GreenDIGIT Project Progress and Updates

Welcome to the 2nd edition of the GreenDIGIT Newsletter! In this issue, we bring you the latest updates from our ongoing efforts to enhance sustainability and open science within Research Infrastructures (RIs). Below, we highlight key progress made in the ongoing Work Packages (WPs). A comprehensive description of the general scope / targets, as well as the analytical action points of GreenDIGIT project are given in 1st newsletter.

1. Introduction

The GreenDIGIT project addresses key sustainability challenges, focusing on Energy Efficiency, Decarbonisation, and Reducing Environmental Impact within Digital RIs. The following list provides an executive summary of GreenDIGIT's objectives.

- **O1: Assess the status and trends** of low impact computing within 4 DIGIT RIs (EGI, SLICES, SoBigData, EBRAINS) and wider ESFRI community, to produce recommendations and roadmaps for RIs green transition.
- **O2: Provide reference architecture and design principles**, reflecting on the **whole RI lifecycle** and including the digital infrastructure components.
- **O3: Develop new and innovative technologies, methods, and tools** for digital **service providers** within European Research Infrastructures.
- **O4: Develop and provide for researchers the tools** to support the design and execution of environmental sustainability aware scientific applications with Open Science and FAIR data management considerations.
- **O5: Educate and support RI service providers and researchers** about good practices on environmental impact conscious lifecycle management and operation of infrastructures and services.

2. (WP3) RI Survey and Landscape Analysis for Sustainability and Impact Reduction

The work of **WP3** focuses on evaluating the environmental friendliness of participating RIs and mapping the broader landscape of digital service providers across Europe. This includes surveys, interviews, desk research on best practices, and the development of metrics to assess and monitor sustainability in digital services.

Based on the objectives of WP3, Deliverable 3.1 (***'Landscape review, best practices analysis, and identification of needs within the ESFRI RIs'***) has submitted and published in November 2024, providing a comprehensive overview of existing sustainability practices, metrics, and gaps in digital RI operations. Building on these findings, WP3 is now developing an impact assessment methodology to monitor, assess, and quantify the environmental impact of RIs, along with guidelines for sustainability practices across the RI lifecycle phases (Concept development, Design, Preparation, Implementation, Operation, Termination). These will be detailed in Deliverable 3.2, due in August 2025.

As part of this effort, WP3 has identified three key **environmental impact categories** to be assessed in the methodology: **Climate Change** (Kg CO_2 eq), **Cumulative Energy Demand** (Joule [J] of primary energy demand), and **Resource Depletion** (Waste, inluding WEEE). These categories will be assessed across the **implementation, operation, and termination** phases of RIs. Currently, work in ongoing to define **impact metrics** to be used across the GreenDIGIT project, which will also be aligned into the WP3 methodology. The next phase will involve **implementing use cases** with participating RIs (**EGI, EBRAINS, SoBigData, and SLICES**) to test and validate the methodology, aiming to bring it to **TRL6**.

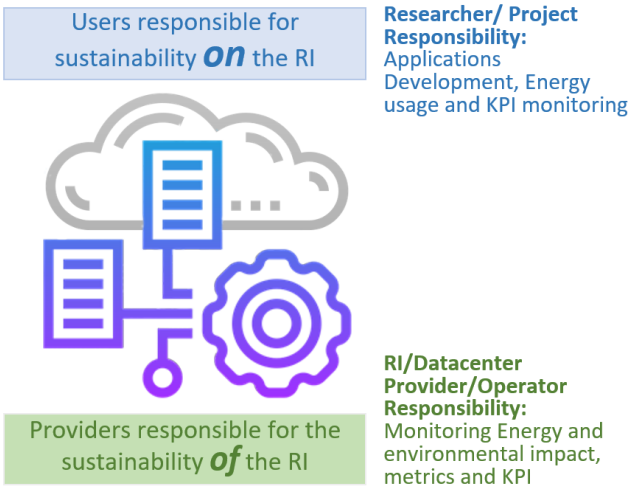

Figure 1: GreenDIGIT novel Approach - Shared Responsibility in Sustainability and Sustainability by Design

3. (WP4) Architecture and Requirements Specification for Sustainable RI

Following, **WP4** explores the current **state-of-the-art in sustainable technologies, architectures, and practices** within the digital domain and aims to propose practical recommendations for both providers and users. The goal is to develop a **sustainable RI architecture** with reduced, **measurable environmental impact**, supported by clearly defined **technological requirements** for its digital components.

Initially, significant progress has been marked on WP4, as the Deliverable 4.1 (***'State of the Art in RI and digital infrastructure sustainability and technologies assessment for energy efficiency and impact'***) has submitted and published in February 2025. There, the presented State of the Art (**SotA**) analysis provides a comprehensive overview of existing **technologies, methodologies, and best practices** for improving energy efficiency and enhancing the sustainability of scientific computing and digital RIs. This also serves as a foundational study for **WP4, WP5, and WP6**, supporting the design, development, and deployment of GreenDIGIT's sustainability-oriented frameworks and tools addressing aspects such as energy efficiency, carbon-aware computing, sustainable data management, and research reproducibility.

Furthermore, **WP4** contains the significant and intense efforts given for the **Architecture** development. It is worth noting that architecture is a way to **coordinate, synch and unite**:

- *Developers of Infrastructure and Applications*
- *Operators*
- *Users/Researchers*
- *Decision makers*

and refer to TOGAF architecture principles (as an approach accepted by the majority of businesses). The architectural designed is being carried out through the general view on the RI optimisation and Green IT, based on sustainable architecture design principles and with correlation to existing Standards / Regulations.

At this point through the work conducted in WP4, GreenDIGIT develops and proposes a **novel and consolidating** approach for **Shared Responsibility in Sustainability and Sustainability by Design**, which is depicted in Figure 1). This approach comes with some challenges which can be summarized in the list below:

- **Architecture for Sustainability by Design**
  - *Functional components, layers, API, Requirements*
  - *Sustainability Architecture Design Principles (SADP)*
- **Software and application components that can be optimised during design and controlled during operation**
  - *Energy Efficient Software Design*
  - *Green aware API including necessary energy, performance, environment information*
- **(!) Common information/data model and metadata (naming)**
  - *Including Requirements, KPI, Metrics*
  - *Metrics and Metadata Registry*
  - *Federated monitoring infrastructure*
  - *Create a basis for research reproducibility*
    - + FAIR for Sustainability
- **RI and applications lifecycle**
  - *RI lifecycle stages (concept, design, development, deployment, operation, termination) and scientific workflow and research data*

Finally, systematic work has been also carried out from WP4 task leaders and partners on identifying the list of metrics that will be used in the upcoming **WP6** and **WP7**.

4. (WP5) Tools for energy efficient, reproducible Open Science

WP5 is focused on improving open, reproducible science and data management for experiments conducted on RIs. Ensuring data is Findable, Accessible, Interoperable, and Reusable is a key focus (**FAIR**). This involves developing strategies for data curation, metadata standards, and long-term preservation. Optimizing data workflows within RIs is crucial. This includes data collection, processing, analysis, and sharing, while maintaining reproducibility. WP5 aims to enhance the reproducibility of

RI-based research. This involves promoting open access to data, code, and methodologies, as well as developing tools and platforms for reproducibility. Encouraging open access publishing of research outputs is a priority. This increases the visibility and impact of RI-based research. Developing and utilizing robust data repositories and platforms is essential for data sharing and reuse. This includes exploring cloud-based solutions and interoperability between different platforms. WP5 will support the development and adoption of software and tools that facilitate open science and data management within RIs. Fostering collaboration between RIs, researchers, and other stakeholders is crucial for the success of WP5. FAIR and Open Science principles reflect in the design and implementation of all aspects covered by WP5.

WP5 is developing a web-based virtual research environment that researchers can use to perform reproducible experiments on the RI. Plugins, e.g., on the basis of Jupyter Notebooks, will guide users access to reproducible workflows across the whole experiment lifecycle. Automated energy data reports and prediction are currently being developed, to assess ecological footprint of scientific work. Results obtained in such sustainable testbeds can be shared and accessed in a federated data management infrastructure.

5. (WP8) Policy first recommendations for sustainable RI

WP8 focuses on assessing current policies and regulations related to the environmental impact of Research Infrastructures (RIs), identifying existing gaps, and proposing actionable improvements to enhance sustainability, especially for digital RIs. Through T8.1, a thorough review of the regulatory landscape to pinpoint discrepancies between current frameworks and the project's sustainability goals has been conducted. In close collaboration with related tasks and work packages, this analysis will guide the development of practical tools and recommendations for advancing greener RIs. Building on these insights, T8.2, a self-assessment questionnaire that will help RIs evaluate their sustainability practices and connect them with actionable strategies based on WP3 guidelines, is being now designed. Meanwhile,

The actions above, will draft policy recommendations aimed at RIs, European strategic initiatives (like ESFRI), and policymakers, promoting a more sustainable framework for research infrastructures. These recommendations will also explore the concept of a GreenRI certification, setting the stage for its deeper development in the subsequent phases of the project.

5. (WP10) Initial Outreach and Community Engagement

Finally, over the past months, the consortium members have been actively engaged in a variety of dissemination and outreach activities to promote the results and vision of our project. GreenDIGIT's partners have participated in numerous international conferences, workshops, and public events, presenting key findings and engaging with stakeholders from both academia and industry. Important results have been produced in various formats, ensuring the scientific visibility of the project outcomes. In addition, members have contributed to public talks, webinars, and community events, fostering broader awareness and dialogue with diverse audiences. These collective efforts have significantly enhanced the project's visibility, strengthened collaborations, and laid the foundation for future impact and innovation. In addition, by taking into consideration the progress of the project, the consortium has organized open-sessions for the widespreading the objectives and the progress of GreenDIGIT.

6. Supplemental material

- All the submitted deliverables can be found at: `https://greendigit-project.eu/deliverables/`
- Follow our social media pages and stay updated:
  - LinkedIn: `https://www.linkedin.com/company/greendigit-eu/`
  - X: `https://x.com/GreenDIGIT_EU`