FINAL ENVRIPLUS PROJECT REPORT

PROJECT NUMBER
654182

FUNDING SCHEME
Research and Innovation action

PROJECT WEBSITE
www.envriplus.eu

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ABOUT ENVRIPLUS

ENVRI PLUS lasted over 51 months with a very large number of activities, workshops, internal and external consultations, and creation of new tools and services mainly for the benefits of the participating Research Infrastructures. The conclusions below represent the overall strategic conclusions from the action, and how they reflect the development of European Research Area, particularly in respect to development of Environmental Research Infrastructures.

CONCLUSIONS OF THE ACTION

Collaborative development saves effort, resources, and creates better services

The ENVRI PLUS project collaboratively developed a wide variety of technical, e-science and other tools to be used throughout the cluster. Compared to individual developments by each Research Infrastructure, this has been time and resource efficient, used hard-to-find expertise in an optimum way, and created interoperable services. Due to large differences in maturity and resulting expectations, such joint developments are not necessarily easy and mapping which parts of the services are common and which parts need to be developed separately is non-trivial, and require their own efforts.
The experiences from the earlier ENVRI project(s) were very useful to overcome management and coordination challenges. Since we applied the same co-development cycle (Research Infrastructure internal and external experts developing solutions together), the joint technical developments were extremely successful in creating common tools and services, and the practical operational increase in the capacity of the ENVRI Research Infrastructures was demonstrated by the numerous Use Cases for the Data-for-Science activities of ENVRI PLUS, this strategy clearly sets the foundations for fully interoperable data systems, a key aspect of the upcoming European Open Science Cloud.

Coordination of heterogenous environmental RI field has great potential

ENVRI PLUS united a large number of ESFRI projects, landmarks and initiatives, with widely varying missions, disciplinary customs and operational maturity. The broad approach beyond the ESFRI Roadmap was applied on purpose in order to include and engage the whole landscape.
The project clearly demonstrated the added-value of enhanced collaboration and demonstrated the need for further collaboration and coordination, especially on aspects such as interoperability of services, access provision to the facilities, possibilities of co-location, RI-to-RI services and many other features.
The bottom-up development system of the ESFRI Research Infrastructures is excellent for producing key services for selected research communities, but even moderate coordination efforts demonstrated to be very cost-effective.

The project thus concludes that coordination mechanisms towards a further development of the Research Infrastructure landscape would be extremely beneficial. This should be done by combining at least four different viewpoints:
(1) multi-disciplinary scientific questions,
(2) overarching societal Grand Challenges,
(3) common user expectations, and
(4) economic benefits of synergies.

ENVRI PLUS
27 RESEARCH INFRASTRUCTURES
19 WORK PACKAGES
97 DELIVERABLES

“Soft” developments can be extremely beneficial for the impact of the Research Infrastructures

The ENVRI PLUS experience shows that actions not generally considered to be crucial for the Research Infrastructure operations can be actually extremely beneficial both for the Research Infrastructure and the interoperability of the Research Infrastructure cluster. For example, activities towards environmental literacy and ethics are crucial for the socioeconomic impact of the Research Infrastructures. The same counts for the provenance and reliability of the provided services and data. Similarly, community building and communications can be crucial to keep the Research Infrastructure staff efficient and well connected – making the interoperability and efficiency goals far easier to reach. Collaboration with societal actors, such as schools and businesses can lead to far improved long-term impacts of the investments to the Research Infrastructures. The experiences of ENVRI PLUS have proven that a broader thematic approach is stronger than a narrow focus on technical or data-related topics.

Joint strategic actions make the ENVRI Research Infrastructures better suited for societal and science impact

The in-situ segment of the Earth Observing system is very complex and involves multiple players, many of them now organized in the framework of ENVRI. Coming together and creating a strategic approach has made the ENVRI Research Infrastructures far more visible and influential in the international Earth System arena (e.g. via COPERNICUS, WMO, and GEO(SS)), and it has strengthened the impact of ENVRI Research Infrastructures on European developments (e.g. in European Open Science Cloud). Work is at initial steps but joint planning and decision making in the cluster has been a very successful way to align the downstream activities in EuroGEOSS projects. Clustering the Research Infrastructure collaboration have had direct implications for the partnership for the European private sector, offering, for the first time, a single voice and potentially offering a much larger and potential market for innovation and collaboration with industry, societal actors, and education facilities.

Figure 1: Following figure illustrates the different domains of the Earth system and the environmental Research Infrastructures operating in such system. These are 26 Research infrastructures that have collaborated in ENVRIplus. (Note: not all RIs we worked with are depicted in this figure, since the landscape is constantly evolving)

SOCIO - ECONOMIC IMPACTS

The ENVRI Research Infrastructures are major investments from many European Union members states and associated countries. It is expected that such investments will yield a long-term return in the form of socio-economic impacts on their societies. The ENVRI PLUS - as a project of medium magnitude - is a very small additional coordination layer on top of these multi-billion investments, but has been very successful on leveraging the existing facilities towards societal, economic and scientific impacts.

ENVRI PLUS has incubated some approaches responding to the increasing demand for methodologies and tools that can assess the social and economic impact of Research Infrastructures.

While Research Infrastructures. are designed for research needs, their impacts reach beyond science, particularly in the environmental field. ENVRIs have a specific socio-economic impact because, besides scientific interest to understand the Earth system, humans have a large stake in a sound understanding of it to support their own lives. Improved insights into the functions of the Earth system, in a rational world, should lead to an improved management and behaviour.

The related changes in policy lead to, or are in themselves, socio-economic impacts mainly by conserving existing rather than creating new wealth. Thus, the description of socio-economic impact of Research Infrastructures is non-trivial. Some impact will be achieved far in the future, and it will be hard to pinpoint them to a specific project. Hence, the main impact the ENVRI PLUS can demonstrate is the increase in the potential for new services and interactions, which will (in the future) have significant benefits for the society. Moreover, the work towards making the data and data products from environmental Research infrastructures multidisciplinary, increases the quality of environmental information, and encourage the innovative use of existing information. These achievements may look small against the assets that are at stake related to environmental risks, but may be crucial in generating the knowledge to avoid them.

Economic efficiency of the Research Infrastructures themselves has been increased by joint technical and data developments that created far more integrated services for the participating RIs. Staff training and exchange improved operational services and enhanced the efficiency of organisational structures. Integrated access mechanisms will improve the usability of the RI services for the scientific users, particularly for interdisciplinary research.

15M €

ENVRI PLUS received a 15 million euro funding from the European Union's Horizon 2020 research and innovation programme.

Such investment makes the Research Infrastructures more efficient and harmonised, it improves their innovation potential and cost/benefit ratio of the Research Infrastructure operations.

The first steps towards integrated up and downstream collaboration with the private sector was started, and this joint approach is a very efficient way of providing for the Small and Medium Enterprises (SMEs) a reasonable market base for their operations. The common basis for new data services is directly impacting the EOSC service development, and increases the usability of the Research Infrastructure services for the COPERNICUS service provision.

The citizen science activities led to a development of several tools that are now being used by the public. This will not only help to gather a new data, but also increase the awareness of the importance of (environmental) science within the society.

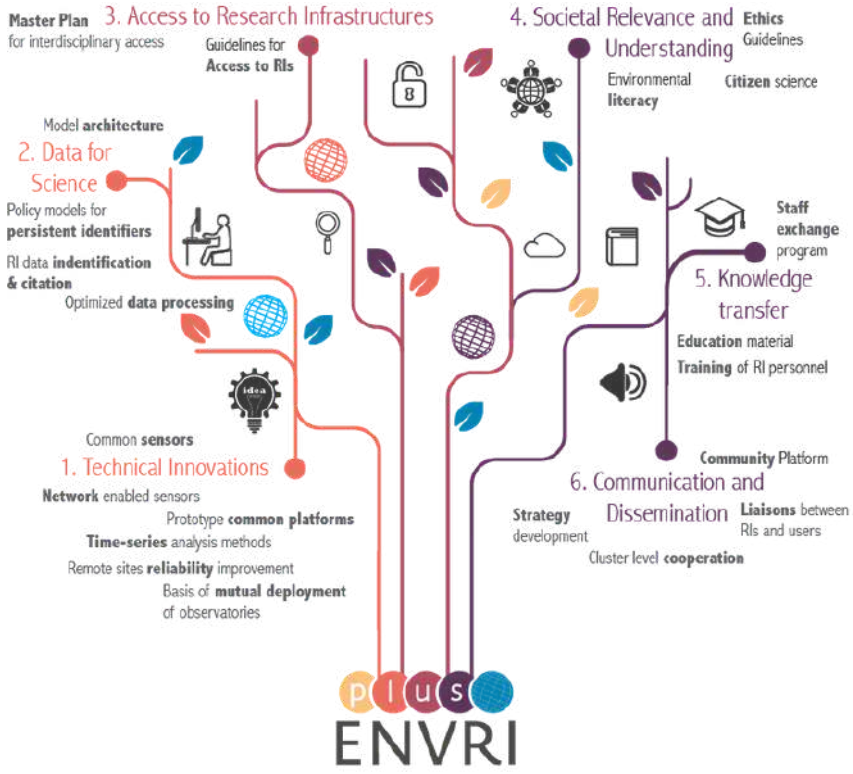
OVERVIEW OF THE RESULTS AND THEIR EXPLOITATION AND DISSEMINATION

The ENVRI PLUS project was a successful endeavour to increase the efficiency, sustainability, operational capabilities and long-term strategic development of major European environmental and Earth system research infrastructures. For these purposes, the ENVRI PLUS concentrated on six key activity groups, with a corresponding set of products and results, referenced below.

Before going to the individual key results, it should be noted that the main target group of the whole initiative were the research infrastructures themselves. The main purpose was to deliver common solutions from joint undertakings that benefit the actors themselves, and at the same time, create synergies and increase efficiency at the landscape level.

Results were never developed for the internal purposes of a single RI only. Experiences were always shared and documented since the ENVRI landscape is in constant change and new Research Infrastructure initiatives (e.g. recently funded IA projects) were included as Associate partners in the project. Similarly, some of the results are of general usefulness on national level, for other fields of science or for international infrastructures operating on other continents.

Main results of the ENVRI PLUS project are presented in the following chapters in six categories, following the overall Themes of the project.



ENVRI PLUS tree - this figure illustrates how the work was organized within the project. 18 work packages of ENVRI PLUS were further clustered within so-called Themes. These were identified as key areas for the Research Infrastructure cooperation.

Joint development of observational capabilities

The work concentrated on improving the Research Infrastructure's abilities to observe the Earth System, particularly in developing and testing new sensor technologies, harmonising observation methodologies and developing methods to overcome common problems associated with working at remote sites with often harsh conditions. Most of the ENVRIs operate in such conditions, and the methodologies are typically developed separately without coordination, especially between facilities which are not closely connected. The diverse and separated developments are challenging with regards to key national and regional metrological organisations or when developing new services across traditional scientific disciplines. This heterogenous distributed approach also makes the connection to the private sector challenging, as the size of the markets for technological solutions was not necessarily made clear.

During the ENVRI PLUS, the partners joined their forces for improving technical developments in many aspects. A common evaluation and experience sharing of drone observation system [1] increased the feasibility of such platforms in ENVRIs. The developed testing facility for on-site energy production [2] at extreme environments, including the recommendation manual for station operators increased the sustainability and reliability of the European Research Infrastructure observational facilities.

Similar developments led to formulating recommendations for sensor embedded processing capabilities [3], leading to new potential for network enabled sensor fields in the RI observation sites, and joint development of best practices on instrument reliability in extreme conditions [4], and a practical demonstrator application for environmental control [5] in these environments.
The ENVRI Research Infrastructures also collaborated on common observational inter-comparison experiments, such as with marine pCO2 observations or for comparing atmospheric observations from aircraft and ground platforms. Similarly, the ENVRI Research Infrastructures explored key methods for analysing heterogenous time series [6] – a common problem of many ENVRI Research Infrastructure products – and investigated how to implement them in potential new virtual services in their data portals.

The ENVRIs also worked together to create a better traceability of environmental observations to the metrological standards [7], identifying the metrological needs of ENVRIs, including a gap analysis; current metrological and QC/QA practices for key parameters and derived best practices for the use of the ENVRIs; and a general assessment of the traceability to standards in the Research Infrastructures of ENVRI PLUS. This work also included several liaison workshops with key National Metrological organisations, and practical implementations (e.g. IAGOS, SIOS and ACTRIS) of these metrological standards in research infrastructures.

This standardisation activities were also directed towards major institutional data users for environmental data, specifically to increase the use of the ENVRI Research Infrastructure data in COPERNICUS programme [8], in the CAMS, CMEMS, and CEMS services, and to provide ground validation for the satellite products. One key element in data provision for these and other critical users is their need for Near Real Time (NRT) environmental data [9].

For that reason, ENVRI PLUS had a series of actions towards standardising and streamlining the data quality control closer to the hardware. However, employing current standards was difficult to implement as typically the manufacturers are using their own proprietary sensor hardware and software. Consequently, no standards supporting ready-to-use solution for data transmission existed until now. ENVRI PLUS developed a robust hardware prototype, which is capable to support standardised data collection and transmission [10]. This Open Source (both software and hardware) sensor data harmonisation and communication unit was built transforming manufacturer specific, proprietary sensor output signals into standardised formats. Similar NRT solutions were developed for atmospheric LIDAR observations [11], together with a range of shared online QA/QC software tools [12].

The ENVRI PLUS also supported industry participation in the upstream and co-development models of innovation, by inviting the major instrument manufacturers for the 1st EU Environmental Research Infrastructures – Industry Joint Innovation Partnering Forum [13] held in Grenoble during the 4th ENVRI week. This work was augmented with the analysis of emerging environmental observations technologies [14] (sensors and platforms) that could be of reciprocal interest for Research Infrastructures and industry, and that represent a natural way to foster a linkage that helps to develop all their market potential.

The joint technical developments culminated in 2019 by an organisation of the test cruise in the Black sea [15]. Four Research Infrastructures joined their sources and studied methane transfer from the seafloor up to the atmosphere [16]. This highly successful expedition highlighted the sensitivity of methane emissions to perturbations, created a very successful visibility for the ENVRI community and acted as a test bed for combining the measurement systems in a holistic joint study. Similar, but smaller scale, direct demonstration of technological advances was demonstrated by collaboration between marine and solid earth Research Infrastructures in benthic stations for standardised workflows for seafloor time-series data [17]. The combined use of several ENVRI Research Infrastructures data, together with the technological developments within the ENVRI PLUS project, proved the feasibility of joint work on the Research Infrastructure observational capabilities. It is important to realise that even though all of the results produced in the technological collaboration were naturally disseminated using standard dissemination channels (articles, publications, conferences, social media, deliverables, etc), the key point of the exploitation of these results comes from the direct application of such advances in the normal operations of the participating Research Infrastructures, and sharing these experiences inside the ENVRI community as well as to upcoming new research facilities and networks. Many of the advances are already used in the Research Infrastructure operations, while others are actively being implemented throughout the networks.

Importantly, many of the developed technological advances have also been done in collaboration with a private sector, or, their potential for innovation activities is being evaluated.

A photo collage from the ENVRI PLUS methane cruise organized in Black sea. Scientists from four different Research Infrastructures combined forces for a joint expedition. They studied methane transfer from the sediment up to the atmosphere. The process is crucial to understand in order to improve current predictions of climate change.

Joint development of data management, processing and publication

Most of the ENVRI community Research Infrastructures produce data and other virtual products for the research communities. The amount and complexity of the data products is constantly increasing and cross-disciplinary use of such products is crucial for our ability to answer complex socio-ecological questions. Additionally, almost all environmental (and other) Research Infrastructures will need to develop their data management and service provision, particularly for the upcoming requirements of the European Open Science Cloud. Common developments in this direction have been considered crucial for the success of the ENVRI community. The work has been guided by the ENVRI Reference Model (RM) approach. The ENVRI RM was developed during the precursor project and has been constantly updated during ENVRI PLUS. It has become a valuable archive and a toolbox for Research Infrastructures in the early stage of their implementation. Th ENVRI RM will also be an important tool to guide for the further integration of the data life cycles of the ENVRIs and their connection to the EOSC.

The work began with an extensive evaluation of the current data systems and management practices [18] in the ENVRI community, appraised using the extended and updated common ENVRI Reference Model (RM) [19]. The ENVRI RM is capable of modelling the Research Infrastructure data generation and curation processes from multiple organisational, computational and process viewpoints. Such evaluation helped to prioritise the work needed and guided the development of common tools where possible.

The understanding of the existing and planned data architectures was strengthened using developed ontology of Open Information Linking for Environmental research infrastructures (OIL-E), which specifies the terminologies and relationships to describe the Research Infrastructure processes. The ENVRI PLUS used the existing knowledge of the system architectures to assess the possibilities of common data architectures, as well as creating several practical demonstrators. The work concentrated on getting away from "silo" approaching data management, and evaluating the practicality of using external service provision.

The data processing and analytics mechanisms of the ENVRI Research Infrastructures were improved by creation of several platforms and shared tools (particularly in D4Science platform). The mechanisms were strongly demonstrated in a series of use cases for Virtual Research Environments (VREs) of participating research infrastructures. The processing developments also created several optimisations for used e-infrastructures, such as Dynamic Real-time Infrastructure Planner (DRIP), virtual overlay for Information-Centric Networking, and Data Subscription Service for EURO-ARGO data.

The ENVRI PLUS evaluated the required architecture for interoperable data curation [20] between the Research Infrastructure products, together with relevant best practices for data curation in ENVRI Research Infrastructures [21].

Similar activities on metadata harmonisation and data catalogues improved the interoperability of the ENVRI Research Infrastructures, particularly inside the subdomains (marine, atmosphere, terrestrial ecosystem & biodiversity, solid earth). A key result of this activity was a production of the ENVRI Flagship Data Product Catalogue [22]. Other tasks included joint activities on improving and standardising the documentation of data provenance [23] in the ENVRI Research Infrastructures, often a key factor in a usability of critical environmental data.

Even with a functional and interoperable data systems, the Research Infrastructures would not be able to support their activities without a reliable way to follow the data usage, and thus demonstrate their value to the research community and to the society. Additionally, many of the Research Infrastructure operators are dependent on showing their own contribution for their personal evaluation. Data citation practices are one of the key issues in this development, and ENVRI PLUS took strong actions to create the technological and cultural advances for their efficient use in relation to the ENVRI RI data. The ENVRI PLUS created good practice guidelines for for proper data

citation and data publishing [24], based on practical demonstrators and use cases shortcomings of current systems, e.g. on data loss between the content providers and aggregators. The guidelines were actively tested in ENVRI infrastructure data systems. Additionally, workshops were held together with main publishers on creating a dialogue for generating a global data citation practice, naturally, in this project, from the ENVRI Research Infrastructure point of view. These advances were demonstrated in three use cases [25] on publication of marine biodiversity data from peer-reviewed journal to EU data infrastructure, on the development of a citation and usage tracking system for greenhouse gas monitoring data and on facilitating quantitatively correct data usage accounting.

All of the data services developments were either by a real world demonstrators, or, in many cases, involved in the operational systems of the participating Research Infrastructures [26].

The ENVRI PLUS work involved service prototyping and operationalisation via nine science demonstrators [27], covering many of the technologies developed in actual science cases, and documented promoted through Wiki and online videos. Perhaps more importantly, they are also shared in the ENVRI and other Research Infrastructure communities, and the ENVRI community has taken a strong part in the development of European Open Science Cloud and further disseminated and developed globally via Research Data Alliance.

A book summarising the findings and solutions for the topics outlined above will soon be published by Springer.

Development of access mechanisms for Research Infrastructures

Access mechanisms for the researchers from their own domain to distributed networks of sites are the default model for ENVRIs. Thus, they access is often suited for the purpose of a specific research infrastructure. However, many of our environmental challenges cannot be only approached from the viewpoint of a single discipline or domain. Indeed, multi- and cross disciplinary research is crucial to solve these challenges.
Additionally, the distributed nature of most of the ENVRI Research Infrastructures provide a very good opportunity to use existing facilities of another field of environmental research to support e.g. campaign-wise observations done by visiting researchers. However, creating this kind of multidisciplinary access to the facilities is not usually supported by existing access mechanisms, such as Transnational Access (TNA). ENVRI PLUS has piloted a novel model for multidisciplinary access and from the practical experiences made there, a set of recommendations has been concluded.

ENVRI PLUS created recommendations to be used as a reference for the Environmental Research Infrastructures when defining data and access policies [28].
This set of recommendations is based on the existing policies in ESFRI and other Research Infrastructures, research institutions and international projects as well as on the current European policies and regulations in place. The document sets the base for a charter for access that specifically targets environmental research infrastructures. It defines the types of access provided, the selection modes, the procedures to select users, the support provided to users, post-access provisions, data and access policies, as well as the considerations related to access costs. Confidentiality and IPR rules, legal and ethical issues, and principles for the monitoring of Research Infrastructures performance are also considered. The recommendations were then further developed in the Master plan to facilitate and encourage access to Research Infrastructures [29], and investigated the sustainability of

different access mechanisms [30] and funding mechanisms [32] needed to support them. This information is key for further development of existing and future European Research Infrastructures.

ENVRI PLUS created a pilot programme for multidisciplinary access [33] by supporting a set of high-quality projects. The selected projects presented a clear added value to ENVRI PLUS Research Infrastructures´ impact, beyond the limits that a single environmental Research Infrastructure could achieve. This programme consisted of a selected set of distributed observation stations, with access provided on specifically multidisciplinary projects, selected in a series of competitive calls. The excellence of these proposals was evaluated by an independent multidisciplinary board, drawn from the participating Research Infrastructures. This multidisciplinary TNA pilot [34] proved to be extremely successful in creating new and innovative ways to use the facilities, and supported much research which could be otherwise been hard or impossible to conduct. The feedback both from the researchers and from the sites was extremely positive. In the analysis of the TNA activities, the project ended up in a set of recommendations on best practices for implementing physical access in interdisciplinary research [35], with main categories of identifying the full capacity of joint observation sites; creating a central access management with coordinated access process; enhancing the use and availability of multidisciplinary research data; creating a funding instrument of physical access to multidisciplinary research; coordinated communication and outreach and coordinated access framework being attractive to users. The access mechanisms and related studies were widely distributed in the ENVRI and ESFRI communities,

Societal interaction of research infrastructures

Environmental research has a specific interaction with societies since the knowledge transfer is immediate and of strong impact on societies that are facing environmental challenges such as climate change, loss of biodiversity or risks by natural disasters. The research infrastructures work together with societal actors in many ways. The priorities of environmental research should thus be developed considering the needs of the society. ENVRI PLUS has developed a mechanism that enables ENVRIs to systematically explore their relation to Grand Challenges and to seek specifically cooperation among each other across scientific domains or disciplines. The societal responsibility is mirrored by ethical challenges that have been thoroughly analysed and assimilated into ethical guidelines. With this work, the ENVRI Reference Model has been extended beyond the data theme and has become a more general toolbox for ENVRIs.

The Research Infrastructures are developed from bottom up, but the needs of the society and practical network coverage cannot often be achieved without a further analysis. The ENVRI PLUS evaluated the response of the environmental Research Infrastructures to three major Grand Challenge classifications and created a landscape of the ENVRI Research Infrastructures relating to challenges they respond to.
These grand challenges were then also included in the ENVRI Reference Model development. The bottom up nature of the Research Infrastructure development has also led to a fact such Research Infrastructures facilities are distributed all around the Europe.
Similar sites can be located near to each other, but operated by different facility providers. It is sometimes hard to understand, even for the Research Infrastructures themselves, how complex the organisational topology behind each distributed site is, what are the Research Infrastructures it supports and what are the organisations responsible for different operations. For this reason, the ENVRI PLUS also created a prototype distributed site catalogue [35],

As research infrastructures are designed to provide societally important information, this naturally requires an understanding of ethical issues linked to providing these services. The society can use the services, and how they are presented can have a significant effect on their uptake, and how the results are perceived. ENVRI PLUS worked on several aspects of bringing the ethical questions to all ENVRI Research Infrastructures: The project surveyed the awareness of ethical aspects among the Research Infrastructure staff, created Ethical Label Template [36] for Research Infrastructure products, and the Ethical Guidelines for ENVRI Research Infrastructures [37]. These were then extensively disseminated in the cluster and beyond. On a related issue, the research infrastructures are often concerned on answering to security of communities. However, how, when and how, can be challenging, particularly when the societal need is new to the facility in question. ENVRI PLUS developed for these purposes, mainly based on experience of EPOS infrastructure, a white paper on general guidelines, recommendations, and best practices for communication and decision making under uncertainty for environmental hazards and natural disasters [38].

A necessary component of environmental research infrastructures is and will increasingly become participatory or "citizen" science. This is for two key reasons: 1) it helps to raise the societal awareness and engagement about environmental change and public's understanding of science, and 2) it provides data that would otherwise be logistically inaccessible for monitoring change on our planet.

The Citizen Science (CS) work in ENVRI PLUS included several practical applications and real work CS tools. These included designing a gamified online image annotation tool involving citizens in processing marine biology images [39] (deepseaspy.com), citizen science web app (Crab Watch) helping people both learn about, and submit records of, the crab species they find on the shores around Europe [40], developing the EMSC Quake Catcher network for earthquake detection and analysis, including a new hardware tool development for detection, and experience collecting from workshops dedicated to the citizen science, culminating on the set of online training material for Citizen Science inclusion in Research Infrastructure's activities [41].

Enhancing skills and knowledge

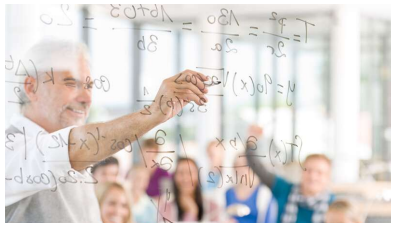
Running an environmental Research Infrastructure requires many skills from the operators, managers and directors. Similarly, usage of Research Infrastructure products and services can often require training material for the users. One aspect of ENVRI PLUS was to develop different methods for sharing the experiences on running a Research Infrastructure within the cluster and beyond, and to create effective training materials for the results of the project itself.

The ENVRI PLUS created a wide array of training materials that are available on the ENVRI e-learning platform [42]. The platform was as well developed within the project and is accessible to everyone through the ENVRI community platform. This included a set of products from the science use cases from the data work packages, as well as training material on e.g. use of the Reference Model [43] in mapping the RI functions.

A selection of videos, webinars, summer schools and workshops sharing the gained tools were also developed. An own video channel to store and share the webinars was also launched within the project. These tools were actively marketed and disseminated inside and outside the project consortium. The e-learning platform will be available after the end of the project.

A second major concentration of training was aimed towards secondary schools [44], and included multimedia education [45] (25 courses in total). The training addressed the major thematic research areas and challenges in Biodiversity and Ecosystem Services, Greenhouse effect and Earth Warming, Ocean acidification, and Environmental sustainability. These materials were augmented with a development of the ENVRI PLUS Serious Game (http://scientificgame.envri.eu) focusing on four different topics (i.e. Biodiversity and Ecosystems, Hydrogeological Risks, Computing Environment and Marine Science). These games were used in practice in several secondary schools around the Europe.

The training activities also targeted the management of the research infrastructures, and through a collaboration with the EMMRI program (developed in H2020 project RI-TRAIN), organised targeted training workshops for the ENVRI RI management and leadership (http://www.emmri.unimib.it) . These workshops concentrated on the governance, sustainability and strategic leadership of a Research Infrastructure. Additionally, three time series analysis conferences [46] were organised, together with the technical development work packages, bringing the user needs and tools for time series analysis more recognised within the ENVRI Research Infrastructures.



There is a lot of silent knowledge in existing research infrastructures, and sharing the experiences between the research infrastructure is an important way to improve the operational capability of the facilities. The project organised experience sharing symposia that concentrated on e.g. Quality Control procedures, data flagging, station operations in extreme environments, or implementation of communication strategies. Additionally, the project funded a Research Infrastructure exchange of personnel programme [47], which allowed the personnel to visit other Research Infrastructures for extended periods to learn in practice from their experiences. Such visits covered for example, VRE creation, economics of Research Infrastructures, dissemination practices, or access governance and sustainability.

Strategic development and community building

ENVRI community is not only a collection of research facilities, but a community of people and organisations. It has a strong mission towards continued collaboration to ensure the availability of interoperable services for the user communities, and for the society. The cluster thus needs strategic planning, coordination and development to stay relevant in the changing research landscape.

The main tool of the ENVRI community for the strategic collaboration is the Board of Environmental Research Infrastructures [48] (BEERi). ENVRI PLUS project supported its establishment, organisation of their meetings and strategic development. The board consists of the directors (or project coordinators) and deputies from all ENVRI cluster Research Infrastructures and networks (27), including those that are not yet included on the ESFRI Roadmap. The board facilitated further steps on the integration of the ENVRI Research Infrastructure landscape, formed consensus papers and consultations on key initiatives, such as European Open Science Cloud, COPERNICUS programme, Belmont Forum, GEO(SS), and ESFRI (particularly on landscape analysis and KPI development). The Board also directly responded to the requests of consultation from European Commission offices and national and regional funding agencies [49].

Importantly, the BEERi has also updated the ENVRI vision and initialised the creation of a new ENVRI strategic plan for future, ensuring the sustainability of the project results. One of the key documents focusing on strategic long-term development is the white paper on further integration of Research Infrastructures [50] in the environmental field including recommendations on collocating of research sites on national and international level. The white paper evaluates the current Research Infrastructure landscape and gives recommendations and a strategic plan for further integration of Research Infrastructures in Europe.

The cluster also supported the collaboration within a smaller groups of the environmental Research Infrastructures. The ENVRI Research Infrastructures are traditionally (also by ESFRI) divided to four major domains (Atmosphere, Marine, Solid Earth, and Biodiversity / Terrestrial Ecosystems), which simplifies the collaboration on science level interoperability issues rather than on the whole cluster, as well as to answer the domain specific challenges. The ENVRI PLUS facilitated strategic and practical collaboration events [51] for these sub-clusters. The project also initiated a strategic collaboration with a private sector. Work on the long-term opportunities towards the European Institute of Innovation and Technology is particularly important.

The ENVRI PLUS project invested in strategic and comprehensive approach towards dissemination and communication. The main target groups of this work were the infrastructures themselves (for efficient exploitation of results), upcoming Research Infrastructures, other projects, researchers, SMEs and key outside stakeholders, such as research funders, policy makers, COPERNICUS and GEO(ss). The dissemination strategy concentrated on use of targeted methods to reach the various audiences, mainly concentrating on use of digital tools (website platforms, social media) and physical representation at major conferences, augmented by printed material. The development and maintenance of ENVRI community platform (www.envri.eu) is particularly important. The platform is a sustainable exploitation platform for the products developed by ENVRI PLUS as well as by other ENVRI related projects. The project communicated its activities and promoted its results through an active and very well subscribed community twitter account (@ENVRIcomm), participated in many science and science policy conferences with a joint ENVRI conference booths where it promoted the project outcomes as well as the Research Infrastructures themselves. A creation of cluster communication officer network helped to communicate the project developments within the Research Infrastructures. A creation of ENVRI colouring book [52] allowed to transfer the knowledge of ENVRI Research Infrastructure products to the scientists and to public. The project also organized many liaison and collaboration meetings with researchers and non-European research facilities. An open forum discussing the project results and the importance of collaboration among the Research Infrastructures was organized in Helsinki, inviting the wide spectrum of audience including public. Perhaps the biggest activity when it comes to dissemination of the project results was the organisation of Final ENVRI PLUS event in Brussels [53]. The event was attended by a broad range of stakeholders and nicely summarised the biggest outcomes of the project.

Overall the ENVRI PLUS communication efforts have been extremely successful both in informing about the ENVRI PLUS products, and by acting as a communication hub and a resource for ENVRI Research Infrastructures locally, regionally and globally.

1249 TWITTER FOLLOWERS
AVARAGE NUMBER OF IMPRESSIONS PER MONTH: 35.200
103,073 WEBSITE VIEWS

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OCTOBER 2019

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This project has received funding from the European Union's Horizon 2020 research and innovation programme]under grant agreement No 824068