Ref. Ares(2021)5360781 - 31/08/2021

Co-funded by the Horizon 2020 programme of the European Union

HORIZON 2020 – WIDESPREAD-2018-01-TEAMINGPHASE2

EMME-CARE | GRANT NO. 856612

D4.2 Report on the structure of the Research Infrastructure Unit

August 2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 856612 and the Cyprus Government

Deliverable Number	Deliverable Title	Lead Beneficiary	Type	Dissemination Level	Due Date (in months)
D4.2	Report on the structure of the Research Infrastructure Unit	4 – UH	Report	Public	M24

Version	Date	Changed page(s)	Cause of change	Partner
V1	10/12/2020	Initial version		UH
V2	08/06/2021	Revision and refinement of the template-document	Finalisation of Template-document, with concrete indications of inputs needed	UH
V3	01/08/2021	Amendments/ Revisions throughout the document	Integration and refinement of inputs from CYI and MPG	All UH
V4	06/08/2021	Revisions/ Refinements throughout document	Creation of revised version to be Validated by CARE-C Director and RISO before submission to the Management board	UH
V5	24/08/2021	Revisions/ Refinements throughout document	Creation of the Final Version based on the suggestions of the CARE-C Director and RISO team	CYI UH

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1. Introduction

The **"Eastern Mediterranean Middle East – Climate and Atmosphere Research" Project** *(EMME-CARE, H2020 GA no.856612)* provides scientific, technological, and policy solutions by establishing a world-class Center of Excellence focusing on environmental challenges. To address these objectives, the Atmosphere & Climate Division (ACD) of the Cyprus Institute (CYI) has been upgraded, its partnerships with world-renown institutes strengthened, and its status and contribution in the field's regional/global networks enhanced. The new CoE established (in January 2020) is the Climate and Atmosphere Research Center (CARE-C) of the CYI.

The Deliverable 4.2 at hand reports on **the Centre of Excellence (CoE) Research Infrastructure Unit (RIU).** It presents an update on the establishment of the RIU, its governance and economic models, and its functions. It showcases the role of the RIU in alignment with the EMME-CARE scientific and educational objectives, the linkage to national and international research infrastructures (RI), and the overall expected and realised impact. The roadmap adopted by the RIU is introduced following the tasks of WP4: *Physical and Research Infrastructures*. The information delivered here has been partly reported in Deliverable *"D1.5 Implementation Report to European Commission corresponding to First Reporting Period – RP1"*.

Operational Context

The Research Infrastructure Unit (RIU) manages the seven (7) CARE-C's research infrastructure (RI) facilities. These facilities are divided into three types: observational facilities, exploratory facilities, and data centres, following a similar scheme found within EU Research Infrastructures (e.g. ACTRIS).

The *observational facilities* are managed by the Cyprus Atmospheric Observatory (CAO) and the Environmental Chemistry Lab (ECL). They include 1) on-line atmospheric measurements for CAO and 2) off-line atmospheric measurements for ECL, both dedicated to long-term observations in multiple sites representing contrasting environments.

The *exploratory facilities* are dedicated to experiments and field campaigns, and they include, the Instrumentation & Nano Laboratory (INL), the Unmanned System Research Lab (USRL), the Environmental Chamber, and the Mobile laboratory (MoLa).

The *data centres* are dedicated to storing and managing easy access to the environmental data generated from observations and modelling.

The core mission of the RIU is to coordinate and integrate the activities of the 7 RI facilities towards developing a flagship RI in atmospheric and climate research both nationally, regionally and internationally (Figure 1). The RI will support comprehensive, continuous long-term observations, extensive field and laboratory experiments, satellite data processing, and advanced modelling. This holistic approach is necessary to understand and propose sustainable solutions and policies for complex environmental challenges like climate change. The RI facilities will either become part or lead the national nodes of different thematic RIs operating in Europe, such as ICOS (Integrated Carbon Observation System), ACTRIS (Aerosol, Clouds, and Trace gases Research Infrastructure), eLTER (Europe Long-Term Ecosystem Research Infrastructure) and globally, such as TCCON (Total Carbon Column Observing Network), AGAGE (Advanced Global Atmospheric Gases Experiment) and GAW (Global Atmosphere Watch). They will be equipped with RI compatible instrumentation and operated following the guidelines set by the thematic RIs. CARE-C's RI framework extends regionally in the Eastern Mediterranean and the Middle East via joint research activities, field campaigns and training programs. Furthermore, the RIU will contribute to innovation and the development of advanced methods and instrumentation by CARE-C's research departments. The interrelation between the RIU and CARE-C's research departments is presented in Figure 2. The **RIU acts as the resource centre for CARE-C's research departments** providing instrumentation, information (data), and technical support to foster the centre's research, innovation, and education agenda. Additionally, the RIU's state-of-the-art instrumentation and technological expertise will provide hands-on practical support for the CARE-C education and training programme.

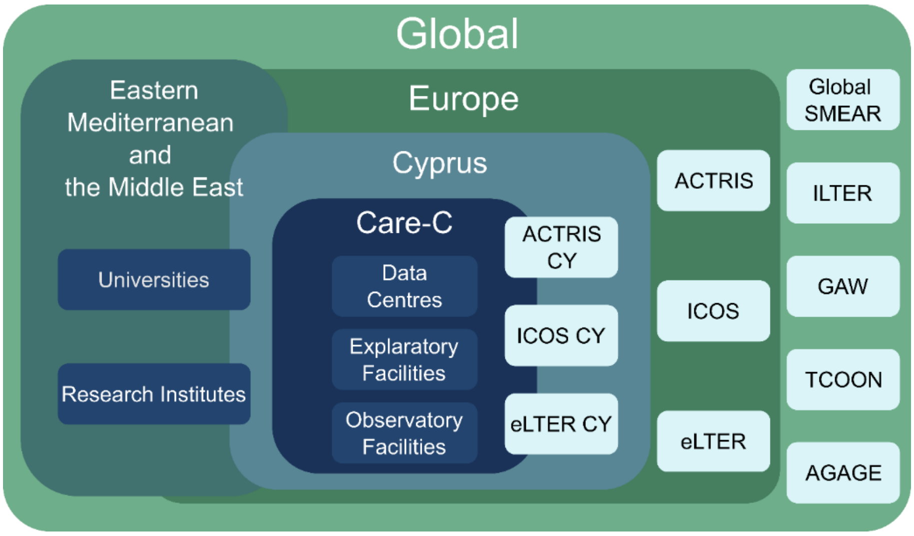

Figure 1 - CARE-C Research Infrastructure (RI) facilities at the national, regional, European and global scales.

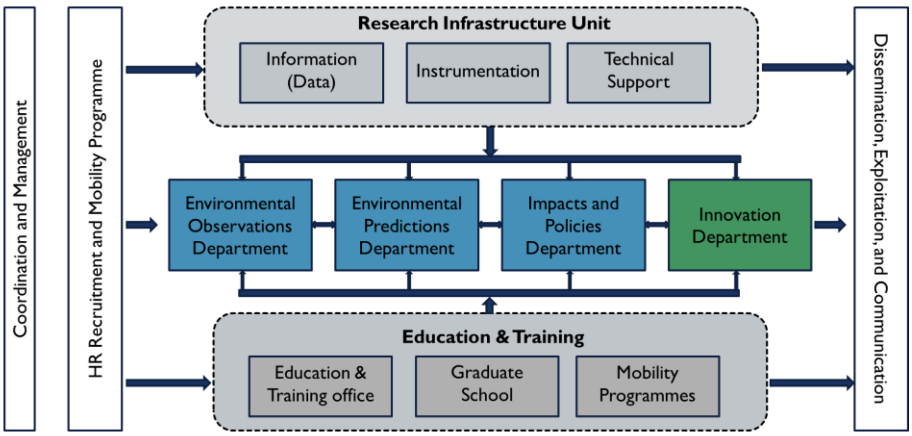

Figure 2. Figure 2 -The interrelation between the RIU and CARE-C's departments.

2. Structure

2.1. Establishment of the Research Infrastructure Unit

The RIU was established on the first day of CARE-C operation (01/01/2020). It is composed of 22 Full-Time Equivalent (FTE), of which 15 new members have been recruited since the start of the EMME-CARE project (M1-M24). The RIU will operate seven RI facilities (two new and five upgraded) that provide resources and services for CARE-C's research community to conduct research and foster innovation (Figure 3).

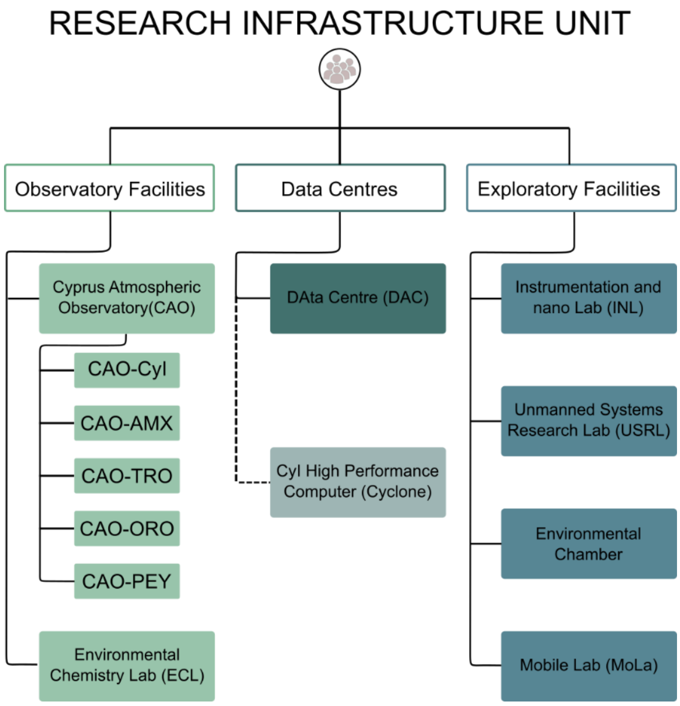

Figure 3 - The structure of the Research Infrastructure Unit of CARE-C composed of seven facilities.

The "Mobile Lab" and "Environmental Chamber" facilities will be developed in YEAR 3 as reported in the Grant Agreement. The Cyclone facility is co-operated with The Cyprus Institute.

2.2. The RIU Governance Model

The RIU operational governance is embedded in the governance structure of the CoE (Figure 4 and 5). Strategic decisions are taken by the CARE-C Management Board (MB), supported when necessary by the advisory contribution of the CARE-C Scientific Expert Panel (SEP) and a scientific instrumentation committee:

- The Management Board is the ultimate decision-making body of CARE-C, with full oversight of and responsibility for the centre's operations, including the RIU. The Management Board makes decisions on the budget (expenditure), recruitment (of Senior Staff), and internal affairs.
- The Scientific Expert Panel is an advisory panel of international experts supporting the management board's decision-making on the centre's affairs, including the RIU.
- The Head of RIU is representing the seven Facility Heads and reports to the CARE-C Director for the routine operation of the RIU. Each Facility Head is responsible for leading and managing the function and operation of his/her facility.
- The Scientific Instrumentation committee comprises members from CARE-C and the advanced partners. This committee advises on the priority list of instrument purchases needed to support the centre's international and regional research agenda.
- Each of the 7 facilities of RIU is composed exclusively by Research Support staff (technical research specialists) whereas researchers and students are operating within the 4 CARE-C departments.

- The Facility Heads are Faculty conducting their research and innovation (R&I) activities in the different Departments of CARE-C. This model ensures an optimal prioritization of resources towards R&I activities at the closest of the needs of Departments.

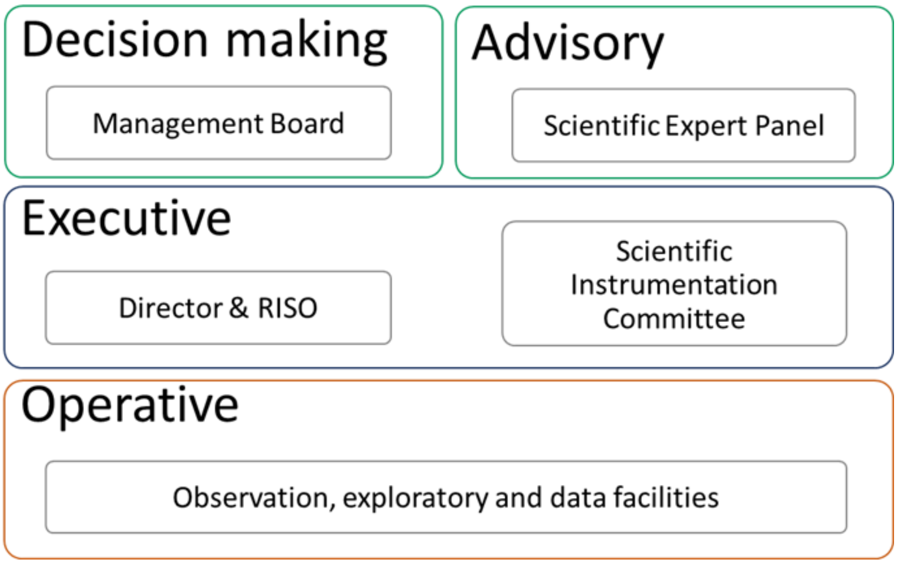

Figure 4 - The RIU governance model.

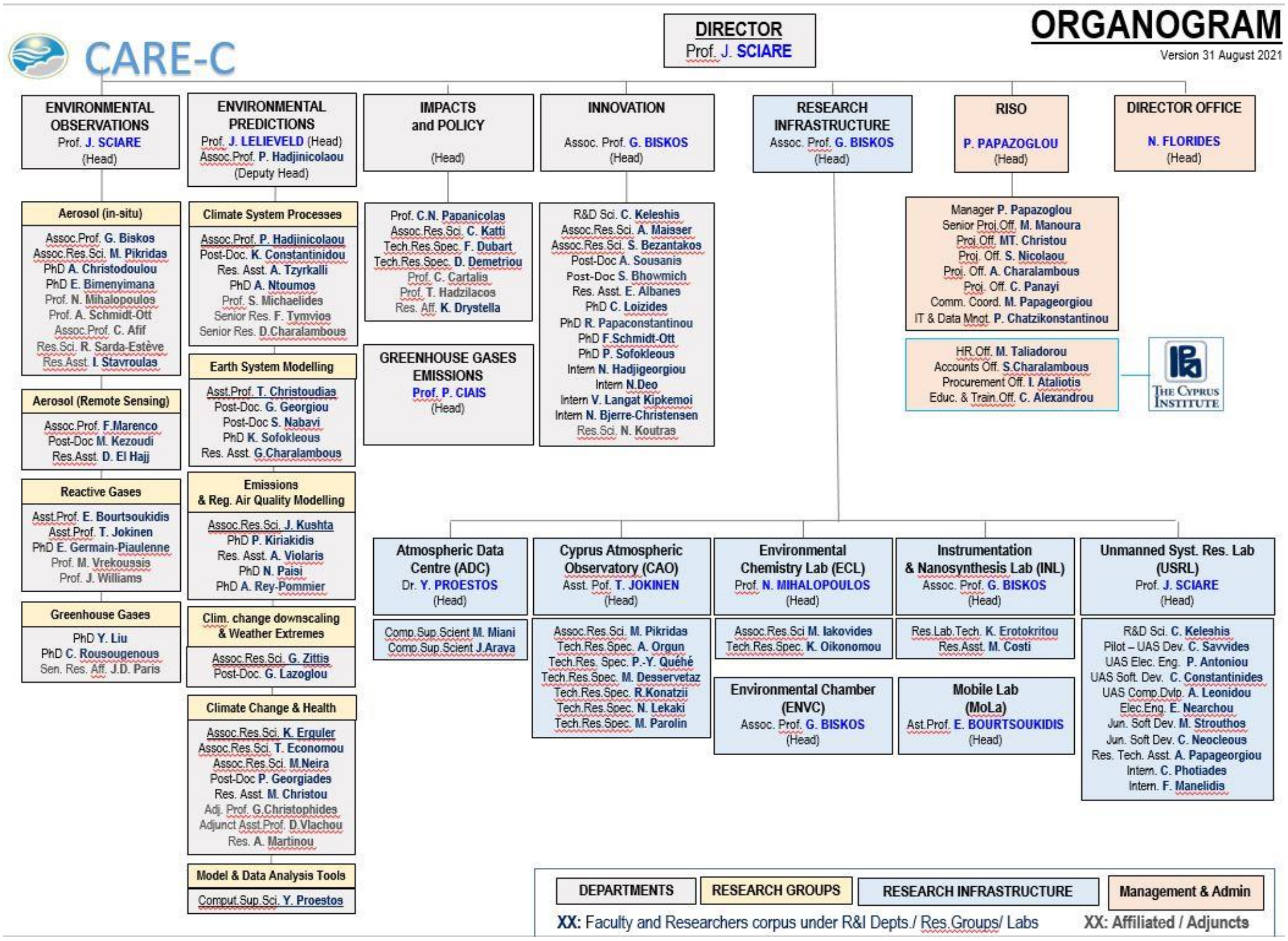

Figure 5 - The Research Infrastructure Unit within the CARE-C structure

2.2.1. Scientific Instrumentation committee

A "Scientific Instrumentation" committee has been formed to review the priority list of instrument purchases on a yearly basis. The members of the "Scientific Instrumentation" committee are:

- UH: Prof. Markku Kulmala and Mrs. Rima Baalbaki,
- CEA: Prof. Philippe Ciais and Dr. Michel Ramonnet,
- MPG: Prof. Jos Lelieveld and Prof. Jonathan Williams,
- CYI: Prof. Jean Sciare and Prof. George Biskos.

Terms of Reference of the scientific instrumentation committee: The list of Scientific Instruments to be purchased in the framework of the EMME-CARE project has been established end of 2018 and is integrally reported in the Grant Agreement for each of the 7 facilities. So far, the vast majority of the purchases has been following this list. Nevertheless, together with the recruitment of new faculty and the development of new R&I thrusts, the needs in terms of instrumentation have evolved over the past 3 years. Some investments need to be postponed or reassessed while few others need to be considered. The Scientific Committee is the body that is in charge of this reevaluation of the investment plan and yearly prioritizations.

2.3. The RIU Economic Model and Financial Sustainability

Each of the 7 facilities of the Research Infrastructure Unit is responsible for supporting a range of research and innovation projects that are managed at Department levels; as such, Research and Innovation is not performed within the facilities.
R&I projects are contributing financially to the operation cost of each facility (at the level of the use of the facility), in terms of staff salary, consumables, calibration/maintenance and when possible depreciation of scientific instruments. An "Internal Service Provision" (full-costing) model has been established so as to ensure that every cost engaged by the facilities in projects are properly sized and recovered. This model ensures a proper and sustainable operation and development of RIU. It empowers the most competitive/attractive facilities in further developing in size and capacities.
The development of RIU is partially supported by EMME-CARE in terms of scientific investment and staff recruitment. Services undertaken by RIU are also contributing towards the enhancement of the capacities to facilities as competitive as possible (e.g. new scientific instrumentation, etc).

3. Alignment of the RIU Objectives with EMME-CARE Objectives

The main objective of the RIU is to supply state-of-the-art resources to support scientific, innovation, and education excellence on the local, regional, and international scales. The cornerstone element to achieving the RIU's objectives is its highly instrumented facilities linking comprehensive in-situ observations with remote sensing, technological development, experimentation, and modelling. The structure presented here is unique regarding the coherent and coordinated operations between the RIU facilities and CARE-C's departments (Figure 6). The RIU offers cutting-edge technical services supported by highly equipped stations, state-of-the-art laboratories, advanced computational methods, and modern data management systems. The clustering of these technical services with highly qualified researchers will inspire new research questions, method development, technical design, knowledge exchange, collaboration, and training opportunities.

The Eastern Mediterranean and Middle East (EMME) region faces grand environmental challenges related to climate change, air quality, biodiversity, and water and food supply (Cramer et al., 2018). Global climate projections suggest a significant intensification of summer heat extremes and pronounced regional warming and drying compared to global trends (Lelieveld et al., 2016;Zittis et al., 2019). The impact of climate change on Cyprus has been shown to exhibit significant climatic gradients, regardless of the island's small size (Zittis et al., 2020). This local variability indicates that it is essential to have observational data from multiple locations and environments. Observational data from the EMME region are either insufficient, unavailable or of limited quality. Now more than ever, comprehensive in-situ measurements of environmental parameters are needed in Cyprus and the EMME region to monitor the effects of climate change, validate regional models, and assess the effectiveness of mitigation strategies. The RIU of CARE-C will respond to this deficit by providing high-quality observational data following European harmonised standards and procedures.

Complementarity and synergies between the different facilities: CAO stations will be developed to provide long-term continuous observational data from distinct environments with local and regional representation. The stations will be equipped with RI compatible instrumentation and operated following the guidelines set by the thematic European RIs (ACTRIS, ICOS, eLTER…). USRL will conduct vertical profiling to connect ground-based in-situ (CAO) and remote sensing (satellite) observations. Online measurements will be complemented by offline sampling on filters or in special media. These samples will be analysed at the ECL facility using their state-of-the-art instrumentation and internationally accredited procedures. Complementary to the long-term analysis, the MoLa facility will be used to conduct intensive field studies in Cyprus and the EMME region, expanding the geographical representation of the observations and responding to emerging needs of building regional capacities in environmental observations. The INL facility will be used to calibrate and test the field-deployed instruments based on the recommendations of the thematic European RIs. In addition, the continuous development of miniaturised air quality monitoring instruments at INL will broaden the environmental monitoring capabilities of the RIU as these instruments are easier to transport and mount on UAVs and can be used in multiple locations being cheaper to produce/operate. Finally, the Data Centre (DAC) digital tools and services will enable the curation and storage of the gathered data for further exploitation, and the promotion of FAIR principles and Open Science.

Alignment with EMME-CARE Research Objectives: These versatile capabilities and complementary interrelations between the RIU facilities enables CARE-C's Environmental Observations Department (EMME-CARE Work Package 5) to "*Characterise changes in regional atmospheric composition and quantitatively link them to the sources of greenhouse gases (GHG) and pollutants*" (EMME-CARE research objective #1). The Environmental Predictions Department (EMME-CARE Work Package 6) will utilise the gathered in-situ and satellite data combined with environmental models to *identify the processes that govern regional climate change, leading to weather extremes, air quality deterioration, desert dust storms, and hydrologic cycle alteration* (EMME-CARE research objective #2). While, the Impact and Policy Department (EMME-CARE Work Package 7) will combine the data produced by the two departments mentioned above with modelling tools to *assess the impact of environmental and climate change on public health, society and economic sectors* (EMME-CARE research objective #3). The Environmental Predictions Department and the Impact and Policy Department environmental and climate modelling activities rely strongly on the high-end computational resources and supercomputers, provided by the CyI High-Performance Computer (Cyclone) and the data centre.

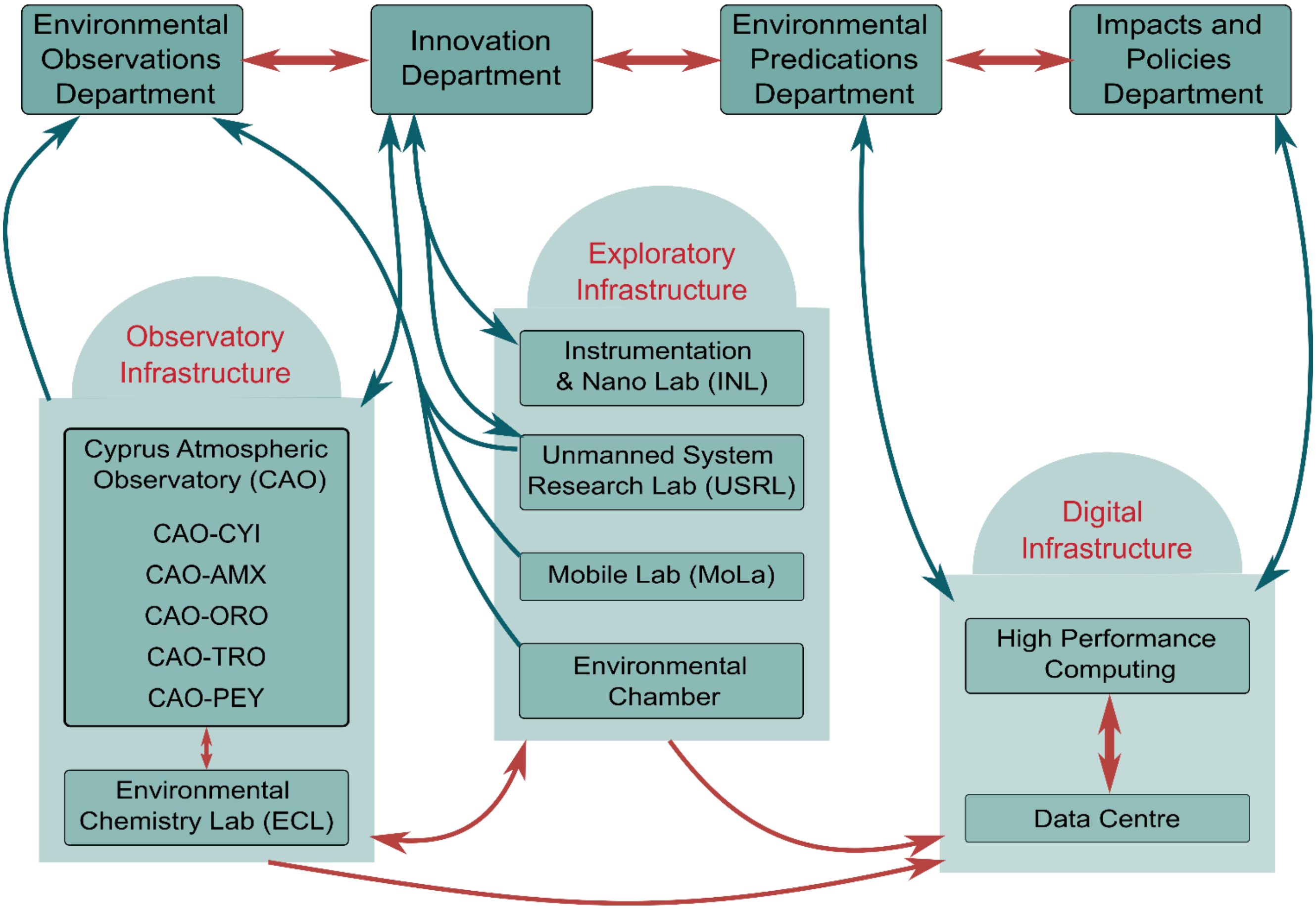

Figure 6 - The relationship between CARE-C's departments and the RIU facilities.

Alignement with EMME-CARE Innovation Objectives: The research objectives of the EMME-CARE project are highly linked to its innovation objectives which are further implemented in the framework of the EMME-CARE Work Package 8. The development of cost-effective atmospheric sensors, specialised UAV products and services, and high-quality chemical analyses (EMME-CARE innovation objective #1) are among the primary goals of the INL, USRL, and ECL facilities, respectively. These facilities will be upgraded with the needed instrumentation, resources, and know-how to meet the Environmental Observations Department's needs of new products and technologies in environmental monitoring. The development of atmospheric and climate forecasting products and services featured for key economic sectors (EMME-CARE innovation objective #2) will be made possible through the computational resources of the RIU available for use to the Environmental Predictions and the Impact and Policy Departments.

Alignment with EMME-CARE Education and Training Objectives: The success of the RIU and its capability to reach its objectives is highly dependent on its human capital. The RIU will support the continuous recruitment of talented staff and engage them with the present staff in training programmes to acquire the specialised skills needed to develop/upgrade/operate CARE-C's facilities. The training programs will be organised in the framework of the EMME-CARE Work Package 3, in collaboration with the advanced partners: Max Planck Institute for Chemistry (MPIC), the French Alternative Energies and Atomic Energy Commission (CEA), and the University of Helsinki (UH). These institutions provide world-leading expertise in atmospheric and climate research, at a fundamental level (MPIC), low carbon technologies and innovation (CEA), along with the provision of advanced graduate education and experience in the coordination of major European research infrastructure (UH). The training offered by the advanced partners will include short-term staff exchange, hands-on technical training at the premises (labs) of the advanced partner institutions, or CARE-Cs facilities. Additional training opportunities will be leveraged by participating in the thematic research infrastructures annual workshops, specialised courses and schools, and station support services.

With its highly qualified human capital and competitive physical infrastructure, the RIU will support the EMME-CARE objective of establishing a world-class higher education programme on atmosphere and climate change within the EMME region (EMME-CARE education objective #1). The RIU will offer a wide range of training opportunities, including in-depth, hands-on training and courses on instrument operation and maintenance, calibration procedures, setting up measurement sites, instrument development and benchmarking, data analysis and modelling, thus enhancing the regional scientific and technical culture (EMME-CARE education objective #2). It will also promote and facilitate international exchange (EMME-CARE education objective #3) by offering open access to comprehensive multidisciplinary observation data and physical or virtual access to research and computing platforms.

4. Impact

4.1. Research Infrastructure's Added Value and Impacts

Impact on scientific excellence: The observations offered by the RIU will support the analysis of climate system processes and the recognition of previously unknown emission sources. For example, measurements of high mixing ratios of non-methane hydrocarbons (NMHCs) over the Arabian Gulf, backed by air mass back-trajectory investigations and Positive Matrix Factorization analysis, led to the conclusion that the Red Sea deep water is an unexpected, potent source of atmospheric NMHCs (Bourtsoukidis et al., 2020). The data provided by the RIU will further help explore climate feedback loops, which are important for understanding how ecosystems will respond to environmental changes and for defining sound mitigation and adaptation strategies. Furthermore, these observations will be used to verify weather and air quality predictions and will improve the assessment of environmental changes on public health, society, and economy.

Other examples of benefits for the society include: identification of air pollution causes, development of a model for predicting the impact of city planning on air quality, delivery of crucial information to local authorities, development of early-warning systems for atmospheric pollutants (e.g., desert dust, forest fire, pollens, spores, and bacteria), quantifying the consequences of pandemic lockdown to air quality, evaluating the effectiveness of air filtration in hospital intensive care units in lowering the airborne viral counts, and many others.

Impact on Innovation: The continuously operated, comprehensive measurement stations and experimental platforms are a unique niche to foster innovations. These innovations provide the business sector with tools to monitor environmental changes and move towards carbon-neutral and environmentally sustainable operations. Backed by resource and competence incubation strategies, these innovations enable the establishment of start-up companies (Clarysse et al., 2005).

Impact on employment on human resources: CARE-C's RI will support employment, education, and human capacity building. Since the establishment of the RIU, fifteen (15) new members have been recruited to support the operation of the RI facilities. Additional job opportunities will be generated in the upcoming years partly to support the development of the new RI facilities, but more importantly, because better data and resource availability will create new collaborative models and new opportunities to develop environmental services leading to data-oriented private enterprises and integrated research projects. Generally, RIs are knowledge hubs where science, education, and innovation meet. They are a prerequisite for collaboration between industry and academia, and they provide unique training opportunities for the new generations of scientists, engineers, and data professionals (ESFRI, 2020). They stimulate the local business sector through technological development in Small and Medium-sized Enterprises (SMEs), participation in technology clusters, and creating a market for the local service sector (such as hotels and restaurants). The increased mobility through national and transnational access will increase intellectual exchange and foster national and international cooperation. The highly equipped research infrastructure will attract PhD students and junior scientists, create training opportunities, and spread knowledge-based growth. With its open science policy and plan for the dissemination and exploitation, the Communication & Outreach Office (COO) will maximise the visibility and impact of the new knowledge created using the RI facilities, raising public environmental awareness, providing science-based, policy-relevant information to the public and advocating for climate action.

Impact on the national Research Infrastructure roadmap: In connection to European RIs, the RIU will contribute to developing the national roadmap for Research Infrastructures, as encouraged by the European Strategy Forum on Research Infrastructures (ESFRI). With its integrated and distributed facilities, the RIU is currently leading the national efforts to join European thematic RIs such as ACTRIS and ICOS. It will combine the national interests, find synergies to save resources, and foster integration at both the managerial and scientific levels.

4.2. Significance of the Membership in International Research Infrastructures

4.2.1. ICOS

ICOS (https://www.icos-cp.eu/) network consists of more than 140 measuring stations, 500 researchers, and 80 renowned universities and institutes located in twelve countries in Europe. ICOS RIs produce high-quality, standardised data on the long-lived greenhouse gas concentrations and fluxes between the atmosphere and the ecosystem. The membership in ICOS RI has very positive impacts on CARE-C's aspiration for scientific excellence. It ensures the use of the highest standards for greenhouse gas observations following stringent protocols, thus increasing the reliability of CARE-C's measurement sites. ICOS provides an open access data portal, which would expand the visibility of the CARE-C's observations and encourage collaborative and multidisciplinary integrative analyses. The data collected within ICOS RI is a valuable source to support the decision-makers in their policy choices, which is particularly relevant for the region, already renowned for methane (CH_4) quantities generated by oil and gas production. As part of ICOS, CARE-C's scientists will have access to ICOS-related science and training events. This access will enhance the scientific exchange within the ICOS community and increase chances for collaboration and funding opportunities.

4.2.2. ACTRIS

ACTRIS (https://www.actris.eu/) focuses on studying short-lived atmospheric constituents via in-situ and remote sensing techniques. It provides access to many high-quality services, which would benefit CARE-C's scientific, technological, and innovation agenda. These include providing access to ACTRIS observational and exploratory facilities, quality audits, training, and the development of measurement solutions. As a member of ACTRIS RI, CARE-C's state-of-the-art facilities and services will be open for trans-national access through ACTRIS newly launched open calls, thus supporting its mission to become a regional hub in the atmosphere and climate research. ACTRIS, like ICOS, provides an open access data portal, which ensures fulfilling FAIR (findable, accessible, interoperable and re-usable) principles.

4.2.3. eLTER

Membership in eLTER RI (https://www.lter-europe.net/) is a key for harmonising and streamlining the currently scattered collection, management, and environmental data products into more coherent and usable datasets. eLTER is developing a harmonised measurements and operations site design with a cost model, setting a clear budget and sustainable framework for site operations and hosting organisations. The membership allows participation in European major research funding calls, such as the recently started eLTER PLUS (H2020 Advanced community project, led by UH, total budget 10 M€). Additionally, one of the significant objectives of eLTER is to open a network of ecosystem research and monitoring sites to the broader science community, thereby increasing and diversifying the use of sites. eLTER will increase the level of knowledge and skills through the systematic training of site Principal Investigators (PIs), managers, and technicians to meet the high standards and provide high-quality services, including socio-ecological research methods and expertise. The eLTER Topic Centres will liaise with SMEs, local and international industry for method and instrument development and testing, allowing cost-efficient implementation of novel technologies at the sites. eLTER's data integration plan serves a diverse user community. The eLTER data portal will provide a unique access point to distributed harmonised data and metadata databases, access to additional data for sites (e.g., COPERNICUS data products), and training in these technologies.

4.2.4. AGAGE

AGAGE (https://agage.mit.edu/) has been continuously measuring the global atmosphere composition since 1978. It comprises a global network of gas chromatograph-mass spectrometry (GC-MS) instruments that make high-quality measurements of anthropogenic compounds such as CFCs, halons, hydrofluorocarbons, perfluorocarbons, and other organohalogens that contribute to stratospheric ozone depletion. In addition, these systems track species with both biogenic and anthropogenic sources, including N_2O, CH_4, CO, H_2, CH_3Cl, CH_3Br, CH_2Cl_2, and $CHCl_3$. These measurements can monitor the growth and fall rates of crucial chemicals in the global atmosphere. They are crucial to assess the total radiative effect of trace gases, the impact on stratospheric ozone, and the global oxidation capacity of the OH radical.
Having CARE-C as part of the AGAGE network is an important step for both sides. For AGAGE, the CAO sites would provide valuable new measurements in a region with periodic influence from poorly covered regions such as the Middle East and Eastern European outflow. For CAO, acceptance into the network and accreditation of the provided data quality bring worldwide recognition. The AGAGE-CAO data stream opens the possibility to discover new regional sources of the compounds mentioned above. This cooperation offers vast potential for significant findings, particularly involving fugitive emissions from Eastern Europe and the Middle East. As the key GC-MS instrument used in the AGAGE networks is being commercialised and the main CAO measurement site is being developed, it is forecasted to introduce this capability in the later stages of EMME-CARE.

5. Research Infrastructure Unit roadmap

Research Infrastructures play a vital role in accelerating scientific achievements, advancing knowledge and technology and finding solutions for societal problems. Successful RIs rely on systematic strategic planning for the two main building blocks of research capacity: 1) the human capital consisting of research support personnel and 2) the physical capital consisting of scientific equipment, platforms (infrastructures) and expenditure necessary to operate it. These two are entirely complementary to each other, and none can function without the other. This section presents the strategies adopted by the RIU to support and develop its human and physical capital.

5.1. Supporting Recruitment of Qualified Technical Staff

The sustainability and effectiveness of the RI facilities depend on qualified technicians. The recruitment, development, and sustaining of such staff require a strategic human resource (HR) management approach. The CARE-C HR Office carries out recruitment in cooperation with the CyI HR Department. This office is responsible for the timely recruitment of young research talents, high-level international researchers, and technical specialists, the implementation of an optimal working environment, the compensation and benefits scheme, staff performance evaluation monitoring, and other related career development activities. The functions and procedures of this office are detailed in D2.1 "Report on the Functions and Procedures of the HR Office". The CARE-C HR Office builds upon the established experience and expertise of the central-CyI HR strategy, which follows the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers. With these proven policies, strategies, and methodologies in place, fast and efficient development of the CoE is expected.

However, recruiting qualified technical staff is particularly challenging in scientifically emerging countries that constitute most of the EMME region. These challenges could be summed up by a shortage of qualified people both at the Research Infrastructures' operation and management levels, shortage of technical support staff, especially at remote locations, and other low attractiveness unrelated to expertise or pay (OECD, 2017). The recruitment procedure in Cyprus suffers from the challenges mentioned above and from additional challenges posed by the Cypriot regulation and the fact that Cyprus is one of few EU States that have not joined the Schengen Area, which also limits the EMME-CARE Mobility Program for third country nationals.

In this context, the RIU role in supporting HR development is crucial for the functions of the RI facilities and CARE-C's departments. The RIU has proposed and is currently exploring the following procedures and incentives to support the recruitment of qualified staff:

- **Continuous Job Openings** (with regular selection sessions, typically every 3 months) to be in capacity to "catch" high performers when they become available (whose availability is usually lasting, at the best, only few weeks within a year). This strategy of time extended Job Openings will also allow to better find highly specialized staff who are very few in number. – CARE-C HR Office will explore the relevant modality of job announcements with Central CyI HR Department for coordination and future steps.
- Using "**attention-grabbing**" to describe job position announcements. The title of the position should be as descriptive as possible to grab job seekers' interest quickly. The job description should give a clear and accurate picture of the responsibilities and authorities for each staff position, including all activities and tasks that should be performed (they are competency-based and reflect any skills needed). – CARE-C HR Office in collaboration with CARE-C Communications Coordinator to implement this stratetgy.
- **Advertising job openings within specialized networks** of the earlier mentioned European and international thematic RIs and their social media channels in addition to conferences where the RIU activities are promoted. – Aleady performed, however both the CoE and the Advanced partners will intensify their efforts for wider dissemination.
- **Considering past applicants** for new position openings, if they fit the requested profiles. – Aleady performed by CARE-C HR Office, however efforts can be enhanced.
- Enhancing CARE-C's **orientation plan rendering it specific for the RI facilities**. The plan includes:
  - A general orientation tour to RI facilities
  - Information about the role of the facility and its mission

  - Introduction to all management and staff key personnel and lines of authority
  - The policies and procedures regarding RI facilities and safety
  - Personnel policies - ethics - confidentiality - employee benefits - work schedules (and where to find this information)
  - An overview of the followed standard operating procedures (SOPs) and quality management system
- Offering **international training opportunities** at the premises of the Advanced partners and other European RI. These opportunities are part of a staff development plan designed by the RI facilities' heads and in line with the educational objectives and activities under the EMME-CARE project (WP2/WP3).
- Exploring along with CARE-C HR Office and the CYI HR Departmenht, offering **permanent positions** for the staff operating the long-term observations, converting fixed-term engagements to open-ended engagement after a maximum of 3 years.

The RIU will additionally respond to the shortage of qualified staff by offering annually recurring courses, training opportunities, and workshops in cooperation with CARE-C's Education and Training Office and the Advanced partners. The Objectives of these training programs are i) to educate the next generation of specialists in the environmental research, ii) to establish future collaboration between students and researchers, iii) to provide comprehensive training addressing all aspects from instrument development, data provision to data application in numerical models, iv) to provide transferable skills applicable on a wide range of scientific and expert tasks in the society as a whole, and v) to support career development in RI management and operations. These training opportunities are further detailed in Section 5.5 of this Deliverable.

5.2. Supporting Instruments Acquisition Installation and Operation

The competitiveness of CARE-C's science base and its ability to deliver excellent research highly depends on its access to state-of-the-art scientific research instrumentation. Such instrumentation must be maintained in good working condition and operated in an institutional setting that allows researchers to exploit it fully. Thus, instrument acquisition is only one component of the scientific instrumentation management package. Proper management strategies should be put in place to ensure the long-term competitiveness of the infrastructure managed by the RIU. In specific, the RIU has developed the following instrument management guidelines:

- <u>Identifying the need for instrument purchases</u>: the list of new instruments to be purchased is handled by the Scientifc Instrumentation Committee (see above). It must be justified by declaring the added value of the purchase. For example, the added value could be opening up new research opportunities, filling in a gap in research needs, updating facilities with the latest technological developments or standardised methods required by accreditation bodies and Thematic RIs, or increasing time-efficiency of services. The critical mass of researchers making use of new instruments is another critical parameter that will maximize the utilization and exploitation of new scientific instruments.
- <u>Creating an investment plan</u>: the RIU realises that the cost of purchasing instruments is not a one-time payment. As such, the provisions of an instrument cost should take into account the expenses of maintenance, upgrades, and its lifetime before replacement. It is also advised to make wise decisions about the long-term needs of specific instruments or equipment.
- <u>Supporting the cost-effective acquisition of instruments</u>: the procurement procedure will follow the Cyprus Institute internal procedures, which achieve value for money and ensure transparency

abiding by the provisions of the relevant Republic of Cyprus Law 73(I)/2016, its amendments, and the relevant EU directives.

- Defining the duties and responsibilities of facility staff: to ensure that instruments are running as they should, each RI facility Head will assign responsibilities for all activities related to instruments' operation, ensuring that responsible personnel have been adequately trained. These responsibilities include, but are not limited to, operation, maintenance, monitoring, and reviewing all equipment records routinely. The training on these responsibilities is detailed in section 5.5 of this deliverable.
- Defining instrument-specific management plans: each RI facility will place a clear management programme for each instrument purchased. This programme should include provisions on installation requirements, calibration and performance evaluation, maintenance schedule, troubleshooting, service and repair, retiring and disposing of equipment. Ideally, this information will be documented in the form of a standard operating procedure.

The RIU additionally recognises specific challenges that prevent the swift acquisition of instruments. These challenges and possible solutions are discussed below:

- A 20% VAT that is applied on investments, when many (most) EU Research Performing Organizations are exempted from VAT.
- Prices are often 10-20% higher compared to the rest of Europe (mostly due to the small size of the Cyprus market with low demands and lack of local competitors).
- The highly bureaucratic pre-tendering process, which involves identifying the preferred specification and supplier and working out how an item would be funded, installed and supported, is costly in terms of time and effort required from the principal investigators. – To support the researchers in this process each RI facility has its own dedicated RISO Officer who provides guidance for all relevant processes. In addition, CARE-C have a dedicated Procurement Officer providing additional support to researchers in line with the CyI Procurement Department policies and procedures.
- Operational and logistic problems might arise when facilities of adequate size and quality are not available to house purchased instruments. – To avoid any operational or logistical installation problems arising, prefabricated containers are put in use until the CARE-C Headquarters building is constructed.
- Laboratory instruments often have expensive service contracts. – To defray such costs, the potential for allowing supervised access to research equipment by industrial users could be evaluated at higher charge rates.
- The delay between planning a proposal and getting funded and purchasing instruments can be a matter of years. Often, by the time an order is placed, the list price of an item has risen significantly. – To avoid such problems, market research and early informal discussions with suppliers can be initiated once the funding has been officially secured.

5.3. Upgrading Facilities and Creating New Ones

5.3.1. The Cyprus Atmospheric Observatory (CAO)

Mission: The Cyprus atmospheric observatory's mission is to provide continuous, comprehensive, high-quality, in-situ and remote sensing measurements of key atmospheric species, optical properties and environmental parameters relevant to air quality and climate change for Cyprus and the EMME region. The atmospheric data and products produced by the CAO are the cornerstone for the Environmental Observations Department scientific scopes, which are closely related to the EMME-CARE project research objective #1. These observations will offer a comprehensive description of the atmospheric boundary layer at a remote site representative of the regional (EMME) environment and at other sites representative of the local environment. In addition, they will help characterise the trends in the regional and local atmospheric composition, quantify the sources and evaluate the effects on the air quality, climate and ecosystem cycles

History: The CAO was first established in 2015, comprising one rural station for long-term measurements of the atmospheric constituents at Agia Marina Xyliatou (AMX). The AMX station is co-operated with the Department of Labour Inspection, the governmental body in charge of the air quality network in Cyprus. Air quality measurements at the site date back to 1997 and were complemented with a suite of instruments to measure atmospheric aerosol chemical, physical, and optical properties. The AMX station is a member of the co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP) and is a designated regional Global Atmospheric Watch (GAW) station.

Outlook: The CAO facilities will be upgraded to meet the scientific demands of the different departments of CARE-C and to provide comprehensive observations of the local and regional environments. The foreseen upgrades are mainly concerned with CAO premises, instrumentation and digital tools. Mainly, CAO premises will expand to include three new and two upgraded research stations, each having its specific but interrelated research vision.

Figure 7 - The location of CAO stations.

The CAO-AMX station is a rural background station located close to the villages of Agia Marina (~ 630 inhabitants) and Xyliatos (~ 150 inhabitants) and has an elevation of 532 m above sea level. The site is surrounded by vegetation, as it lies at the northeastern foothills of the Troodos Mountains. Agriculture areas surround the site from the north direction and are approximately 4 km away. The nearest main urban agglomeration is at least 35 km away. Therefore, it is not directly affected by any major local pollution source. This station is optimal for providing long-term atmospheric observations of key atmospheric pollutants (gases/aerosols) relevant to climate change and air quality. It is a designated EMEP and GAW station and will become a part of the ACTRIS research stations. The station will continue to operate with its current instrumentation and will be upgraded with extra aerosol measuring instruments. The site is also strategically located near the Peristerona watershed, where ecosystem measurements are expected to take place in collaboration with the Energy, Environment and Water Research Center (EEWRC) of the Cyprus Institute.

The current plan is to transform this station into a SMEAR type site. It will be designed to feed high quality regional data into many EU research infrastructures and international networks (e.g. EMEP, WMO, ACTRIS, ICOS, eLTER, AGAGE, BSRN) over the long term. It will also contribute to important international scientific initiatives such as the IPCC. It will provide physical access and high quality logistical support for international research teams and intensive field campaigns focusing on the EMME, thereby increasing its international profile.

Figure 8 - The AMX station consisting of two containers for aerosol measurements and an EMEP container for trace gas and meteorological measurements.

The CAO-PEYIA anticipated station will be located northwest of Paphos at a remote coastal location next to the Akamas Peninsula national park.The establishment of this station is pending the private donation of the former president of the Republic of Cyprus, which includes a large plot of land and the construction of an observatory building. The latter has been delayed due to legislative issues. As a contingency plan, CAO-AMX site is being developed to potentially host the SMEAR type station. In addition, another nearby site (CAO-INE) is being developed to host the ICOS flux measurement tower to avoid the delay in establishing GHG measurements.

The CAO-INE site is planned to take advantage of the CYTA telecommunication company tower located at the Ineia military base. The location is optimal for ICOS approved GHG measurments. Current negotiations are taking place with CYTA company and the observations will be started as soon as an agreement is reached.

Figure 9 - The anticipated location of CAO-INE GHG observations.

The CAO-ORO station is located on the plateau between the villages of Orounda and Peristerona and is 4 km north of the AMX station. The site hosts the private runway and dedicated airspace for atmospheric profiling performed by USRL, enabling the direct comparison of the ground-based and airborne atmospheric measurements. Recently the lands nearby the runway have been purchased where measurement containers will be installed.

Figure 10 - The CAO-ORO UAV runway and airfield. The three grey areas surrounding the runway in the right photo delimit the land that has been purchased recently.

The CAO-TRO station is located inside the Troodos mountain range at an elevation of 1820 m above sea level. This station will allow observations from the free troposphere of the East. Mediterranean, which observations do not exist so far. The land for this site has been leased and a measurement station container installed. The anticipated station will host a suite of meteorological sensors that will be integrated into the existing network of met stations operated by the Cypriot Department of Meteorology under an existing MoU between CyI and that authority. The environmental station, which is not yet operational, will monitor legislated gas pollutants (O_3, NO_y, CO, SO_2), aerosol mass (PM_1, $PM_{2.5}$, PM_{10}) using optical sensors and black carbon. Many of the instruments have been already purchased. The measurements will commence after securing electricity connection.

Figure 11 - The CAO-TRO measurement container.

The CAO-CyI is an urban background station located in the premises of The Cyprus Institute at Athalassa, Nicosia. It consists of a two-story container ventilated by a "zero-carbon" novel A/C system. The bottom floor is used to maintain and calibrate equipment while the upper floor is dedicated to long-term measurements of black carbon, PM mass, and gaseous pollutants (O3, NO_y, CO, SO_2). In addition, the station contains a suite of monitors for aerosol characterization, including an online trace metal analyser, optical particle, submicron, and supermicron chemical composition monitors complemented by a weather station. Due to space restrictions, complementary operations have been initiated at the rooftops of CyI. These observations include PM chemical composition using filter-based methods, greenhouse gases and remote sensing (LIDAR, TCCON, Sun photometer). The remote sensing activities are now part of AERONET, PREDE, and TCCON. The latter is a container-sized station that monitors integrated columnar CO_2. In addition to the above-mentioned observations, CAO-CyI hosts long-term measurements of pollen, spores and other airborne particles between 5 and 100 μm in size using EU (EN16868:2019) compliant instrumentation.

Figure 12 - The CAO-CyI station

Provisions for national and transnational access: The CAO measurement stations will be designed to feed high-quality regional data into many EU research infrastructures and international networks (e.g. EMEP, WMO, ACTRIS, ICOS, eLTER, AGAGE, BSRN). Through these networks, it will provide physical access for international research teams and intensive field campaigns focusing on the EMME.

5.3.2. The Unmanned Systems Research Lab (USRL, https://usrl.cyi.ac.cy/)

Mission: USRL offers on-site facilities and related infrastructure for research, development, and testing of technologies related to UAVs (Unmanned Aerial Vehicles). The mission of the USRL is to provide high-quality observations of atmospheric pollutants and other parameters relevant to air quality and climate change. Taking advantage of several other CARE-C's infrastructures, such as the instrumentation and analytical laboratories for testing and qualifying miniaturized sensors, as well as a private runway and dedicated airspace at CAO-ORO, USRL performs regular UAV flights to document and contrast long-range transported pollution from three continents (Europe, Africa and West Asia) and dust aerosols from the largest desert regions in the world (Sahara, Middle East).

Outlook: As per the EMME-CARE Grant Agreement, USRL capacities are upgraded within four priority axes:

1) Operational fleet of UAV-sensor systems for science: The integration of USRL as a National (Cyprus) Facility of the EU research infrastructure ACTRIS (as exploratory platform) does illustrate the level of maturity of USRL, being recognized at EU level for its capacity to perform high quality long-term atmospheric observations. Major achievements on UAV-sensor systems for atmospheric research have been performed for that purpose over the last 2 years and are gathered in the

recently published paper "*The Unmanned Systems Research Laboratory (USRL): A new facility for UAV-based atmospheric observations*" by M. Kezoudi et al. (2021, Atmosphere, in press). These systems are deployed in a large number of (inter)national research projects dedicated to the vertical profiling of air pollutants.

2) Development of innovative UAV solutions for atmospheric research: These developments (e.g. UAV-balloon system) are currently implemented within large projects funded by the European Space Agency (e.g. ASKOS, https://askos.space.noa.gr/) for the calibration/validation of Aeolus satellite.

3) Specialised UAV products and services: Tenders (e.g. University of Crete, Greece) and direct assignments (e.g. Cyprus Agriculture Payment Organization) have been won and concern the provision of specialized UAV products and services (air pollution profiling, hyperspectral imaging of agriculture fields). Further products/services are currently under development and concern Forest Fire Monitoring (live streaming of HD visible/IR imaging in collaboration with the Cyprus Department of Forests), Control of sulphur content of ship emissions (compliance with EU directive)

4) Education and Training in operating UAV-sensor systems: Hands-on training on UAV-sensor systems are now integrated within our Environmental Sciences Master (ES407 'Atmospheric Measurement Techniques'). USRL is also opened for Training in the framework of two EU projects (H2020-ACTRIS IMP; H2020-ATMO-ACCESS) through the provision of TransNational Access.

5.3.3. The Instrumentation for Nanoparticle Synthesis and Characterisation Lab (INL)

Mission: The mission of INL is to develop instruments and sensors for assessing air quality. More specifically, the INL is manned by engineers and scientists capable of designing and building advanced instrumentation for determining the concentration, size, and other intrinsic properties of aerosol particles, including their volatility and hygroscopicity. An important niche of the INL is the development of low-cost aerosol instruments, aiming to expand CARE-C's observational capabilities and the broader scientific community of atmospheric sciences. Examples of such instruments include Differential Mobility Analyzers that can be manufactured using 3D printing technology and optical counters that employ inexpensive optical sensors.

Outlook: INL will be upgraded to enable the development, characterisation, and testing of the most recent miniaturised air quality monitoring instruments, including systems that go beyond the current state of the art. The lab's activities will be expanded to include the development of miniaturised gas sensors and integrated air quality instrumentation for ground-based in-situ measurements and remote sensing instruments. The facility will be equipped with the most advanced tools for building both the instruments' hardware (mechanical parts and electronics) and software. It will operate setups to calibrate aerosol instruments and gas sensors. It will also operate tools for synthesising and characterising materials for the development of inexpensive gas sensors. The facility will establish a metrology and calibration unit to ensure results are traced and measured in internationally agreed units and will act as a hub for the entire EMME region for such activities. The INL instrumentation laboratory has been recently extended in order to include activities related to nanomaterial synthesis for gas sensors in the framework of the RIF AQ-SERVE project. This is in synergy with a national infrastructure project that is also underway, and in synergy with EMME-CARE. The new extended laboratory includes state-of-the-art instrument for synthesising well-defined aerosol nanoparticles, tools for immobilising them on well-defined substrates to form nanomaterials for that can be employed in the next generation of gas sensors, and systems for characterising them in the gas phase their performance under different operating conditions.

5.3.4. The Mobile Lab (MoLa)

Mission: Complementary to CAO (which will provide 24/7 continuous measurements), MoLa will allow CARE-C to perform intensive fields studies of several weeks or months per year in different locations in Cyprus, the EMME region, and beyond. Mola offers a flexible and cost-effective way to monitor GHG, reactive gases, and aerosols in locations that do not have fixed air monitoring stations. It extends the geographic monitoring capabilities of CARE-C and can be used to assess the need for longer-term monitoring in a specific location. MoLa intensive campaigns can help understand the root causes of reduced air quality and to address them. It can also be used to respond to emerging environmental concerns and assess their impact on the environment. Thus, this facility will directly contribute to EMME-CARE research objective #1.

History: MoLa is a new facility that will be developed in the second half of the EMME-CARE project.

Outlook: MoLa will be a facility incorporated on a 4-wheel drive truck providing a key advantage for field experiments. It will include state-of-the-art instrumentation for measuring levels of GHG, reactive gases, and aerosols and will be able to deliver critical information on emission sources and atmospheric processes (fluxes, emission factors, chemical fingerprints) to a variety of urban and remote locations. The initial steps have been taken towards building this facility with an agreement between CARE-C and STARC (The Science and Technology in Archaeology and Culture Research Centre of the Cyprus Institute), which gave CARE-C the ownership of the STAR-Lab, a vehicle once used for archaeological research. This vehicle will be redesigned and refurbished to fit its new purpose. It will be equipped with 'fixed' instrumentation with provisional spaces for additional instruments according to specific campaign needs and purposes.

Provisions for national and transnational access: The MoLa facility will offer researchers from other national research and governmental institutes and international researchers the opportunity to access its state-of-the-art instrumentation allowing dedicated investigations of specific processes, species, or interactions in desired locations with provisions to add their own instrumentation. The Mola facility will also participate in intensive campaigns in the EMME region, either through shipping the whole container or specific instruments.

Possible links to national networks, industry: The Mola facility will be equipped with ACTRIS- and ICOS-approved instruments and thus will serve as a platform for these thematic RI within the national networks. In addition, Mola environmental monitoring services can be leveraged by the public and the private sector to detect emerging environmental concerns, for example, during forest fires or accidental industrial discharge or explosions.

Figure 13 - The mobile laboratory that will be refurbished into the MoLa facility.

5.3.5. The Environmental Chamber

Mission: The environmental chamber will have the capacity to perform experiments under simulated environmental conditions to facilitate greater understanding of field observations. It will further the understanding of various atmospheric processes such as the influence of air temperature, solar radiation, relative humidity, reactive gases and of radicals reactions on aerosols and the modification of their properties (physical, chemical, thermodynamical, optical). It will also have an educational goal: providing students and researches from Cyprus and elsewhere in the region with the training necessary for them to operate in more advanced chambers such as EUROCHAMP 200040 or the CLOUD chamber at CERN.

History: The environmental chamber is a new facility that will be developed in the second half of the EMME-CARE project.

5.3.6. The Environmental Chemistry Lab (ECL)

Mission: The Environmental Chemistry Laboratory (ECL) is a key component of the CARE-C center of excellence as it performs a wide range of analyses related to its field activities. It has very close links with the CAO, USRL, and generally with the Environmental Observations Department. This facility will support the long-term atmospheric monitoring programme, including field studies as well as the construction and long-term operation of a regional atmospheric network with high-quality offline gas and aerosol measurements.

History: Environmental chemical analyses services were performed by the Cyprus Institute "Facility for Chemical Analyses (FCL)" before establishing CARE-C's ECL. ECL currently uses the same infrastructure as the Cyprus Institute FCL but will relocate to its own laboratory in summer 2023 after constructing the CARE-C Building.

Outlook: ECL has a state-of-the-art infrastructure that allows it to perform a broad spectrum of chemical analysis on aerosol samples (such as ions, carbonaceous aerosols, trace metals, specific organic tracers, including polycyclic aromatic hydrocarbons, sugars, persistent organic pollutants). ECL will implement additional, advanced analytical techniques and develop training and services to become a regional hub for environmental chemical analyses. It will be supported by an ISO accreditation level, which has now become a prerequisite for (EU-regulated) air quality analyses. ECL services will be enhanced with multi-purpose liquid chromatography time-of-flight mass spectrometry to detect a broader range of organic aerosol species and tracers at high resolution. Additionally, the ECL will provide independent quality control for in situ GHG by offline GHG flask sampling utilising the ICOS recommended automated flask sampler and dedicated flask systems (Levin et al., 2020). Furthermore, the facility will be equipped with dedicated speciation techniques to measure bioaerosol (pollen, bacteria, spores). ECL will continue developing and implementing standard operating procedures (SOPs) according to EU environmental directives. It has already reached a very high level of development with SOPs audited several times per year by international organisations and networks (e.g., WMO and EMEP for ions, ACTRIS for carbon, IAEA for trace metals). The National Observatory of Athens (NOA) is helping ECL in getting the required ISO certification, and the process will resume after travel restrictions are lifted. In addition, the management of the facility will follow WHO set recommendations (WHO, 2011).

5.3.7. The DAta Centre (DAC)

Mission: The mission of the Atmosphere and Climate DAta Centre (DAC) is to facilitate access to state-of-the-art computational and data storage resources that will continually support the research goals and activities of both the Environmental Predictions and Environmental Observations Departments of CARE-C centre of excellence. CARE-C Research facilities will generate a mass of environmental data from observations and climate modelling simulation experiments (Figure 11) that will need automated processing according to quality control protocols (some of them performed in near real time), curation, and storage for further exploitation by different R&D departments and third parties. Based on the successful "SmartSMEAR" system (involving near real-time data and online visualisations; Junninen et al., 2009), and the SMEAR data web portal, DAC will provide well-documented open access to observational data and related process chains and flows. In addition, quality-controlled climate model simulation output will become publicly available in the context of FAIR and Open data framework (OpenAIRE) leveraging resources provided by DAC and in collaboration with the CyI High-Performance Computing Facility (HPCF).

History: The climate modelling division of CyI (now part of EPD/CARE-C) used to have direct access to dedicated, on-site, compute and storage resources prior to the establishment of CARE-C and DAC research infrastructure unit. The CyI HPCF, which officially hosts and maintains the DAC equipment, has recently been upgraded with new high-end dedicated storage and supercomputer clusters (e.g., Cyclone). These improvements coincided with the establishment of CARE-C. CARE-C researchers have access to enhanced computational resources after upgrading the CyI HPC infrastructure (Cyclone) into a Petaflop/s peak performance. It will thus facilitate the expansion of environmental and climate modelling activities, while maintaining the Cyprus Institute HPC Facility Cyclone supercomputer as the largest open-access computer in the EMME region.

Outlook: A Research Assistant was recruited mid of 2020 to help the processing (data mining and analysis) and formatting of the large CAO atmospheric database (following normalised standards) and its submission to (open access) international data repositories. The CARE-C atmospheric database is under construction with real-time visualisation website/mobile App planned to be launched in 2021.

The DAC infrastructure units located at the premises of the CyI HPCF have been upgraded with faster, high-end data storage with the installation of Cy-Tera II supercomputer cluster (Cyclone), which has been in production mode since April 2021. It is noted that our researchers (climate modellers) have secured additional computational resources on the Cyclone system through a competitive application process that will allow them to expand their climate modelling experiment portfolio. Furthermore, to be able to meet the near future anticipated increased storage resources and compute processing demand for environmental and climate model simulation data, the CyI HPCF administration, in collaboration with the Environmental Predictions Department (EPD), has proceeded with an additional upgrade/expansion of the HPC data storage units (June 2021). The existing HPC storage and computational infrastructure are projected to be sufficient to support the data storage and compute needs of our centre in the near future (roughly up to 2023). The anticipated EMME-CARE computer modelling activities will involve development and production runs including: i) coupled (atmosphere, sea, land, natural and managed vegetation) global and regional models to study feedbacks within the earth system that are relevant for the EMME; ii) high spatial resolution of dynamical climate change scenario downscaling, initially using existing modelling tools, and in future using the new ICON modelling system, to connect global with regional and local urban scales; iii) operational modification of the existing regional air quality and dust forecasting model (WRF), with custom-made applications in early warning systems for Cyprus and serving societal sectors. These applications will be further improved as the new ICON system becomes available.

Utilising committed EMME-CARE and Republic of Cyprus government funds, we plan to purchase new HPC equipment including storage and computational units. The proposed equipment will be purchased through a procurement procedure that will be initiated during the third quarter of 2021, in order for the equipment upgrades to become operational through the first quarter of 2023.

Figure 14 - Depicted are components of the DAC storage infrastructure and Cyclone supercomputer hosted by the CyI HPCF (Photo courtesy of CyI HPCF).

5.4. Integrating EU Research Infrastructure's Activities in Cyprus

5.4.1. ICOS

Benefiting from the major role of CEA in operating the ICOS Atmosphere Thematic Center, and the recruitment of two technical experts (working previously in the ICOS Department at CEA), CARE-C has established ICOS greenhouse gases measurements at CAO-CyI since beginning of 2020 while discussions on the optimal station location for conducting long-term GHG observations in Cyprus fulfilling ICOS criteria are still ongoing. The station in question will go through the official labelling process of ICOS once Cyprus officially joins the ICOS network. This labelling ensures access to services for atmosphere stations provided by the ICOS Atmosphere Thematic Centre. These services include: data processing, quality control performed by the metrology laboratory and mobile unit; software that centrally processes and quality-control the data from the atmosphere stations; regular survey, test and analysis of new measurement technologies for GHG and isotope instruments; graphical applications to provide NRT data products and services from the Calibration Laboratory; provision of calibration gases; routine measurement of integrated air samples with specific sampling equipment; analysis of flask samples for components that are not measured continuously at the stations (such as O_2/N_2 ratios, stable isotope ratios of CO_2 or 14C radiocarbon for estimates of fossil fuel CO_2); development of improved methodologies to determine fossil fuel CO_2.

On the institutional level, first contacts were established with the international affairs unit of ICOS where the administrative/political pathway towards integrating ICOS could be streamlined. ICOS is a landmark infrastructure that has the statutes of an ERIC since end 2015. Countries being members of the ERIC, the Cyprus country financial contribution was computed and a template for a formal application letter was provided. The total contribution of a country to ICOS is composed of three parts:

- The common basic contribution, identical for each Member or Observer country, has a fixed amount of 18,861.38 €.
- The common GNI-based contribution, for which each Member or Observer country pays a different amount according to its GNI.
- The station-based contribution, for which each Member or Observer country pays a different amount according to the type, class and number of stations. The number of stations can be revised every year in June for the following year. The final annual contribution of a country results in the sum of the previously mentioned amounts.

In the coming months, the application for an integration into ICOS will be established for a presentation to the responsible Cypriot ministries, mainly the Ministry of Research, Innovation and Digital Policy and the Ministry of Agriculture, Rural Development and Environment.

5.4.2. ACTRIS

ACTRIS is currently rank first of the Cyprus roadmap for ESFRI projects with strong support from the Cyprus Government (DGEPCD) to support it financially (annual membership). CyI/CARE-C (J. Sciare) is acting as the national contact point for ACTRIS and has organised the kick-off meeting of H2020-ACTRIS-IMP in Larnaca in March 2020 (a week before the lockdown). CAO and USRL are part of the ACTRIS network of national facilities and are receiving EU financial support to perform TransNational Access (TNA) in the framework of H2020-ACTRIS-IMP (started beginning of 2020) and H2020-ATMO-ACCESS (to start beginning of 2021).

5.4.3. eLTER

The integration into eLTER was discussed in the WP4 meeting on September 25th, 2020. Membership to eLTER Europe is challenged through national network of institutes and scientists. Therefore, the first step is to establish national connections to the relevant Research Performing Organisations in this field within Cyprus and subsequently approach national funding structures, such as ministry of Environment. After national discussions, a letter indicating a request to join eLTER Europe should be submitted to the Chair of LTER Europe.

5.4.4. BSRN

The BSRN (Baseline Surface Radiation Network; https://bsrn.awi.de/) network, developed by the World Meteorological Organization (WMO), is the most internationally prestigious solar radiometric network and was initiated by the World Climate Research Programme (WCRP) of the WMO. The objective of the BSRN is to provide observations of the best possible quality for short- and long-wave surface radiation fluxes with a high sampling rate to detect important changes in the Earth's radiation field at the Earth's surface, which may be related to climate changes. Within the past two years, the Cyprus Institute has upgraded the capabilities of its Platform for Research, Observation, and TEchnological Applications in Solar energy (PROTEAS) to measure solar radiation and other meteorological variables of interest by defining, designing, procuring, and erecting a BSRN station. The PROTEAS BSRN station has been equipped with state-of-the-art solar radiation sensors attached on a high-end sun tracker, able to measure the Direct, Diffuse, and Global solar irradiance as well as the down-welling infrared radiation. Apart from solar radiation sensors, the station is also equipped with high-end meteorological sensors, including air temperature and humidity sensors, wind speed and wind direction sensors, atmospheric pressure, and accumulated precipitation sensors. Moreover, the station has been expanded beyond the BSRN requirements by installing a sky imaging camera that complements the solar radiation measurements and facilitates assessing their quality. The PROTEAS BSRN station will enable access to high-quality data that various research departments can utilise to validate and evaluate satellite-based estimates of the surface radiative fluxes, compare climate model calculations,

and develop representative radiation climatologies for cloud absorption modelling, forecasting, and other modelling activities. These advances in observation capabilities are crucial for the research carried out by the CyI/EEWRC/Energy Division and for increasing co-located measurements and complementing CARE-C's RI.
The PROTEAS BSRN candidacy has been successfully defended by Dr. Kypros Milidonis on the BSRN 2020 Virtual Workshop (October 1st, 2020) and currently has a ''pending'' status. It is envisioned that the PROTEAS BSRN station will be established as a full member of the BSRN at the next biennial BSRN meeting.

5.4.5. TCCON

A TCCON (Total Carbon Column Observing Network, http://www.tccon.caltech.edu/) station for long-term observations of GHG has been set up at CAO-CyI and is operational since September. This station provides the first-ever standardised and high-precision continuous data of column-integrated greenhouse gases (CO_2/CH_4/N_2O) observations in the EMME region and will operate for more than ten years to uncover the long-term trends of GHG in the region. These measurements will feed the ongoing Ph.D. project "Temporal variability and sources of Greenhouse Gases in the Eastern Mediterranean Region" co-supervised by CyI and Univ. Bremen. They are further used to calibrate the NASA OCO2 and OCO3 satellites. In parallel to the TCCON measurements, five (5) vertically-resolved GHG measurements (up to several tens of km altitude) were performed by the mean of "AirCores" flights. These flights were achieved in collaboration with colleagues from CEA and the French AirCore (AC) program. The AirCore in-situ GHG profiles are used to further validate TCCON observations. They provide an additional constrain for the validation of atmospheric transport models.

5.4.6. CTBT

Comprehensive nuclear-Test-Ban Treaty Organization, https://www.ctbto.org/). Initial contacts were taken with CTBT at their Austrian Headquarter back in Spring 2018. The Government of Cyprus (Ministry of Foreign Affairs) has been mobilised to integrate this network and (through the Department of Meteorology) will operate (at no cost) an infra-sound system in Cyprus in the next couple of months. This system will allow a better investigation of the atmospheric dynamic of the upper atmosphere, which is very relevant for EMME-CARE/CARE-C. The deployment of a radionuclide monitoring station in Cyprus is currently under discussion.

5.4.7. AGAGE

The AGAGE network is a global measurement network of GC-MS instruments coordinated by Prof. Prinn (MIT) and Prof. Weiss (Uni. San Diego). The focus is on organohalogen compounds, particularly those regulated by the Montreal Protocol and subsequent replacement species. In addition, several other globally relevant species are measured. The network has a reputation for extremely high-quality measurements and regularly produces high impact publications.
A meeting was set up on November 25th to discuss joining the network. The coordinators were very interested and supportive of the proposal. The location of the proposed instrument would be on the west coast main measurement site, which is in the outflow of western Europe, eastern Europe (from where fugitive methyl chloroform emissions have been previously seen), and even Arabia. Co-ordinates of CAO-PEY site were given to Prof. Prinn, and he intends to run back trajectory simulation to assess the site footprint.
The AGAGE coordinator mentioned that they had agreed with Aerodyne Research Inc. to produce the Medusa Cryogenic preconcentrator. This preconcentrator is combined with a GC-MS to make the AGAGE measurement, and the entire package is under development. In January 2021, we contacted Doug Worsnop, head of Aerodyne. He informed us that Aerodyne would sell this instrument as a

package, probably starting at the end of 2021. Standard gases are supplied to all members of AGAGE by Scripps.
Given the current delay in building up the CAO monitoring sites and the development of the commercial package, this instrument is not a priority purchase in the first stages of EMME-CARE. Nevertheless, it would be an excellent addition to the second wave of investments once the measurement site infrastructure is established.

5.5. Technical Training and Staff Exchange

The most important RI resource is competent, motivated personnel. The RIU will support the development of its personnel and provide opportunities for continuing education. The type of training differs depending on the RI facility in question and the employees' specific duties. However, common training material will be available to all operators, mainly those concerning safety practices and techniques. Some of these materials will be provided as online short courses.

In collaboration with the advanced partners, the heads of RI facilities will outline the specific training needs for the personnel within each facility. Together, they will draft a long-term training program taking advantage of training opportunities offered by Thematic RIs and organising custom workshops based on the facilities needs. The training material of these workshops will be archived for later use, and when possible specific training sessions will be recorded. Ideally, a portal will be created containing all training material, operation instructions, calibration procedures and troubleshooting guidelines.

The agenda for the completed and planned staff exchange for the first 24 months of the project are presented in the below Table, while a list of potential training opuurtunities is presented in the Annex. Planning for the upcoming period related to trainings has been limited due to existing COVID-19 restrictions, that do not allow for big group staff exchanges.

Agenda for CARE-C staff exchange and training (completed and planned)				
Research Facility	**Name**	**Location of training**	**Dates**	**Training information**
CAO	M. Pikridas	Lebanon	01.05 - 15.05.2019	Training on source apportionment given by CARE-C's researcher M. Pikridas to Saint Joseph University students
CAO	C. Rousogenous (PhD)	Univ. Bremen, Germany	27.08 -12.09.2019	Operation, troubleshooting and data management of the Michelson interferometer used in the TCCON network
CAO	A. Orgun (Tech. Res.)	French National Network for Aerobiological Surveillance (RNSA)	13-24 .01.2020	Recognition and counting of pollens using certified optical techniques
CAO	P-Y. Quéhé (Tech. Res.)	CEA, LSCE, Gif/Yvette, France	24-28 .02.2020	Aircore / vertical profiling of GreenHouse Gases

USRL	M. Kezoudi (Post-doc)	ETH, Zurich, Switzerland	25-28 .02.2020	Operation of the COBALD atmospheric sensor for UAV application (ESA-Aeolus project)
CAO	M. Pikridas D. El Hajj	Online organised by NILU	24-26.06.2021	Training on ebas flagging for aerosol instrumentation
CAO, INL	Michael Pikridas Fabian Schmidt-Ott Panagiotis Stagianos	CCC, UH, Helsinki	20.09-01.10 .2021	Calibration, operation and maintenance of nano-Condensation Nucleus Counters and Neutral and Air-Ion Spectrometers - mobility particle size spectrometers

5.6. Plan for Data Management and Digital Platforms

The data management plan for the newly established "CARE-C" Centre of Excellence (CoE) has been presented in D9.3: *Data Management Plan (Open Data Pilot)*. It details the overall approach for producing, collecting and processing research data for CARE-C's Research Departments and the RI facilities. The Data Management plan abides by the Guidelines on FAIR Data Management in Horizon 2020 and The European Code of Conduct for Research Integrity. In this section, we present information about the data collected within the RIU and data sharing provisions.

5.6.1. Description of data

Considering the wide range of activities carried about by the RI facilities, the data collected are of diverse types and file formats. Here we list the most common types of data encountered:

- Observational data collected from in situ measurements of atmospheric and Earth surface processes, like concentrations, compositions and fluxes of greenhouse gases, trace gases and aerosols, terrestrial and aquatic ecosystem processes, and meteorological parameters. These data are frequently stored as tables of whitespace or comma-separated ASCII (American Standard Code for Information Interchange) plain text. Few instruments that produce vast amounts of data record the data in binary data formats such as NetCDF(network Common Data Form) or in hierarchical data format (HDF). Alternatively, processed observational will follow the format defined by the respective thematic RI. For example, data submitted to ACTRIS will be saved as ASCII, which is the format defined by EBAS (ebas.nilu.no). ICOS and WMO databases also use the ASCII comma-separated values (.csv) format
- Satellite observations which are generally open and freely available, as the space agencies are archiving and distributing the satellite data products at different levels (typically Level 1b, 2 and 3 data). The satellite data sets are typically provided in HDF or NetCDF formats
- Earth system and climate models data available in the 4-D output of multimodel systems, including atmospheric, oceanic and biospheric data and specific submodule data. These are a combination of Network Common Data Format (NetCDF), HDF and GRIdded Binary form (GRIB) file formats
- Experimental data collected in a laboratory. These include manual entries into paper or digital forms and notebooks as well as equipment-generated records of a format specific to the instrument manufacturer
- Documentation data or Metadata which provide information about other data or are are essential to understanding a dataset.

5.6.2. Documentation and quality

Documentation of data involves technical documentation for contents and interpretation of the data and administrative metadata that describes the ownership and terms of use for the data.

- Environmental data will be documented so that it is compatible with the COPERNICUS (Global Monitoring for Environment and Security), GTOS (Global Terrestrial Observing System) and GEO-GEOSS (Group of Earth Observations-Global Earth Observation System of Systems) standards.
- Experimental design, instrument setup and raw data formats of observation data are documented in commonly used file formats on data servers and infrastructure databases.
- Field documentation, such as instrument maintenance and calibration records, are documented using the electronic logbook software, accessible with web browser. The underlying file format is plain text, and there is also a possibility to export in commonly used file formats, such as .csv or .xml and save attachments, of any file format. Other field documentation is also saved in widely-used formats; ASCII or Unicode standard (UTF-8) encoded text, portable document format (.pdf), Microsoft (MS) Word documents, MS Excel or OpenDocument spreadsheets.
- Documentation of data processing procedures is saved with the processed data and documented with online tools such as wiki. Processing software/scripts and software for reading proprietary data formats are also archived and opened if the original licence allows redistribution.
- Processed end-user data include essential technical documentation in the files as header lines or in a more structured way that allows for a complete metadata presentation (e.g. HDF).
- The climate model data and the satellite data in NetCDF and HDF formats support the inclusion of metadata in the file structure. The climate model annotates relevant metadata during runtime: time of the experiment, global model attributes, details on parameterizations. Further post-processing of NetCDF files will include details on types of post-processing in the file itself as a diary.

Ideally the metadata collection will follow the standardized procedures within each domain. In case standard procedures for collecting metadata do not exist, the provisions will be made to collect the following classes of metadata descriptors :

- Data set descriptors: Basic information about the data set (e.g. data set title, associated scientists, abstract and keywords, coordinates of measurement, height of measurement, station code, station name, measurement type, measurement domain, parameters measured, units of parameters measured, date and time of measurement, time interval, time zone,)
- Research origin descriptors: All the relevant metadata that describe the research that generated the data set (e.g. hypotheses, site characteristics, experimental design, and methods)
- Data set status and accessibility descriptors: The status of the data set and associated metadata (e.g. data quality, data version) and information related to data set accessibility.
- Data structural descriptors: All attributes related to the physical structure of the data file (e.g. file size, number of headers, file delimeter, column descriptors, data format, flags)
- Supplementary descriptors: All other related information that may facilitate secondary usage, publishing and auditing of the data sets (e.g. type of software used to generate the data, equations used in some calculations, citation of a relevant paper, maintenance logs of instruments)

In addition, the responsible persons within each RI facility will evaluate the applicability of using a Metadata generation tool such as the EPA Metadata Editor or if they need to create a custom program to create Metadata using, for example, MATLAB® or other programming languages. Finally, they will create custom unique file identifiers for raw data created within each RI, following standard rules if those exist. Otherwise, the identifiers will at least contain the location, date and time of measurement, and type of measurement.

In terms of data quality, relevant measuring protocols, such as WMO, ACTRIS, ICOS and eLTER standards, will be followed whenever possible to produce data consistent with other environmental research networks. All observational data are quality-checked frequently by RI staff and responsible researchers. Controlling large amounts of data is possible with the aid of extensive automated online processing with preliminary quality control and production of diagnostic graphics and log files for further quality check by human. If necessary, responsible researchers and technicians reprocess the data to final quality-checked datasets.

5.6.3. Storage and backup

The initial storage of observational data and field documents takes place on instrument computers at the research stations. All data are copied daily or more frequently to a secure central repository which can be accessed through the CyI network. For redundancy and quick access by the station staff, copies of data are kept on the stations as long as it is economically feasible. The original observational data and documents are stored on servers where only a few persons have writing access. There are separate user accounts for the station staff and data managers on these servers, for the researchers who use the data, and for automated data processing. Working copies of the data are kept outside the primary data storage to reduce the need to access the original data, for instance, using cloud services with more flexible access control.

5.6.4. Data sharing and long-term preservation

The observational data generated within CARE-C will become available following the FAIR guiding principles. End-user data from continuous environmental measurements will be openly accessible in near real time (when possible) through the CAO website. Data collected under thematic RIs will be made available primarily via the central facilities of the infrastructures: Carbon Portal (ICOS), World Data Centre for Aerosols (ACTRIS) and DEIMS (eLTER). As much as possible, the EUDAT (European Data Infrastructure) services (B2DROP, B2SHARE, B2SAFE, and B2FIND) will be used for data storage and distribution.

Campaign data will be shared from the RI's databases and whenever possible from Thematic RI databases or through EUDAT services, latest during publication of scientific papers on the data. The original raw data that is not directly usable in Earth system research will be available upon request via contacts to the PIs.

The climate model simulation data will be available via the DAC infrastructure. Access to the publicly available datasets on the CyI HPCF/DAC systems will require a (simple) registration procedure, where the user will be asked to provide a name, email, and a reason for using the data (e.g., via an End-user agreement), through a user-friendly webpage interface. Specific model datasets will be saved in trustworthy repositories (e.g. Zenodo or B2SHARE) and published as part of publications. The rest of the data are available via contacts to the PIs.

5.6.5. Websites

A CoE website was created since the start of the EMME-CARE project. It is continuously updated and improved according to the plan presented in *Deliverable D9.1: Consolidated and Upgraded Website for CoE*. The website showcases, among others, CARE-C's research facilities and links to dedicated web pages for each facility. These web pages are under construction and will be updated to follow the structure of USRL website (https://usrl.cyi.ac.cy/), with increased multi-media contents, technical information and links to data portals. Additionally, an Environmental Data webpage with a data visualization tool to display weather and air pollutant observations in close to real-time has been created and is under development. Further information on this subject can be found in *D9.4 First Annual Report contents of the PDER, knowledge and data management, and IPR protection, communication, outreach & public engagement*.

6. Sustainability

The long-term sustainability of Research Infrastructures is a policy priority for the European Commission, which have launched targeted consultation and a call for action towards sustainable European research infrastructures (EU, 2017). The working group have identified the pre-conditions and challenges for developing sustainable RI. The sustainability challenges in relation to CARE-C RIU are:

- Ensuring scientific excellence (e.g. investment in cutting-edge instrumentation) with the support of the Environmental Observation/Prediction Departments for dissemination
- Attracting and training the managers, operators and users of tomorrow
- Unlocking the innovation potential of RI with the support of the CARE-C Innovation Department
- Exploiting the data generated by the RI and in particular maximize the utilization rate of Facilities (e.g. provision of TransNational Access)
- Structuring the International outreach of RI for enhancing visibility and reputation
- Develop new products and services that will contribute to generate and diversify revenues and sustain the long-term operation of the RI

The Deliverable at hand has introduced the RIU strategy and roadmap in relation to the above mentioned challenges.

7. Updated Risk Management Plan for the RIU

Description of Risk	Proposed risk-mitigation measures (contingency plan)
Staff recruitment plan does not meet targets (quantity/quality) Probability: medium-to-low. A specific programme has been designed to enhance the attractiveness of the CoE. Excellent past experience will improve because of induced prestige. Severity: high. Advanced Partners will temporarily support the development of the CoE.	Related to HR Recruitment & Mobility Programme (WP# 2) Short-term measures: 1) Revise and consider a more proactive recruitment strategy (headhunting, publicity, and involvement of recruitment firms); 2) Better engage Advanced Partners and their respective networks; 3) Extension of the “Living Laboratory” Programme. 4) Review the cause critically and redefine hiring strategy, including remuneration aspects.
Construction of CARE-C premises is delayed, compromising the development of the new CoE Probability: Medium. This construction is a prerequisite for the establishment of the new CoE.	Related to Physical & Research Infrastructures (WP# 4) Construction of CARE-C Headquarter building at Athalassa: 1) Adjust investment plan (between building and equipment) to temporarily redirect funds

Funds and admin support will be available from day one to address this issue Severity: Low (short-term). CyI premises capacity can temporarily act as a buffer.	to building; 2) Rent in nearby location commercially available space. 3) Activate contingency plan for accommodating temporary CoE staff in CyI premises. Construction of the Cyprus Atmospheric Observatory (CAO) at Peyia: Maintain CAO at Agia Marina Xyliatou (postpone transferring instrumentation to Peyia).
Funding shortage Probability: low Severity: high	There is a strong national and European commitment for the CoE and development towards a regional science hub is rapid. If needed, financial resources could be redirected among budget lines to fund rising needs of Research Infrastrcture.
Lack of interoperability and coordination between research stations owned by different organisations Probability: low Severity: medium	Open and inclusive dialogue between the different organizations. Support from the Advanced partners in initiating the discussions and providing guidance.
Shortage of qualified people (scientific staff, technical support staff) Probability: medium Severity: high	Active recruitment strategy, utilizing the connections provided by the advanced partners to attract staff to Cyprus.
Continuing COVID-19 pandemic Probability: high Severity: medium	Lockdowns influencing operation and development of infrastructures, long term monitoring and observation campaigns. Detailed planning can be conducted remotely. Local work can be phased to proceed in small teams. Non-critical steps can be postponed.

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ANNEX I

Table A1. Potential staff exchange, training and conference opportunities.

Type	**Research Facility /organisation**	**Name**	**Location**	Dates	**Topics**
Conference	University of Granada	The 3rd edition of the European Lidar Conference (ELC)	Granada, Spain (hybrid format)	16-18.11.2021	Lidar technology– Lidar algorithms and data products– Lidar applications –challenges –synergies –open forums.
Conference	SPIE remote sensing	Remote Sensing of Clouds and the Atmosphere XXVI	Madrid, Spain	13-16.09.2021	remote sensing– radiative transfer– lidar, radar, and other active and passive atmospheric measurement techniques and technologies – applications
Course	UH/ACTRIS	Atmospheric observations of aerosols, clouds and trace gases	Hyytiälä, Finland	Yearly in May	In-situ measurements and ground-based remote sensing techniques of aerosols, reactive trace gases, and clouds.
Course	Météo-France and WMO	Climatology, foundation for climate services		annual	The latest state of the art technologies and best practices in climatology
Course	ICOS ERIC, ICOS Carbon Portal and ICOS Finland.	The 5th ICOS Summer School "Challenges in measurements of greenhouse gases and their interpretation."	Hyytiälä, Finland	9-17.12.2021 (organised every second year)	Ecosystem fluxes and measurements– Atmospheric composition and measurements (in-situ and remote sensing)– Modelling of the global climate, carbon cycle, atmospheric transport and chemistry – Data management and cloud ('big data') methods
Conference	ICOS	ICOS Science Conference 2022	Utrecht, the Netherlands.	13-15.09.2022	Greenhouse gases and biogeochemical cycles.
Course	Hellenic Aerosol Research Company	Theory and practice of aerosol chemistry and engineering for climate, air quality, emissions and health effects	Navarino Environmental Observatory, Greece	Annual	In-situ instruments for measuring the concentration, size and chemical composition of atmospheric particles– systems for probing the vertical distribution of the atmospheric aerosol– new integrative approaches using models and observations for impact assessment.

Course	GAWTEC	Global Atmosphere Watch - Training & Education Centre courses	Environmental Research Station Schneeferner haus, Germany	twice a year	consist of lab courses, measurement techniques, data evaluation and theoretical background of atmospheric physics and chemistry
Workshop	Aerodyne	Aerosol Mass Spectrometer user meeting		Annual	Usually includes: tutorials on AMS use and data analysis– latest technical developments– software and hardware development – presenting data from around the world
Workshop	Aerodyne	CIMS user meeting		Annual	Usually includes: tutorials on CIMS use and data analysis– latest technical developments– software and hardware development – presenting data from around the world

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 856612 and the Cyprus Government