeholders. A partnership strategy for smart future innovation will be based on the identification of areas of excellence and specialisation across Europe, and create a framework of sustainable collaborations with the aim to promote the presence of cultural heritage priorities in the regional/national agendas for research and innovation. Focus working groups, among national coordinators and main access providers, but also experienced users, stakeholders, and policy makers, will need to work together to develop smart strategic positioning in the future E-RIHS ERIC and ensure optimal sustainability of the RI.

Improvements: Gap analysis will provide data to promote smart investments in infrastructure and knowledge by national hubs or to suggest future new developments to reinforce the excellence of E-RIHS and to support participation of national nodes. Identification of excellence and gaps will maximize chances of success for national hubs in their applications for funding (regional, national or international) for strengthening their offer in the future E-RIHS. There are several areas where the operations and output of E-RIHS can be improved. According to the EU's '*Long-term Sustainability of Research Infrastructures'* report, [22] in order to unlock their potential for innovation, RI's are asked to address continuing weak links in the research value chain, such as:

- open access and data provision;
- mobility of expertise and the right time and in the right place;
- creating publically exploited services for citizen needs;
- working with business and industry for both the economic and public needs;
- involving national and EU bodies in the expansion of RI's at both levels;
- creating systemic support services and resources for innovation within RI's;
- placing themselves at the forefront of scientific excellence;
- identifying innovations deriving from other scientific fields with relevance to HS.

Innovation radar: E-RIHS will set up a mechanism to exploit emerging opportunities. The priority assigned to different directions will depend on the evolving challenges but also on the current momentum and related potential (human resources and funding schemes). The radar will be a mechanism/tool that will detect

[31] InnovationManagement: 5 Key Points to Consider when Developing an Innovation Strategy, W. Koetzier & Ch. Schorling, https://innovationmanagement.se/2013/07/03/5-key-points-to-consider-when-developing-an-innovation-strategy/

[32] Innovation Strategy in R&D projects: a step by step guide, http://health2market.eu/results/step-by-step-guide

emerging opportunities in terms of financing innovation, collaboration opportunities, funding schemes and encouraging synergies between stakeholders. All E-RIHS partners could contribute to this mechanism (likely in the form of an online repository) where they could submit their information on emerging opportunities so that all E-RIHS partners could have access to it.

Dissemination of Innovation: Mechanisms that will enable the dissemination of innovation (e.g. novel scientific knowledge, exploitable research outcomes, etc.) coming from E-RIHS should be established. Synergies should be made with appropriate stakeholders at regional, national and European level in order to create standard communication and well-tuned dissemination channels reaching the different types of "industries" and commercial enterprises associated with or interested to the heritage sector.

Openness: Open innovation requires courage to be open for innovation and to seek (and discover) the new knowledge which might lead to disruptive solutions. Openness to innovation requires also courage for seeking the unexpected. Experimentation may involve failures but as long as these are not fundamental and/or costly ones, the probability of finding timely scale-up solutions is significantly higher when compared with the traditional project approach.[33] The five important elements in the open innovation process need to be significantly addressed by E-RIHS:

- Networking;
- Collaboration: involving partners, competitors, universities, and users;
- Corporate Entrepreneurship: enhancing corporate venturing, start-ups and spin-offs;
- Proactive IPR Management: creating new markets for technology;
- Research and Development (R&D): achieving competitive advantages in the market.

3.6 Monitoring Innovation

According to the Cambridge dictionary, research is defined as a "*detailed study of a subject, especially in order to discover (new) information or reach a (new) understanding*". Through such a process many observations and novel outcomes are obtained, often leading to new products and services. When the appropriate mechanisms are well placed and organized by the hosting institutions, the researchers and the Research and Technology Organisations (RTO's) can obtain relevant support that could subsequently lead to commercialization and capitalization of knowledge and expertise with multiple socio-economic benefits. Commercialization of research outcomes can leverage initial investment and lead to creation of new companies and jobs and thus economic prosperity and social welfare.

The beauty of research is the 'chaos' that often researchers find themselves in. Hundreds of new ideas and observations lead to interesting hypotheses that need to be further investigated and tested. New paths and methods are followed often leading to results completely different and unexpected in comparison to those initially conceived of. Living in chaos is not always easy and often rather important and significant research results are lost or not adequately appreciated along the way, therefore a structured methodology for recording initial ideas, developments, changes and outcomes should be in place at each research lab and furthermore appropriate technology and business advisors should constantly evaluate results and findings so as to guide researchers accordingly.

[33] Curley M., Salmelin B. (2018) Openness to Innovation and Innovation Culture. In: Open Innovation 2.0. Innovation, Technology, and Knowledge Management. Springer, Cham. https://doi.org/10.1007/978-3-319-62878-3_13

A key point in demonstrating the effectiveness of an investment in research and innovation is the ability to properly monitor all the novelties and positive aspects deriving from the research labs and the RTOs so as to finally translate innovative results into products and services. An effective monitoring process will not only allow the recording of the final outcomes but also assist in the process of recognizing promising research outcomes with great potentials so as to properly support them for further exploitation.

Therefore, an essential process in the innovation pipeline is the establishment of appropriate non-intrusive and straightforward mechanisms capable to monitor the generation and growth of innovation from its early stages. This will allow to:

a) obtain a thorough and transparent assessment of the progress made, the goals achieved and the impact produced and

b) understand the extent to which investments and resources were used optimally.

The role of E-RIHS in innovation is to foster generation of ideas and monitor their evolution in the conversion and diffusion stages. Monitoring innovation in the context of E-RIHS is of major importance. Given that E-RIHS is a distributed partnership of innovators, monitoring and evaluating innovation should be carefully designed and implemented. Furthermore, in the case of E-RIHS, very diverse types of innovation are expected to derive ranging from instrumentation, technology development and user servicing to education and training activities.

In order to properly monitor the innovation derived from E-RIHS it is essential to set up an internal mechanism that will liaise with local technology transfer units in the participating organizations which are in charge of assessing the innovation produced, in an effort to exchange good practices and optimize actions at the local level and overall. Furthermore, certain procedures and methodologies should be introduced for monitoring all steps in the pipeline of innovation. An **evaluation mechanism** will be established by the Central Liaison Office (CLO), as explained in the following section, to **monitor progress**, **advice on key areas for development**, **indicate exploitation opportunities** and **suggest adjustments** when things 'go wrong'. In the same context, a **central online registry** should be created that will record specific KPIs and keep track of the research and innovation actions performed within E-RIHS.

A systematic approach in defining metrics and indicators (KPIs) that would provide a reliable assessment of the innovation impact is essential. This is expected to maximize the visibility of E-RIHS and contribute to enhancing the E-RIHS potential for attracting investments and producing further innovations with impact in various fields and researcher communities. E-RIHS is in complete alliance with the recent suggestion of the ESFRI working group as recorded in the "*Monitoring of Research Infrastructures Performance*" report.[34] Therefore, E-RIHS is adopting the KPIs suggested by the ESFRI working group for monitoring purposes as listed in Figure 11. Aligned with the ESFRI KPIs model, and per set objective, certain additional KPIs or adapted to HS domain specificities will be set and measured to monitor E-RIHS TNAs performance vs innovation. E-RIHS KPIs list will be regularly reviewed and updated to stay operational and effective as it is a key pillar of E-RIHS quality system[35]. The main source of related data derives from TNAs users' evaluation reports and dedicated workshops or regular meetings, but will be fueled with data collected by the National Communication Officers network. To give an indicative example, specific KPIs related to more than one objective, as the **Optimisation of data use** and the **Outreach to the public,** will be set to measure the impact

[34] https://www.esfri.eu/sites/default/files/ESFRI_WG_Monitoring_Report.pdf

[35] E-RIHS PP Deliverable D2.2 "Quality Manual and KPIs"

of innovative data or innovative use of data obtained via TNA services to successful conservation projects or novel services for Museum or Heritage Sites visitors, etc.

Objective	KPIs
Enabling scientific excellence	1. Number of user requests for access 2. Number of users served 3. Number of publications 4. Percentage of top (10%) cited publications
Delivery of education and training	5. Number of master and PhD students using the RI 6. Training of people who are not RI staff
Enhancing collaboration in Europe	7. Number of members of the RI from ESFRI countries 8. Share of users and publications per ESFRI member country
Facilitating economic activities	9. Share of users associated with industry and publications with industry 10. Income from commercial activities and the number of entities paying for service
Outreach to the public	11. Engagement achieved by direct contact 12. Outreach through media 13. Outreach via the RI's own web and social media
Optimising data use	14. Number of publicly available data sets used externally
Provision of scientific advice	15. Participation by RIs in policy related activities 16. Citations in policy related publications
Facilitating international co-operation	17. Share of users and publications per non-ESFRI member country 18. International trainees 19. Number of members of the RI from non-ESFRI countries
Optimising management	20. Revenues 21. Extent of resources made available

Figure 11 Numerical KPIs per Set Objective (source https://www.esfri.eu/sites/default/files/ESFRI_WG_ Monitoring_ Report.pdf)

3.7 Technology Transfer/ TTOs

A key role in the implementation of the E-RIHS Innovation Agenda and in the innovation monitoring process is played by the Technology Transfer Offices (TTOs). The TTOs have a multidimensional role in the technology development chain, that of the dealing with various aspects of the process that transforms research findings and new knowledge into useful and valuable products and services for serving the needs of society. Since technology transfer is quite a complicated procedure involving numerous steps and stakeholders, the TTOs have a coordinating role aiming to create the appropriate conditions among all actors involved (e.g. researchers, investors, industry, etc.) in order to ensure fruitful collaborations.[36,37]

The main responsibilities of the TTOs involve numerous activities, such as IP management, business development, creation of networking and partnering opportunities, information and consultation about funding opportunities, facilitating the commercialisation of research outcomes via the creation of new ventures or training researchers on issues related to technology transfer.

The analysis performed in the context of Deliverable D9.2 [5] clearly demonstrated the lack of organized technology transfer procedures among the organizations involved with cultural heritage science. The Innovation Survey conducted (E-RIHS PP WP9.2 Innovation Survey) revealed the slightly light-handed approach of the involved organizations in regards to technology transfer. More than half of the participants in the survey declared that they have no dedicated staff for activities related to innovation exploitation,

[36] https://www.innovationpolicyplatform.org/sites/default/files/rdf_imported_documents/TechnologyTransfer Offices.pdf
[37] http://www.iphandbook.org/handbook/execguide_files/ipHandbook%20Guide-Section%2006.pdf

whereas a high percentage of them, over 70%, revealed that they were not involved with activities related to innovation commercialization. Therefore, it is essential for E-RIHS to create a culture towards the exploitation of its innovation potential. A solid plan related to technology transfer that will be implemented through certain rules and procedures needs to be established and implemented.

An optimal technology transfer model that will serve the needs of E-RIHS should take into consideration that the E-RIHS partners have their own TT procedures and strategies. Therefore, issues such as IPR ownership, commercialization of research outcomes, ownership, distribution of revenues among partners in case of commercialization, effective ways for dealing with cases of conflicts of interest should be considered. Clear rules and procedures should be established and certain policies must be introduced.

It is essential to introduce a framework that will adopt a consortium TTO-type of model for E-RIHS that will foster the appropriate collaboration mechanisms and networking channels among the various TTO hubs across the E-RIHS partners. As a first step for establishing a technology transfer mechanism among the E-RIHS partners is the creation of a communication network with the solid role to deal with TT processes. A mapping activity between the E-RIHS partners should reveal the TT procedures and strategies followed by the involved organizations and highlight best practices. In this procedure the technology and innovation units of the partners' organization will be engaged (for example, individual TTOs) so as to provide relevant input concerning transfer of knowledge pathways, technology exploitation opportunities and point out key areas for development.

For this purpose, the establishment of a Central Liaison Office (CLO) will be introduced with the aim to coordinate and support the TT procedures within E-RIHS. The CLO will have a central communication/ coordination role that will deal with TT procedures within E-RIHS. It will be the reference point among the various TTOs and will set the basic principles of collaboration. The CLO will diffuse, among partners, information related to all aspects of TT, facilitate collaboration and coordinate those procedures related to business development, will hold responsibility for setting up and updating the monitoring mechanisms and will maintain the central online registry. It is noted that the CLO will not take over the TT procedures of the partnering organisations. On the contrary, it is expected to play a supportive and complementary role that will assist the technology transfer units of the E-RIHS organizations to better deal with the HS cases. In order to establish the TTO network among E-RIHS partners, each TT unit from the partnering organisations will be asked to appoint one of their staff members as a local reference point for E-RIHS who will be dealing with the E-RIHS cases. A network of the TT officers working for E-RIHS will be established for better communication, project handling, IPR management and other issues.

3.8 IPR management

In the process of performing original research, new knowledge is produced across a varied landscape that involves many types of innovations. As described in Deliverable D9.2, in the context of E-RIHS, these innovations can be technological, methodological, service-oriented etc. and often constitute IPRs that are linked to researchers and organizations involved. From a broader perspective, IPRs are those (exclusive) rights that connect a discovery/innovation with the discoverer(s)/innovator(s) and these come in different forms, such as patents, copyright or trademarks. The IPRs, provided they are implemented through a fair and well-defined system/framework, constitute significant incentives for creativity and innovation.

Legal aspects connected to IPRs, on the one hand, and open innovation, on the other hand, are issues that need to be examined across E-RIHS in order to ensure knowledge diffusion without compromising specific rights of individuals (or organizations). Considering the multi-actor nature of E-RIHS (providers, users, support

scientists/engineers, etc.) it is important to work towards a well-defined and balanced IP support system, adjustable to the different types of innovations envisaged so as to promote creativity and innovation exploiting the broad knowledge basis in the E-RIHS ecosystem.

Importantly, all of the above relate to the existing national and EU legal and administrative framework for granting and protecting IPRs as well as guidelines and initiatives of international organisations. National laws on IPR, ownership, access rights, licensing, privacy and on personal and sensitive information have been identified. Systems for continuous monitoring of IPR laws and for assisting the clearance of IPR, successive rights, infringements, etc. have been proposed, and functions, procedures and tools for efficient operation of an IPR office and helpdesk have been defined. Recommendations of IPR management practice, guidelines on how to deal with sensitive IPR issues, Creative Commons, Open Access Movement, ethical and other issues related with IPR within E-RIHS are produced in the framework of WP4 and presented in Deliverable D4.4.[38] A strategy for structuring and implementing an IPR Management Plan (IPRMP) in E-RIHS, taking into consideration the particularities and specificities of the HS sector, involves:

- Assessing and reaching a clear understanding of the portfolio of technological and instrumental assets, newly developed by the partnership, copyrighted works, innovative procedures, confidential information material susceptible to IPR protection, and achieve a comprehensive understanding of their value.
- Evaluating and adopting an IPRMP that is coherent with the distributed nature and the business plan of E-RIHS ERIC and enables the pursuit of its international objectives.
- Developing a dynamical strategy for implementation that foresees future IP developments within the RI in line with the ever-changing HS environment and competitive activities. The strategy should be robust enough to stand periodical reviews, motivate internal IP development and identification and define mechanisms for measuring success regarding IPR protection.

The monitoring mechanisms introduced by E-RIHS will ensure the in-time detection of innovations that need to seek IP protection so as to develop an adequate strategy that will allow further exploitation of those innovations. This is a critical aspect, especially when several actors are involved in the development of an innovation and certain decisions should be made at the very beginning concerning IP rights, ownership and exploitation potentials of the developed IP.

3.9 Dissemination and Exploitation

A well-structured and outreaching plan will outline the dissemination process of the innovative research and technological achievements across E-RIHS and for the exploitation of the innovation potential generated.

3.9.1 Dissemination

The dissemination part refers to all the necessary actions that should be followed by the E-RIHS partners in terms of sharing the knowledge and novelties produced within E-RIHS with the relevant stakeholders and the wide-public. The High-Level Expert Group of the EC[39] during the evaluation of E-RIHS highlighted the critical role that E-RIHS could play for communicating at global scale the solidification of Heritage Science's concept and promoting its role in supporting it. Within E-RIHS PP and in close collaboration with its extra European partners, specific plans, actions and specific initiatives have been already taken for enhancing communication and promoting interoperability in HS at global level, namely: (a) A Proposal has been set for E-RIHS as a Global

[38] E-RIHS PP Deliverable D4.4 "IPR management rules"

[39] https://ec.europa.eu/info/sites/info/files/research_and_innovation/strategy_on_research_and_innovation/documents/ec_rtd_transformative-impact-ris-on-euro-research.pdf

Research Infrastructure (GRI)[40]; (b) a dedicated Task Force has been formed to work for the organization of DIGILAB towards globalization in HS; (c) a Birds of a Feather (BoF) Session has been scheduled on "Linguistic and Disciplinary Barriers to Heritage Science Data Interoperability" in the occasion of the 16th RDA Plenary Costa-Rica (virtual) meeting[41]. Therefore, a well communicated and concrete dissemination plan will assist on maximizing the visibility of E-RIHS and demonstrate the impact of its actions and outcomes to the scientific community, relevant stakeholders and policymakers, industry, investors and the wide public.

To this end, a Dissemination Plan (DP) will be established that will lay out both the internal and external communication strategy for E-RIHS using established communication channels to achieve knowledge transfer and dissemination of results to all relevant stakeholders aiming to maximize the impact of the work performed within E-RIHS and to promote the innovation potential. E-RIHS will adopts a SMART approach to communication with respect to the following objectives:

S – Specific,

M – Measurable,

A – Achievable,

R – Relevant,

T – Time-bound.

In brief, the DP will include a set of standard actions including, for example, participation in conferences and scientific meetings, scientific publications and general ones, training seminars and webinars, summer schools, synergies with other initiatives, etc. Additionally, for enhancing the dissemination of innovation outcomes, E-RIHS will utilize available and create new communications channels to convey key messages to the widest audience possible. The dissemination of E-RIHS innovation on a regular basis will increasingly reinforce the E- RIHS brand name and expand and diversify its user basis.

The E-RIHS website will act as the main communication platform between and the wider community. Constantly enriched with scientific news and achievements, advertising collaboration and training opportunities and announcing meetings and special outreach events, the E-RIHS website will be the main contact point of E-RIHS. For faster and wider dissemination of news related to E-RIHS, known social media will be utilized.

The mission of E-RIHS is to “deliver integrated access to expertise, data and technologies through a standardized approach, and to integrate world-leading European facilities into an organisation with a clear identity and a strong cohesive role within the global heritage science community”. In order to accomplish this mission E-RIHS gives high priority to the promotion of excellence and innovation. For efficient dissemination of the innovative research work, the publication of scientific articles will be encouraged whereas specialized and dedicated training events will be organized addressed to the scientific community. E-RIHS will organize dedicated conferences or special sessions in relevant Conferences or Events, as the ESOF (European Open Science Forum), and will encourage its members to participate in well-known and highly visible scientific conferences and events so as to communicate project outcomes at regional, national and international level. The mission and vision of E-RIHS will be communicated to the wide-public through a set of publications that will present best practices, application of the E-RIHS technologies to cultural heritage,

[40] http://www.e-rihs.eu/e-rihs-as-a-global-research-infrastructure/

[41] https://www.rd-alliance.org/linguistic-and-disciplinary-barriers-heritage-science-data-interoperability

presentations of the innovations produced within E-RIHS, "Science Talks" addressed to the general public, whereas press-releases will be produced when necessary.

E-RIHS will also create synergies with other projects, initiatives, research infrastructures and promote direct contacts with stakeholders and policy makers. In addition, E-RIHS will specifically seek to create a multi-disciplinary Advanced User Community.

3.9.2 Exploitation

It is commonly admitted that innovation examples successfully exploited by E-RIHS partners are disproportionately few in comparison to the great innovation potential demonstrated by the multitude of research achievements in HS, as gathered in the recent Innovation Survey carried out in relation to the work done for Deliverable D9.2. Similar conclusions have come out of the recent survey reported in E-RIHS PP Deliverable D7.1[42]. Over 40 % of the providers who participated in the survey have been involved in some kind of innovation in the areas of technology or software development. However, the proportion of providers who currently collaborate with industry, with the purpose to transform their developments into market-ready products is relatively low (20%). The respondents have mentioned different barriers to commercialization such as cost and specialization of the device. This suggests that there exist gaps that prevent exploitation and commercialization of innovation produced in the context of HS facilities. The above findings make clear the need for training E-RIHS providers on methods and routes towards efficient exploitation of their innovation potential.

Realizing these gaps and needs, E-RIHS places special focus on the exploitation of research outcomes. internal surveys and evaluation reports have demonstrated that scientific excellence in E-RIHS arises fluently as a result of researchers' commitment to the academic impact of their research and innovation advances, and in a considerably lower extent to the societal or even lower to the economic impact (commercialization of the developed products)[9]. For this purpose, the E-RIHS monitoring mechanism, described at section 3.6, is expected to identify promising innovation outcomes that carry strong exploitation potential. Training and substantial support of researchers (technology/services providers or users) will be aimed to assist them in transferring their innovation achievements to the Heritage Marketplace.

It should be highlighted that careful IPR management is a significant component *en route* to successful exploitation of any innovation capacity. Since significant innovation outcomes of major importance are expected to derive within E-RIHS, major attention is given to the management of IPR issues as described in Deliverable D4.4 "IPR management rules".[38]

The Central Liaison Office (CLO) in collaboration with the TTOs of the involved partners will provide customized assistance and consultancy services to researchers in cases of exploitable innovation outcomes. The research teams will be encouraged to discuss with TT consultants concerning issues related to IPR management, business development, market analysis and funding opportunities. Through this process the involved parties will have the opportunity to recognize from the early phases the innovation potential of their work and decide on the appropriate exploitation routes and the related steps. This will allow the maximum capitalization of the innovation potential deriving from E-RIHS.

Innovations deriving from E-RIHS could be exploited using four common pathways:

- Licensing agreements;

[42] E-RIHS PP Deliverable D7.1 "Report on education and training needs".

- Establishing new companies;
- Creating joint ventures;
- Outright sale of innovations.

The most suitable way of exploitation will depend upon several factors (e.g. IP rights, market size, resources needed, etc.). Technology transfer experts will specifically advise the involved parties on the optimal exploitation route and various possibilities taking into consideration the unique characteristics and feature of each individual case that needs to be further exploited. The final decisions about the exploitation route will have to be made by the involved parties and their organisations.

3.10 Funding innovation – Sustainability

The ESFRI Long-Term Sustainability Working Group clearly states in the "Long-Term Sustainability of Research Infrastructures" report[43] that RIs should be created only when they meet two critical criteria:

1. Ensure scientific excellence for a scientific domain of major impact and importance
2. Follow a detailed and realistic plan for funding the initial phases of the RIs along with a certain funding plan guaranteeing its long-term sustainability.

Sustainability is a major topic of concern for all research and innovation initiatives, since it is crucial to ensure that the initial –usually public- investment will assist in the creation of a successful RI that will promote scientific excellence with major socio-economic effects and benefits. The long-term sustainability of a RI can only be obtained when the following criteria are met by the RI (as also schematically shown in Figure 12):

- Ensure and promote Scientific Excellence
- Reveal the innovation potential and encourage RI-industry interaction
- Encourage international outreach and collaborations
- Ensure effective governance and funding
- Demonstrate significant socio-economic impact
- Promote state of the art-skills and competencies
- Promote Open Innovation and maximum exploitation of the data generated by the RI.

Along these lines, E-RIHS is committed to build on the above mentioned principles and conditions to become the single-point of reference in the area of HS, serving the needs of the scientific community for the benefit of science, industry and the wider public. A key component in the puzzle describing the operation of a successful RI is the identification of a funding mechanism that will ensure continuous and sufficient funding for allowing unhindered operation of the RI. Sufficient financing is the key element to moving ahead, converting ideas and research results into innovative methods, products and approaches achieving social and economic value. E-RIHS, in particular, is serving the scientific domain of HS, a highly interdisciplinary field, with relatively limited collaborations with industry and not adequately described pathways for generating

[43] Sustainable European Research Infrastructures – A call for action COMMISSION STAFF WORKING DOCUMENT— Long-term sustainability of Research Infrastructures, 2017, PDF DOI:10.2777/76269 KI-01-17-790-EN-N

impact and profit through its research and innovation activities. Therefore, it is vital for E-RIHS to identify economic opportunities and utilize funding mechanisms that could assist towards its sustainability.

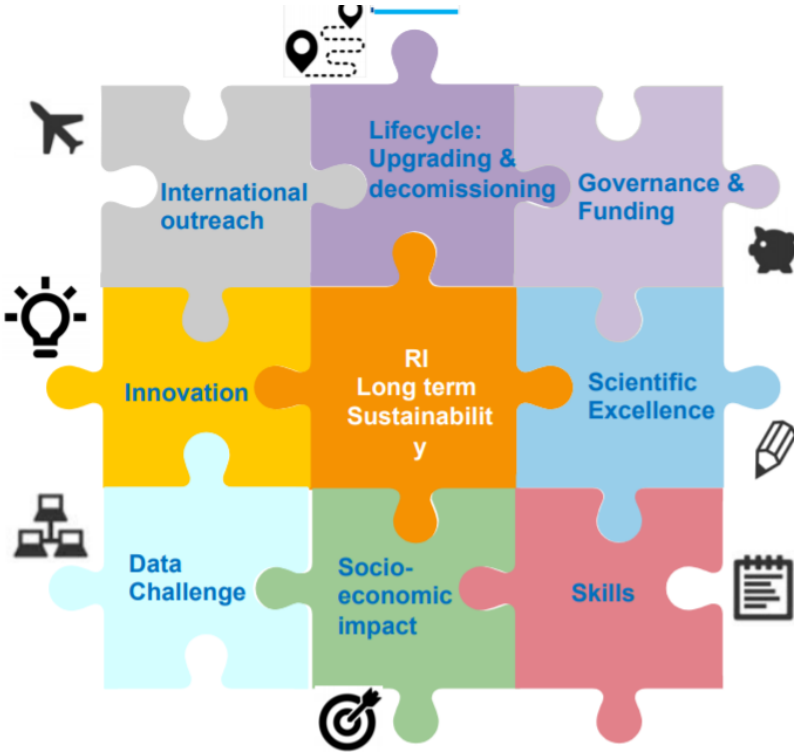

Figure 12 Elements for securing long-term sustainability for RIs. Source: "*Long Term Sustainability of Research Infrastructures - A call for action*" presentation by Ales Fiala, Head of Research Infrastructures Unit.

The "*Sustainable European Research Infrastructures*" report identifies the problems arising for defining a concrete financial policy for RIs since they are subject to several national policies and priorities in addition to the lack of a certain funding framework for the RIs similar to the one existing for international treaty based international research organisations such as ESA and CERN. The report provides a set of policy recommendations at national and pan-European level that could directly provide secure funding to the RIs and allow them to focus on their core activities. The report suggests that political decision should be taken by the Commission to support RIs and provide them some sort of financial security. It also suggests that a minimum investment in research of 3% of GDP could contribute to this scope, whereas a significant amount of the operational costs of the RI could be covered by improving the RI's cost coverage e.g. taking a fixed percentage from any incoming grants or user charges to support the sustainability of the center.

The main funding source, however, for supporting RIs is the appropriate use and combination of available funding sources such as the European Structural and Investment Funds (ESIF), the European Research and Innovation Framework Programmes, the European Fund for Strategic Investments (EFSI), InnovFin etc. RIs are strongly encouraged to identify emerging opportunities and financial instruments that could be successfully combined in order to finance the entire life-cycle of the RI. E-RHIS has identified synergies among various funding mechanisms as a major opportunity for securing sustainability as described in Deliverable D6.3 "Strategy related to the integration of ERIHS in EU-funding instruments and JPI".[44]

44 E-RIHS PP Deliverable D6.3 "Strategy related to the integration of ERIHS in EU-funding instruments and JPI".

E-RIHS is going to take advantage of all the aforementioned opportunities and build on the experience of successful RIs that have managed to effectively combine multiple financing mechanisms. The Extreme Laser Infrastructure (ELI) for example is considered as a best case example for the efficient use of existing tools and funding mechanisms for the establishment and operation of a RI. ELI has received funding from the FP7 & H2020 for the preparatory phase, used ERDF for constructing its state-of the-art infrastructures and receives economic contributions from its members for its operation.

It is important however for the future evolvement and continuous operation of the RI to actively involve industry and promote RI-industry collaborations that could favour further funding opportunities and contribute to the RI's financial sustainability. Furthermore, E-RIHS will adopt a strong partnership strategy for smart future innovation, based on the identification of areas of excellence and specialization across Europe that will allow smart investments from national and regional stakeholders and private investors.

For securing the financial sustainability of E-RIHS, a concrete business plan will indicate explicit routes to be followed permitting a continuous funding flow. The InRoad project[45] has extensively studied and evaluated the operational strategy of existing RIs and has produced a series of recommendation documents regarding several aspects of the RIs like operation, funding instruments, innovation management etc. In Deliverable D5.4 "*Final Recommendations On Best Practices And Common Standards For RI Business Planning*"[46], the InRoad project strongly suggests that all RIs should come up with a concrete business plan, that will determine the interaction between available human and funding resources and define the research and innovation strategy of the RI along with the national and international strategic agendas. The Business Plan is a dynamic document that should be constantly revised taking into consideration the most recent developments and conditions related to funding mechanism and opportunities, scientific developments, national and international policies, RI governance etc. For the purposes of the business plan, E-RIHS has adopted a certain funding model and developed a preliminary financial plan as explicitly described in Deliverable D3.4 "Financial Plan for Implementation",[47] once the ERIC is established. The E-RIHS structure involves a Central Hub that represents ERIC and operates as the access point to the RI, National Nodes operating at national level representing national associations of partner facilities, and local partners. The financial plan proposed for E-RIHS-ERIC, includes two funding levels: one at partner level referring to the funding of the national node/partners and one for the central hub of E-RIHS.

The funding model proposed for E-RIHS partners at national level, presented in Figure 13, includes multiple sources of financing activities such as in kind contributions from partners, national funding, supra-national funding for research activities, service to clients and also research activities with commercial aspect under the E-RIHS label, etc. The funding model proposed for the Central Hub of E-RIHS (Figure 14) is more simplified and consists of cash and in kind contributions from ERIC members. This model suggests that the operation of the Central Hub is fully funded by E-RIHS members and no revenue for the Central Hub is foreseen. E-RIHS will not fund partner operations. It may, however, pay for activities contracted by the Central Hub that go beyond the in-kind contribution. The Central Hub of E-RIHS is not geared for operational activities such as service to clients. Any direct requests by potential clients to the Central Hub will, in general, be forwarded to partners at the discretion of the ERIC management. This financing model serves the strategic mission of E-

[45] https://www.inroad.eu/

[46] https://www.inroad.eu/, InRoad D5.4. Final Recommendations On Best Practices And Common Standards For RI Business Planning

[47] E-RIHS PP Deliverable D3.4 "Financial Plan for Implementation".

RIHS, determining the roadmap for the successful establishment of the ERIC introducing the appropriate framework for a funding mechanism that will allow long-term sustainability.

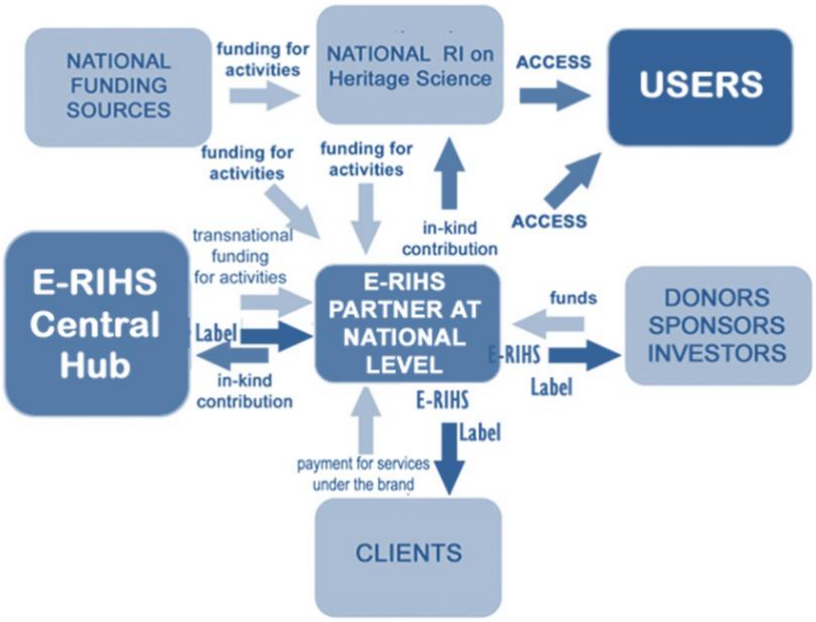

Figure 13 Diagram presenting the funding model proposed for E-RIHS partners at national level.

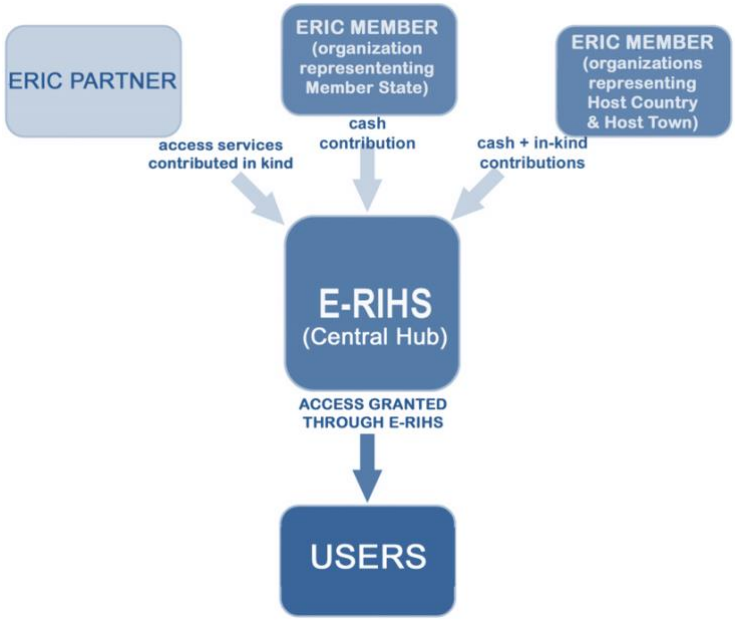

Figure 14 Funding model for the Central Hub of E-RIHS

4 Education and Innovation

According to the OECD's Policy note "*The Innovation Imperative: Contributing to Productivity, Growth and Well-Being*", 2015,[48] "…Innovation rests on people that have the knowledge and skills to generate new ideas

[48] OECD (2015), "The Innovation Imperative: Contributing to Productivity, Growth and Well-Being", Directorate for Science, Technology and Innovation Policy Note, October 2015.

and technologies, bring them to the market, and implement them in the workplace, and that are able to adapt to structural changes across society".

Figure 15 Snapshots from the 1st IPERIon CH Training Camp –"Heritage Science in practice", co-organized by IPERIon CH partners at the Heritage School of Nájera (Spain), 4-18 November 2016.

The Innovation strategy of E-RIHS prioritises a multifaceted educational plan and a multimodal array of training activities in a broad scope based on the development of top level skills but also a multidisciplinary culture. Accordingly, the training offer of the E-RIHS Academy[49] will reflect these values, supporting interdisciplinarity, co-creation, ethics, communication, innovation, complementarity, interoperability and quality in the full spectrum of research activities across E-RIHS. The development of new skills that improve significantly the capacities and qualities of scientists, including early-stage researchers will have a major

[49] E-RIHS PP Deliverable 7.2 E-RIHS Training Strategy

indirect impact to innovation. This capacity building enhances job opportunities either within the RI sector or beyond the latter generating important diffusion of skills, capabilities and innovation to other sectors.

E-RIHS partners have complementary expertise and collective experience in the design and realization of training activities demonstrated also in the framework of successful series of training camps organized in the framework of past projects including CHARISMA and IPERION-HS (Figure 15). Building on this long experience, the E-RIHS central hub will play a co-ordinating role in future E-RIHS-labeled training actions, organized by partners individually or jointly, to promote an innovation mentality in HS and to cultivate innovation concepts and skills. E-RIHS will be providing standard educational materials for different training formats covering related topics such as Open Science, or routes from Innovation to commercialization, in the form of a Training Toolkit addressed to different target audiences including researchers, service providers or users, E-RIHS central hub will also play a key role in disseminating and monitoring the impact of its training actions.

4.1 Building and structuring HS innovation. Training of future Heritage researchers

E-RIHS is operating on the basis of the innovative concept of inter / trans - disciplinary and cross-sectoral integration of heritage-related research activities.[50] Future developments aiming at strengthening and capitalizing on this innovation concept will rely on the E-RIHS Academy.[51] Its strategy and major goal is to: a) enable the creation of a Continuing Professional Development (CPD) system for HS and b) prepare the next generation of heritage scientists/access providers.

The E-RIHS Academy will develop a range of training channels suited to the different training aims and addressing the specific needs of the different trainee backgrounds. User and provider training courses will be designed separately but towards the same goal, the creation of a culture of co-operation, co-interpretation of results and co-creation of new knowledge expanding the innovation potential. HS, as intrinsically interdisciplinary endeavour, combines scientific research with social sciences, humanities and arts. The E-RIHS training strategy will address gaps in interdisciplinary scientific communication skills to build purposeful relationships between different communities of heritage experts so as to facilitate interactions and production of collaborative knowledge at all stages of the research process up to the delivery of heritage science research. E-RIHS training strategy will include training in ethics and management skills for actors engaging with the research infrastructure to empower all providers and users, and ensure that the research process proceeds in an effective and efficient manner.

Design of training for E-RIHS access users will refer to a clear catalogue of expected skills, starting with technical skills but also emphasizing collaborative, communication and engagement, digital skills related to access to the infrastructure and to manage expectations and ensure a high quality of the experience of access.

Design and organization of training for E-RIHS access providers will promote a set of core heritage science skills necessary to deliver E-RIHS excellence. It will equally address the lack of conservation-oriented knowledge to enhance collaboration with heritage practitioners (to understand the curators/ conservators point of view).

[50] 'Radical Innovation: Humanities Research Crossing Knowledge Boundaries and Fostering Deep Change': D/2015/13.324/12, Author: Science Europe Scientific Committee for the Humanities, 4. A New Systemic Thinking of Heritage: A Common Space for Researchers and Cultural Actors

[51] E-RIHS-PP, WP07 - Progress outline (ppt file), E-RIHS PP Florence meeting, Matija Strlic – October 2018

In addition, E-RIHS will promote and exploit opportunities for training both providers and users to foster transferable skills in management, innovation and commercialisation of heritage science knowledge, applications, services or products stemming as an outcome of exchange, interaction, close cooperation or co-creation on an interdisciplinary basis between providers and users.

The relevance of training formats as e-learning modules, webinars or videos available online, but also of workshops and seminars possible to be held in a virtual environment via videoconferencing platforms is pronounced in the new conditions formed after the COVID_19 pandemic. E-RIHS will establish adequate infrastructure for efficiency and security and will promote remote working/learning/collaboration platforms, as alternative, especially in unexpected situations or in cases that traveling is under restrictions.

4.2 Sharing the knowledge produced within E-RIHS

Heritage Science data sharing is essential in fostering interdisciplinary scientific communication and a broader understanding of scientific data for deepening our knowledge on heritage materials / objects / monuments / systems. Sharing HS knowledge will not only prevent duplication of research but will enable new research questions to be addressed and generate the context for innovation. The participation of E-RIHS users and providers to platforms – forum for sharing new knowledge / communicating HS data, sharing good practices, protocols and standards will establish the framework for innovation actions.

Access to HS data and shared knowledge will be enabled through the DIGILAB platform, administrating online access to scientific data concerning tangible heritage, following the FAIR principles (Findable, Accessible, Interoperable and Re-usable). Training covering data science for HS applications needs to be focused on the enhancement of data processing and data management skills to support the development of E-RIHS DIGILAB and reinforce interdisciplinary collaboration for the processing and innovative interpretation of the data.

Finally, effective communication with industry requires that key members of E-RIHS facilities, scientists or engineers, receive appropriate training in business and technology exploitation skills so as to manage to communicate and collaborate effectively towards achieving goals of co-development.

4.3 Open Innovation and Trainings Seminars

In order to generate a collaborative research environment within the infrastructure, the E-RIHS Academy needs to build an understanding of the IPR issues among access providers and users. Open innovation training modules will aim at demonstrating its effectiveness compared to close innovation models and learning how to prepare and develop effective innovation action plans. In order to develop confidence in applying open innovation principles and key innovation tools emphasis will be put in acquiring knowledge on IPRs (patents, copyright, trade-marks, secret know how), legal aspects, Confidentiality issues and Patent management (protection, valuation and exploitation).

5 Collaborations and interoperability

Within E-RIHS, and more broadly within the HS ecosystem, innovation is collective and diversified. It is based on principles of co-creation that permeate the interaction and shape the collaboration between providers and users, building also strong links with industrial partners and the broader heritage industry. Collaborative innovation in HS requires mixing scientific expertise and technical skills, engineering and technologies based on solid, per discipline, background. The paradigm of open innovation, as initiated in the 2000s by HW

Chesbrough[52] finds a fertile field of application in HS, as a *par excellence* inter / multi / cross – disciplinary domain. E-RIHS has adopted the principles of RRI and assimilated the benefits of embracing openness as part of its scientific strategy[53].

The enhanced role of E-RIHS users in innovation development, use and exploitation has been highlighted.[5] The Advanced Community of HS users conveys high level of interdisciplinary knowledge and background data in relation to their specific research subject/project. They formulate detailed, advanced questions to approach and issues to address, in several fields of HS, which expands exponentially the innovation potential. This type of user-provider interaction can be an enabling one, particularly within a proper innovation ecosystem. It has the potential of generating innovation in co-development of next generation instruments, methods or knowledge management tools for advancing the state of the art across the HS domain. On the other hand, the culture of open innovation is a stimulating force among Access providers, the partners of E-RIHS Consortium and constitutes a fundamental pillar of E-RIHS scientific excellence.

To facilitate research and upgrade collaboration among E-RIHS groups, new tools and digital infrastructures, mechanisms and instruments for data-sharing will be explored to enable access to existing knowledge, circulation of new ideas, combination of complementary competences or merging of converging initiatives. The development of interoperability principles, schemes, tools and network will enable integration and will form a self-upgradeable operational collaborative framework for enhancing the innovation potential.

Interoperability in the E-RIHS framework should be understood as connecting all HS actors and communities, data and diverse systems, research frameworks, facilities and services, so that data and provided services are more available to those who need it and processes flow more smoothly. To this end several actions have already been undertaken or are planned as immediate priorities to ensure efficient and effective exchange and use of information. An advanced mapping of E-RIHS research groups, competences, methods, application fields and catalogue of services is essential to foster the exchange of knowledge and expertise, to facilitate technology transfer, and avoid a duplication of investments and a fragmentation of research efforts;

Key actions are also initiated in the framework of the IPERION HS project[54] to improve **interoperability** by investigating and comparing protocols, instrument parameters and practices for documenting data, and by defining the project Data Management Plan towards the development of an interoperable research framework within E-RIHS. The DIGILAB platform will serve as the main gate and a VRE for discovering and providing access to HS research data and procedures.

To this end, investigation and comparison of protocols and instrument parameters and how they are documented and described for the analytical and examination techniques offered within E-RIHS Access Platforms will be carried out. Exchanges relating to protocols will help to identify best practices, and specificities of certain instruments. Better understanding of how each facility or laboratory designs and follows a protocol will allow the determination of common information to needs to be included and formulate appropriate templates for compiling such details in the future catalogue of services for E-RIHS. In particular, actions will be put in place for:

[52] Open Innovation: The New Imperative for Creating and Profiting from Technology. HBS Press. 2003. ISBN 978-1422102831; Open Business Models: How to Thrive in the New Innovation Landscape. HBS Press. 2006. ISBN 978-1422104279; Open Innovation: Researching a New Paradigm. Oxford. 2006. ISBN 978-0199226467.

[53] E-RIHS PP Deliverable 9.3 Scientific Strategy

[54] IPERION HS Technical ANNEX - Grant Agreement number: 871034 - H2020-INFRAIA-2018-2020 / H2020-INFRAIA-2019

- Investigating and comparing practices for documenting the data, including the core set of metadata fields/terms required to describe it. This will be a step towards common standards and practices that will make this documentation more interoperable.
- Investigating best practice for preparing data for a shared repository, including managing/storing and formatting the data output from each technique, license requirements etc., to ensure a shared consensus on description and data interoperability. Review, adoption or extension of existing standards of data formats and data representation models (metadata schemas) for HS will contribute clear steps forward concerning the adoption and use of common standards and practices thus improving interoperability and will upscale the functionalities of a repository shared across E-RIHS.
- Addressing the issue of semantic interoperability, which is highly important and prioritised within E-RIHS. This aspect of interoperability is particularly relevant within the HS multidisciplinary landscape to ensure that the precise meaning of exchanged information is understandable by any other discipline beyond the one for which it was initially developed. It involves the use of mappings, the definition communication protocols and the development of linked vocabularies to ensure consistency in the way that the exchanged information is represented and understood.

Synergies with other RIs in the SSH domain will be fully exploited and emerging opportunities for closer collaboration and/or integration will be periodically assessed. E-RIHS strategic partnership with other Pan-European infrastructures in the SSH domain, which are established ERICs in the 2016 ESFRI Roadmap (CESSDA[55], ESS[56], DARIAH[57], CLARIN[58] and SHARE[59]) and its active role in SSHOC - Social Sciences and Humanities Open Cloud framework[60] is already bearing fruits. The SSHOC synergy is particularly oriented towards Innovation in the Data production, integration, use and Re-use with the ambition to build a SSH Open Marketplace consisting of a discovery portal which pools and harmonises all the SSH tools (services and software), datasets, training materials and activities (workflows and scenarios) useful for SSH research communities, offering a high quality and contextualised answer to researcher questions at every step of the research data life cycle.

While HS innovation impacts the high-tech and manufacturing industries, its core domain of impact is in conservation and sustainable use of heritage, e.g. in tourism. This involves enterprises at the creative end of the global market and cultural institutions in charge of heritage preservation and provision of access –with a huge number of "consumers". The main beneficiary of extended heritage lifetimes or solutions for their enhanced enjoyment, is the general public. Potential returns are in hundreds of billions, considering only the annual revenues of cultural tourism. To this end E-RIHS Communication channels towards end-users and the general public may assume an upgraded role.

[55] CESSDA ERIC - Consortium of European Social Science Data Archives, https://www.cessda.eu

[56] ESS ERIC– The Euroopean Social Survey, https://www.europeansocialsurvey.org/

[57] DARIAH ERIC - A network to enhance and support digitally enabled research and teaching across the Arts and Humanities, https://www.dariah.eu/

[58] CLARIN ERIC – European Research Infrastructure for Language Resources and Technology, https://www.clarin.eu/

[59] SHARE - ERIC – Survey of Health, Ageing and Retirement in Europe, http://www.share-project.org/

[60] Social Sciences & Humanities Open Cloud (SSHOC), https://sshopencloud.eu , is a project funded by the EU framework programme Horizon 2020 and unites 20 partner organisations and their 27 associates in developing the social sciences and humanities area of the European Open Science Cloud (EOSC),

6 Collaboration with Industry

Industry is considered as a key player in the development and the future of RIs, and according to the Innovation Working Group (INNO WG) a "bi-directional" focus is put in all its activities on the improvement of the mutual cooperation between RIs and industry,[61] placing industry among the three actors for enabling regional development, according to the Triple Helix model (Figure 16).[62]

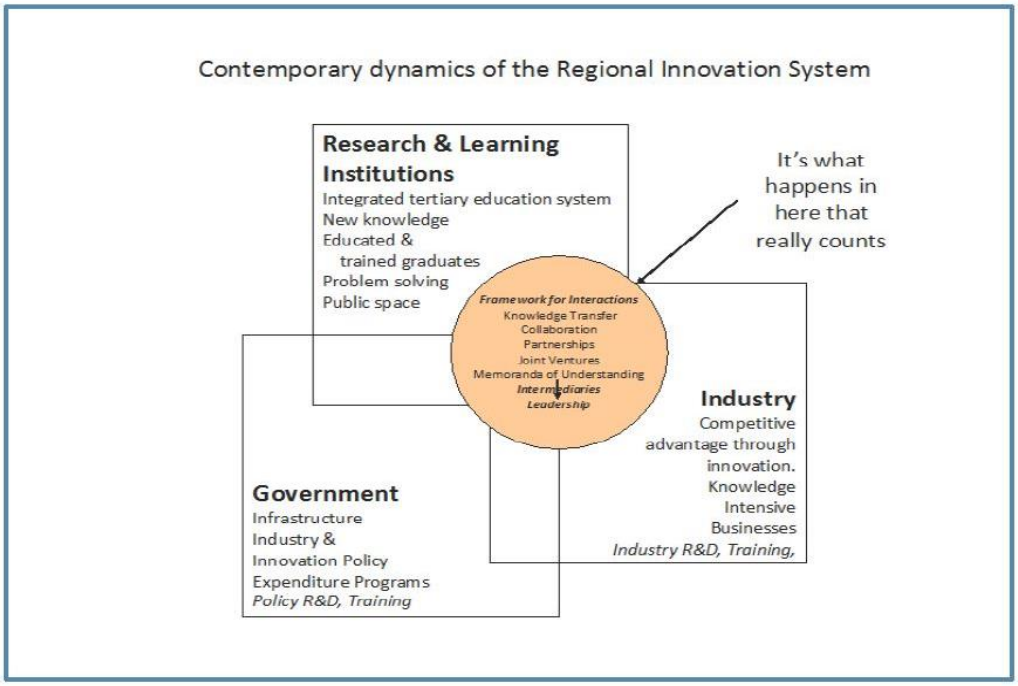

Figure 16 A 'Triple Helix' view of relations between research, industry and government (from the Australia-2030-Stakeholder-Consultation-Report.pdf, Fig. 2)

In the case of HS, such a multi-disciplinary domain with a multi-faceted field of applications, "Industry" may be considered with a wider view as anyone outside of pure academia with revenue/ commercial potential. In general, "application field" might be a more appropriate term than "industry" in the common point of view. Considering industry in a broader sense as revenue-driven commercial companies and/or organisations, museums or galleries, private companies of conservators-restorers, can be considered as specific "industries" in the culture heritage field. Obviously, there is a wide spectrum of what could be classed as industry for HS and therefore, large potential for E-RIHS industry users.

E-RIHS, as an infrastructure in the young but dynamic field of HS, has a large potential of engaging industry. It possesses an excellent pool of novel ideas, which industry can implement, while acting as a reference body for consultation and proof of concepts. The industry users of the E-RIHS infrastructure will be bringing in, due to the complexity and specificity of HS, ever more challenging tasks. To address such tasks, new methods and experimental setups will have to be developed. Here, **industry as a supplier** can assist scientists and/or

[61] The Working Group on Innovation (INNO WG) was set-up in 2013 in order "to propose to the Forum the broad lines of a strategic plan for an industry-oriented cooperation" of the Research Infrastructures (RIs), ESFRI Scripta Volume III, Innovation-oriented cooperation of Research Infrastructures European Strategy Forum on Research Infrastructures Innovation Working Group, ISBN PDF: 978-88-943243-1-0

[62] Report of the Consultations Program undertaken by Howard Partners to assist Innovation and Science Australia develop the Australia 2030: Prosperity through Innovation Strategic Plan, (2018), https://www.howardpartners.com.au/assets/australia-2030---stakeholder-consultation-report.pdf

engineers in the construction or upgrade of facilities (design, engineering), with high opportunities for technology transfer, as sources of (pre-) commercial procurements of new high-tech components, instruments and related services. In parallel, **industry as a user** can have access to facilities for industrial research and innovation, offering opportunities to lower or eliminate technological barriers leading to further innovation and to generate knowledge transfer. Clearly, there are a multitude of ways industry can be involved in innovation produced in the E-RIHS ecosystem including:

- New knowledge production and dissemination
- Training and human resources development
- Knowledge and Technology Transfer
- Contribution to economic activities: Design and co-design of instrumentation and equipment, Joint research projects (with dedicated funding and interface), Contract based R&D, including testing (provision of specialist services), Licensing of IP, Spin-off creation, business incubation and acceleration services.

Considering, for example, the possibility of cooperation of E-RIHS with industry on novel instrumental solutions and methods, it is critical that potential cooperation opportunities for development are identified and elaborated so that appropriate industrial partners are targeted, who are likely to engage with E-RIHS and share the best practices. Additionally, industrial players present in RI Advisory Boards can contribute to better identification of specific innovation potential while exchange programs and staff mobility with industry can help to increase cooperation.

Good cases exist indicating fruitful RI-industry synergies in the field of HS, for instance:

- software tools and data processing methods developed as plugins to existing software solutions for virtual computer generated tomography models that allow thorough investigation of 3D object structures. In cultural heritage, it is often needed to reveal fine details of decoration on corroded or damaged archaeological objects. A specific tool for a sub-sequential erasure of certain areas to visualize the details on curved surfaces would offer great benefit, whereas its implementation is not a highly demanding task.
- the XRF spectrometers, used often for material sorting in industrial environments, after specific modifications and adaptations found their way to the HS field. They are used now for non-destructive analyses of historical pigments and several manufacturers are developing instruments optimized for heritage applications either as portable units or as 2D scanning tools for elemental imaging.

An important consideration concerning the E-RIHS-industry connections, particularly as regards the technology sector, is that industry most often needs to obtain results / solutions in a relatively short time frame and under tight deadlines. To accommodate this sort of pressure E-RIHS facilities, would need to make room and, besides their strategic focus on large and challenging projects, allow for targeted smaller scale projects with industrial partners in order to create trustworthy links. To facilitate the involvement of industry several actions would need to be considered[63] including:

- awareness on the RI services and tools (the available services / tools of the RI must be communicated in a general way to the public, with a special accent on the industry. The suitable approach is informing

[63] https://ec.europa.eu/research/infrastructures/pdf/swd-infrastructures_323-2017.pdf

potential industrial partners about the progress by means of newsletters with overviews of possibilities and examples of usage of the RI (WP8.1))

- training of users that will contain topics important for industrial users
- training of facility personnel (access providers) with focus on communication skills for industrial involvement
- formulating access procedures for industry
- promoting of remote control access and virtual use where possible
- applying simplified access rules for new user groups
- continuous updating of the Catalogue of Services (WP08)
- adopting industry- and innovation-friendly data policies
- having a transparent and efficient IPR policy
- carrying out dissemination and stimulation actions in close connection with sectorial industrial organisations and with EU support

7 Conclusions

This document incorporates and discusses many aspects of innovation considered relevant for HS and therefore included as headlines in the E-RIHS Innovation agenda.

Innovation constitutes the goal and at the same time the medium for achieving the strategic objectives of E-RIHS and therefore the innovation agenda addresses all research actions and services, training and communication as well as collaborations with other RIs and Industry, in the Heritage domain.

A systematic approach in monitoring innovation, defining metrics and indicators (KPI's), will provide a reliable assessment of the innovation impact to Excellence, Synergies and Co-creation, Users and public engagement and the Sustainability of E-RIHS ERIC as the leader in the global HS landscape (Figure 17).

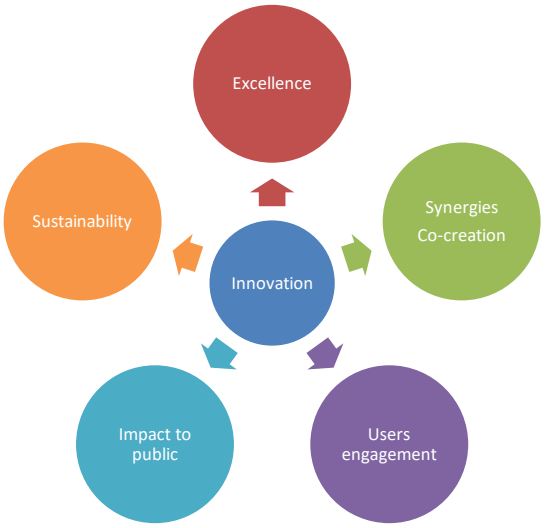

Figure 17 Innovation constitutes the goal and the medium for achieving all E-RIHS strategic objectives

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