D7.4 Green Computing progress and improvements within EGI-ACE

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Deliverable Abstract
This is the report produced by EGI-ACE Task 7.2 and the EGI Green Computing Task force (established by Task 7.2 with the goal of facilitating awareness of Green issues amongst EGI-ACE partners and overall improvements in Green initiatives). It covers an overview of the activities of the T7.2 working group and Green Task force focusing on the development of detailed objectives, actions undertaken to fulfil those objectives, along with appendices providing details of the surveying activities and responses. It closes with overall conclusions and recommendations.

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TERMINOLOGY

Terms used in this document are defined at https://confluence.egi.eu/display/EGIG

Other specific terms are listed in the table below.

Terminology/Acronym	Definition
EGI-ACE	EGI Advanced Computing for EOSC
PUE	Power Usage Effectiveness
ICT	Information and Communications Technology
GPU	Graphic Processing Unit
EOSC	European Open Science Cloud
CO_2e	Carbon dioxide equivalent
CPUh	CPU hours

Contents

1 Executive summary

The key raison d'etre for T7.2 is to make EGI-ACE greener. In order to achieve this the project established the EGI Green Computing Task force with the goal of facilitating awareness of Green issues amongst EGI-ACE partners and to achieve overall improvements in Green initiatives. The working group focused upon:

- Discovering existing good practice already being undertaken by the project partners
- Knowledge dissemination amongst partners (particularly in relation to the existing good practice)
- Measuring key metrics to illustrate progress relating to Green computing over the lifetime the project.

Activities undertaken with these aims in mind were:

- Survey
- Taskforce
- Signposting
- Webinars

Conclusions and overall recommendations:

- There are pockets of good practice amongst the partners.
- Overall engagement in the whole EGI federation is low, larger initiatives are needed to gain momentum.
- A multi-faceted approach, combining reward and compulsion alongside enabling activities/policies is recommended to combat this. Broadly speaking this could be expressed as:
    - Build upon the current knowledge sharing activities.
    - Facilitate the adoption of green initiatives and practices.
    - Incentivise the adoption of green initiatives and practices.
    - De-incentivise non green activities and non-adoption of green initiatives and practices.

2 Introduction

2.1 Context

EGI-ACE[1] is a 30-month project (Jan 2021 - Jun 2023) with a mission to empower researchers from all disciplines to collaborate in data-intensive and compute-intensive research through free-at-point-of-use services that are delivered through European Open Science Cloud (EOSC).

By building on providers from the EGI Community, EGI-ACE delivers:

(1) the EOSC Compute Platform (ECP)[2], a federated system of compute and storage infrastructure extended with platform services to support diverse types of data processing and data analytics cases. The ECP currently includes High Throughput Compute (HTC) and Cloud Compute facilities and will broaden its scope with High Performance Compute (HPC) services later in 2022. The platform layer of the ECP provides assistance for single sign-on, for the transfer and federation of distributed data, for interactive computing, for the management of large number of jobs, for the orchestration of compute clusters, for Artificial Intelligence (AI) and Machine Learning (ML) tasks. Approximately half of the services of the EOSC Compute Platform are 'EGI Foundation' services (in other words, governed and managed by the EGI Foundation), the rest are contributed by the EGI Community.

(2) A growing portfolio (currently 20) of thematic services (data spaces and data processing platforms) that integrate data and applications from different scientific disciplines into the ECP for the scalable analysis and exploitation of scientific datasets. Moreover, 17 additional thematic services, from outside the consortium, are also available via the EOSC Portal[3] because of support received from the ECP. All the thematic services are provided by the EGI Community outside the EGI Foundation service management scope.

A key aspect of the service delivery where the EGI-ACE project can provide guidance relates to Green Computing (GC): by maximising the positive environmental benefits and minimising negative impact of data centres the project aims to reduce the ICT footprint of activities within the EGI Federation and within the computing infrastructure of EOSC in general. This will in turn reduce the overall carbon footprint and pave the way to the implementation of efficiency improvements, environmental friendliness and ultimately cost and energy saving measures (energy saving is particularly timely given the current worldwide energy crisis) at data centres.

In order to achieve these goals, the project task WP7.2 has been working to raise the awareness of GC amongst the participants of the project: the creation of a Green Computing Task Force (TF) was an important milestone to start the involvement of the partners in the Green Computing activities and to bring all together to work on best practices guidelines, disseminate knowledge across the project and beyond, circulate surveys to assess the

[1] https://www.egi.eu/projects/egi-ace/
[2] https://www.egi.eu/eosc-compute-platform-services/
[3] https://www.eosc-portal.eu/

status of and verify the progress and the improvements of measures for reducing energy consumption in data centres, organise training and workshops events.

2.2 Approach

The first task of the work package team was to consider what we could achieve in the time scale allowed, and having set our target, the most appropriate methods we could use to reach that target.

The overall goal for the package can be summarised as “make EGI greener than it currently is”. From this starting point we established five key elements/activities we could undertake to facilitate that core goal:

- Baselining
- Awareness raising
- Seeking out good practice
- Sharing good practice
- Measuring progress

These could be loosely grouped as:

- Good practice
  - Seeking out good practice—finding and categorising good practice both amongst partners and possible beyond
- Knowledge dissemination
  - Awareness raising—both amongst the project partners and beyond
  - Sharing good practice—both amongst the project partners and beyond
- Metrics
  - Baselining partner activities
  - Measuring “Greening” progress over the lifetime of the project

2.2.1 Baselining

A base line of current activities that could be interpreted as “green” in nature was felt to be essential, particularly when it came to measuring any change in “green” practices later in the project. Although the members of the tasks working group (and later the task force) were relatively familiar with green issues and activities/processes undertaken to curb carbon generation, it soon became apparent that there was a wide range of approaches / understanding / maturity amongst the partners ranging from full-on, mature carbon curbing strategies through to issues (lack) of awareness. Good practice was not as widespread as it could be. With this in mind, we decided that, rather than move straight to a baselining of common activities (such as energy usage, PUE and so on), we needed first to understand *if* any green activities were taking place and what they *were*. In other words, we first needed to know:

- how many partners were undertaking green activities/processes already.
- what those green activities/processes were

Only after establishing this activity baseline could, we then approach the task of “making EGI greener than it currently is”; dividing our efforts between raising awareness / sharing

good practice with the lass mature partners on the one hand, and encouraging better practice amongst the more mature partners in the other hand (a strategy that probably would require baselining/monitoring metrics such as PUE, etc.).

2.2.2 Awareness raising

Put simply, make sure everyone knows about green issues and how to approach them.

2.2.3 Seeking out good practice

See who is doing anything green already and if any activities or processes were planned with a view to recruiting them as Green practitioners for the Green Task Force.

2.2.4 Sharing good practice

Persuading partners to share anything they may have already that benefits greening EGI.

2.2.5 Measuring progress

In order to understand the impact, we as a working group / task force were having, we also needed to establish some impact indicators. These included measuring:

- Increase in greening of partners (e.g., increased number/type of green policy, tools, practice)
- Increased awareness
- Increase in numbers of partners who plan to do something.

2.3 Key deliverables

The key deliverables for this work package were:

- An EGI Green Task force (covered in more detail in section 6)
- Signposting for EGI partners and others (which implies a publicly accessible signposting platform)
- Shared resources (which also implies a publicly accessible platform)

2.4 Activities with other work packages and projects

Task 7.2 (T7.2) is responsible for coordinating all aspects relating to Green Computing within EGI-ACE, in particular the development and application of best practice and providing training regarding Green Computing and making recommendations relating to the prerequisites needed to measure, monitor, and improve energy usage and efficiency at data centres in WP3 for the duration of the project. It also liaises with providers within WP4, 5 and 6 on green computing aspects of their virtual access services.

As an underlying theme of many activities within WP7 is seeking collaboration where possible with other EOSC initiatives, T7.2 is also interested to explore possibilities to exchange best practice and knowledge to achieve overall efficiency across EOSC. At the time of writing, they have yet to do so.

3 Methodology

Due to time/resource constraints we had a relatively limited array of tools at our disposal. We had access to the EU survey tool[4], the EGI ACE Confluence Wiki[5], the EGI-ACE mailing list and the EGI video conferencing / webinar infrastructure. We designed our methodology around these tools.

As mentioned earlier, we were aware of pockets of expertise and good practice in EGI-ACE. This awareness also shaped our methodology. We undertook activities intended to facilitate the dissemination of this expertise. The activities and underlying methodologies undertaken were:

- Identifying good practice
  - Survey x 3
  - EGI-ACE VA sheets
  - 1-on-1 interviews
- Knowledge dissemination
  - Signposting site
  - Webinars
  - Workshop
- Taskforce

Sections 4, 5 and 6 will present in more detail the methods, findings and outcomes of these activities.

3.1 Survey

An initial assignment of T7.2 was to identify best Green Computing practices within EGI-ACE.

One obvious way to reach all project partners was to conduct a series of surveys targeting the general Green Computing practice within EGI-ACE landscape, and the more specific topic of software efficiency[6].

The EU Survey tool has been used to create and host the surveys. It provided a great degree of flexibility offering possibility to build sets of questions and dependent questions that covered the surveyed topics in detail.

3.2 Interview

1-to-1 interviews were used to collect detailed information from key partners on specific topics. This approach allowed us to better tailor the set of questions for each member contacted from WP4 and WP5.

[4] https://ec.europa.eu/eusurvey/home/welcome
[5] https://confluence.egi.eu/
[6] We were fortuitous to have some expertise within the group relating to software efficiency that allowed us to explore this often overlooked aspect of Green computing.

3.3 Desk research

The EGI-ACE Virtual Access (VA) sheets used in WP3 to describe the installations provided by project partners (and that listed the costs associated to deliver the compute resources) were used to identify and calculate some energy related metrics that potentially could be considered when choosing brokering parameters to select sites for workflows execution.

3.4 Publishing information

Dissemination of gathered knowledge on Green Computing during the first 24 months of the project was an important assignment of Green Computing Task Force. One of the first action of the Task Force was to create a collection of resources related to various aspects of Green Computing. Hence a public signposting page was created and populated with online materials about policies, publications, analysis, and best practices from Green Computing area.

3.5 Webinar

The EGI Webinar 2022 series offered the Task Force the opportunity to organise an online webinar where representatives of more knowledgeable sites were able to share their experience regarding green computing with the wider community.

3.6 Conference activity

The EGI Conference 2022 was another dissemination / information gathering opportunity. A workshop was organised and dedicated to Green Computing. The format of several talks concluded by a Q&A session offered the participants the possibility to engage actively in exchanging their experience or finding answers or solutions.

3.7 Task force

The creation of the Green Computing Task Force was a milestone assigned to T7.2 and completed in M12 of the project. The Task Force met regularly and was instrumental in coordinating all Green Computing activities in the project. It has an open structure welcoming anyone interested in the 'green' aspects of ICT.

4 Identifying good practice

4.1 Surveys

4.1.1 Green Computing practice survey

One of the first aims of task 7.2 was to evaluate the level of involvement and maturity of project partners in Green Computing activities across EGI-ACE. For this a first survey on Green Computing practices was produced to take a snapshot of existing Green Computing landscape within the project.

This survey was also a step in identifying potential members of a Green Computing Task Force (see 6.1) that would coordinate further activities and measure progress and improvements during the project.

The survey was complex and included more than 40 questions (including dependency questions) and was conducted in Q3 2021. All 43 EGI-ACE partners (beneficiaries and linked third parties) were invited to participate. The relatively high complexity of the survey could be explained by the fact that it covered several aspects of Green Computing like GC metrics tracking, Green activities and programmes, procurement and decommissioning policies, and Green power provisioning.

The survey questions are attached in the appendices (Appendix A1.1). The raw responses are also attached in the appendices (Appendix A2.1). The analysis and comparison of the results of the two surveys are presented in Appendix 3: Survey analysis.

4.1.2 Green Computing practice survey—2nd run

A second run of the Green Computing practice survey was conducted 12 months later (Sep 2022) to measure the progress made by partners in operating their data centres.

This survey included minimal updates and both categories of partners—those that had answered the previous survey but also those that did not respond to it—were invited to fill in the form.

The survey questions are attached in the appendices (Appendix A1.2). The raw responses are also attached in the appendices (Appendix A2.2). The analysis and comparison of the results of the two surveys are presented in Appendix 3: Survey analysis.

4.1.3 Green Computing survey on software efficiency

Feedback received from EGI-ACE mid-term review included a brief reference to Green Computing with the recommendation to investigate any progress on the software and analytics layer, specifically applications and software that can be enhanced by optimising/minimising the consumption of resources needed for execution (and hence could be considered to be more 'green'[7]).

[7] In short Green Software, also known as sustainable software, is software that is designed, developed, and implemented to limit energy consumption and have minimal environmental impact.

As a consequence, the T7.2 members decided to conduct a survey on software optimization for energy efficiency to take a snapshot of existing levels of awareness on Green Software and to further make an informed decision on possible recommendations.

The Task Force members were asked to contribute to the survey content which included around 30 questions (including dependency questions) covering programming languages used and their connection to energy efficiency, power consumption of applications and of the clusters running the applications, also GPU technologies used at EGI-ACE sites.

The survey ran in September and October 2022 with project partners members of Platform Services (WP4) and Thematic Services (WP5) being asked to respond to it.

The survey questions are attached in the appendices (Appendix A1.3). The raw responses are also attached in the appendices (Appendix A2.3). The analysis is presented in Appendix 3: Survey analysis.

4.1.4 Overall survey conclusions

Given the size of the samples it would be unwise to draw definitive conclusions from the survey. However, we felt it was worth noting the following:

- **Engagement**—People not very engaged with 'green'. Green computing is a very minor part of the overarching EGI-ACE initiative (albeit one that potentially has significant long-term impact). Quite understandably, partners are focused on their core objectives—green computing is often an afterthought (if considered at all).
- **Decision makers**—Respondents were aware of various aspects of GC, but not always in position to take decisions within their organisations. Although we had a reasonable response (in terms of number of responses) to our survey, the fact that those who responded were the “engaged” and not necessarily decision makers are perhaps quite telling in this context. Green appears to be a ‘bottom up’ concern and until key decision makers are converted to the cause this will continue to be the case.
- **Change**—Changes are happening. Very slowly, but they are happening.

A detailed analysis is provided in Appendix 3: Survey analysis.

4.2 EGI-ACE VA sheets

The EOSC Compute platform is built on the EGI federation, which is based on the integration of resources provided by several research centres in Europe. It is the largest distributed infrastructure for research in Europe. In the framework of the EGI-ACE project, in order to facilitate the adoption of this infrastructure by users, and to offer a continuum between data, tools and associated services, an integrated environment has been made available thanks to virtual access.

Virtual access is one of the funding mechanisms available to ensure both a viable business model for service providers and a free of charge access to e-Infrastructure for the researcher. It is based on the use of unit costs, that are calculated before the project is submitted and fixed for the duration of the project. The unit cost incorporates different elements, in order to be as close as possible to the full unit cost. Only auditable elements

can be included to calculate its value and reported on the VA sheets. These elements can be categorized in several groups:

- Costs of hardware (yearly depreciated value)
- Costs of contracts for maintenance and repair for the functioning of the installation
- Costs of consumables specifically used for the installation.
- Costs of contracts for installation management
- Costs of energy power and water supplied for the installation.
- Costs of software licence, internet connection or other electronic services needed to provide virtual access services.
- Costs of specific scientific services included in the access provided or needed for the provision of virtual access.

For each VA sheet, the costs of energy power and water supplied is given. For this group, energy power is the most important expense. It is thus possible to calculate the ratio of the cost of energy in the provision of a unit of service (e.g., a CPU-hour). This metric could be considered as one of the parameters to optimise for when sites are chosen for a new customer use case. It should be mentioned that this is not an ideal metric since it does not consider energy cost differences, differences in computing infrastructure and any carbon offsetting. On the other hand, it does lend itself to semi-automated information capture, display and machine actionable processes.

A complementary metric could be the estimated carbon impact of the service. This can be obtained by calculating the energy consumption required per unit of service, which is then multiplied by the value of kg CO_2e per kWh in the country. However, as this is only an estimate, it is important to have it validated by the resource providers.

Finally, the ratio of renewable energy and the Power Usage Effectiveness (PUE)[8] could also be integrated as a metrics to be use as additional brokering parameters when selecting sites for the execution of workflows. The PUE of sites is known, thanks to the two surveys that were carried out.

A summary of the VA information gathered by this group can be found in Appendix 4: EGI-ACE VA sheets.

4.3 1-on-1 interviews

To complement the data that was received through the surveys, the Tas Force members carried out 1-on-1 interviews with platform providers from WP4. EGI-ACE is proposing to contribute to efforts to transition to a low-carbon economy through Green Computing and ICT sustainability. The Task Force took the opportunity provided by the interview program to explore new avenues of technical developments that could improve the environmental performance of the EGI-ACE infrastructure and services at hardware and software levels.

4.3.1 Platform services (WP4)

The providers were asked if ‘energy-based’ brokering strategies could be implemented in their services. A list of possible strategies could include:

[8] https://en.wikipedia.org/wiki/Power_usage_effectiveness

- send compute jobs to or store data at sites where the PUE is the best;
- send compute jobs to or store data at sites where the energy share is the smallest (as regards the compute unit price);
- send compute jobs to or store data at sites with a higher percentage of renewable energy.

It should be noted that this energy centric approach could have unintended negative consequences. On the positive side, an energy brokering strategy should lead to a “race to the top”, each provider implementing better and better Green strategies in order to improve their share of allocated jobs. This clearly favours those wealthier countries who can afford to fund such a strategy. However, on the negative side, less wealthy countries might stop providing service because they know they can never beat the “good guys”.

An alternative strategy could involve partially weighting job allocation based upon measured/observed improvements in green strategies/processes. This would be difficult to implement but might be more equitable in the long run.

Similarly, an energy balancing scheduler might underpin a more equitable job allocation weighting strategy. Again, this would be difficult to implement.

4.3.2 Workload Manager (DIRAC)[9]

In their interview responses the DIRAC team explained that currently the service gives equal chances to participating sites to be sent jobs to run and does not consider any ‘green’ parameters. Whilst at the moment the order of sites to receive jobs is random, any weighting/constraints added in the future (including ‘green’ related weighting) will have a downside as well. The preferred sites will be overloaded and the other sited (those perceived to be ‘polluting’ for instance) will be underutilised (which is clearly a waste of energy and resources). Consequently, should a Green Computing related weighting be introduced in DIRAC for site selection, the weighting logic should also consider and balance out the negative effects of underutilised sites.

DIRAC is able to consume information about PUE or other energy-related metrics (although they are not doing so at present) as long as these metrics are stored in suitable registers or aggregators (i.e., GOCDB[10], VAPOR[11]) and accessible via well-defined Application Programming Interfaces (APIs).

Based on these metrics DIRAC could rank sites and then make decisions (where to send jobs) as long as appropriate policies and business rules are defined and accepted.

4.3.3 Galaxy[12]

The Galaxy (open-source platform for FAIR data analysis) team representative provided feedback similar to DIRAC. The Galaxy platform would be able to implement the brokering

[9] https://www.egi.eu/service/workload-manager/
[10] The information system used in the EGI/EGI-ACE infrastructures - https://goc.egi.eu/
[11] VAPOR: Vo Administration and operations PORtal provides a web interface for job monitoring and data management - https://operations-portal.egi.eu/vapor/
[12] https://galaxyproject.org/

strategies if energy metrics at site level were available, also it could calculate and expose to the user the CO_2 consumption of a given job if a formula was accessible.

4.3.4 Thematic services (WP5)

Partners from Thematic Services (WP5) were also contacted and asked about possible evaluation of the energy footprint of typical workflow and any measurements they had done. Unfortunately, the feedback level was low, with one partner confirming they relied on DIRAC service for jobs brokering and two other partners confirming no evaluation of energy footprint taking place at their sites.

5 Knowledge dissemination

5.1 Signposting

One of the potential quick wins identified early in the task was that of identifying existing, appropriate "green" resources[13] and enabling partners to utilise them.

A quick search showed that there are many, many resources on the internet relating to green computing which is part of the problem when it comes to deciding what is the most appropriate in the context of the working practices of EGI-ACE partners. A long list of uncategorised resources is both difficult to use and difficult to maintain. Categorisation and evaluations would help, but the task group didn't have the resource to undertake such activity. Even if the resources were categorised, the information would still be unwieldy. What's more, it would be limited to publicly published information. The results of the first survey coupled with anecdotal evidence gathered from the Task Force and other EGI-ACE partners led us to conclude that some of the more focused and useful resources for partners were not accessible through the public web.

For these reasons we decided to focus on quality rather than quantity. In this context we used partner use/recommendation as a measure of quality. We asked partners if they:

- used any "Green" resources.
- the source of those resources
- had resources not publicly available that they would be willing to share with EGI-ACE partners.

We gathered a core set of these to form the nucleus of a signposting page. We chose to host this on the EGI confluence Wiki[14] partially because it:

- was simple to utilise as a resource hosting site (for resources that were not available on the public web but were still shareable)
- was a relatively easy to use content management system
- provided us with a relatively simple mechanism to restrict access to EGI-ACE partners should the need arise (some of the resources that have been offered for sharing are potentially commercially sensitive)
- was available.

The signposting site—GC Signposting - EGI Boards and Groups - EGI Confluence—is a work in progress (see Figure 1 that displays a snapshot of the current landing page). Further information will be added in the future along with updates to the format and presentation of the information.

[13] In this context, "resources" could be anything from optimised workflows, good practice recommendations, tools, training, policies and so on.
[14] https://confluence.egi.eu/display/EGIBG/GC+Signposting

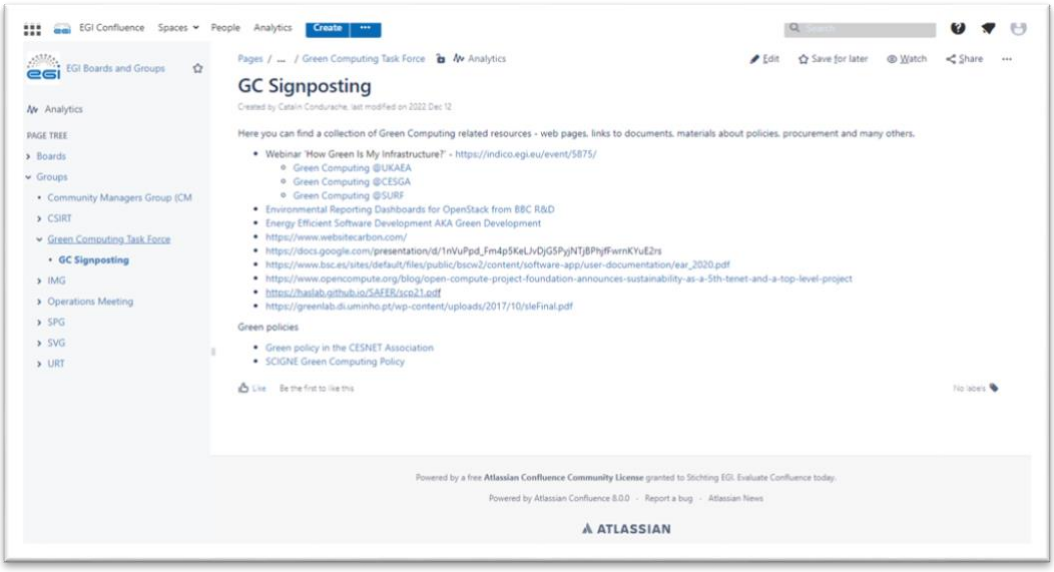

Figure 1—EGI Confluence Green Computing Signposting landing page

5.2 Webinar

As part of the EGI Webinar 2022 series, the Green Computing Task Force members organised the "How Green Is My Infrastructure" webinar[15] on 30th March 2022.

Targeted at IT service providers, data centre representatives, decision makers, and anyone with a keen interest in "green" issues, the event allowed members of the Task Force to share their experience and good practice as regards green computing with the wider community.

More specifically, the agenda included five lightning talks where targeted individuals who participated in the first Green computing survey shared what they had done or were planning to do when "greenifying" their infrastructure and data centres with highlights on key problems and solutions along the way.

A report on Green Computing Task Force status and other activities and a Q&A session completed the session.

The 90 minutes event was attended by 36 participants (out of 56 registered) from 9 countries. 9 of the attendees were from outside the EGI-ACE project.

5.3 Workshop on Green Computing at EGI2022

A full session[16] was dedicated to Green Computing at the EGI 2022 conference[17]. The session was organised by the Green Computing Task Force members, and it brought together EGI service providers, external experts, and service users to discuss the best practices and ways forward to lower the environmental impact of scientific computing services. The main objectives of this session were the sharing of best practices, the broadcasting of the work realised in this field, and to strengthen the link between all the

[15] https://www.egi.eu/event/webinar-how-green-is-my-infrastructure-march-30th-2022
[16] https://indico.egi.eu/event/5882/sessions/4852/
[17] https://www.egi.eu/event/egi2022/

stakeholders. Three presentations were made to kick start the session. These were followed by a round table discussion.

After a short introduction about the task force, a first presentation titled “Identifying the impact of policy decisions on energy consumption in the Energy Data Centre” was given by Catherine Jones of UKRI-STFC. It included an overview of the Energy Data Centre activities, and a focus on the energy measurement of routine jobs. The described process is very important, as it can be reused in other data centres. Metrics are the key for monitoring the overall energy consumption of a data centre and permit to better understand the consequences of our policies.

The second talk was about the “Jisc Industrial Internet of Things (IIoT) & Building Management Services (BMS) PoC with Honeywell Forge”. Made by Matthew Dovey and Paul Stokes of Jisc (a member of the task force), the talk gave an overview of how to use IIoT for the building of a smart campus strategy. This project, undertaken in collaboration with the Honeywell Forge company, aims at reducing carbon footprint and improving building comfort. The main focus was on how measurements drive control mechanisms and can be applied to different needs.

The last presentation by Jerome Pansanel of CNRS (a member of the task force), gave an overview of the processes undertaken to move to a more eco-friendly data centre in France. This talk detailed the different phases of the IT equipment lifecycle (extraction, manufacturing, transport, use phase and recycling) and several ways to decrease the carbon footprint of such equipment as Data Centre manager. It concluded with an overview of the Green Computing related projects in France and how they can be learned from by other European countries.

The session concluded with a round table discussion led by a panel of experts[18] with contributions from the floor. One of the topics discussed was that of a proposal on an ‘Energy Efficiency and Sustainability at Data Centres’ framework supported by a group of external partners. As it has been generally appreciated that time was needed to start working with partners not involved in the task, the agreed plan was to continue the possible collaboration in the next months and present a report at the next EGI Conference (likely before the end of EGI-ACE).

The workshop was well attended with some 30 attendees both in person and remote.

[18] Catherine Jones (UKRI-STFC), Sagar Dolas (SURF), Shaun de Witt (UKAEA)

6 Green Computing Task Force

6.1 Main objective

The Green Computing Task Force was established by the EGI-ACE project in 2021 to coordinate the Green Computing activities of the compute centres that participate in the project, as well those that participate in the broader EGI Federation.

The Task Force aims to map the landscape of green computing activities in EGI, capturing good practices for green computing from the federation members, developing best practice guides for the EGI compute and data centres and monitoring the uptake and the environmental impact of those during 2022 and 2023.

Further information about the task force can be found at Green Computing Task Force - EGI Boards and Groups - EGI Confluence.

6.2 Responsibilities

To support the above mentioned goal, the Task Force has carried out the following activities:

- Map the landscape of green computing activities within the EGI Federation, with specific focus on participants of the EOSC Compute Platform.
- Identify best practices among partners including measures for reducing energy consumption as well as achieving optimal metrics.
- Create a knowledge catalogue including best practices and training material oriented to serve as basic guidelines to improve energy usage and efficiency at data centres.
- Measure the progress towards the key goal of making EGI-ACE greener and improvements achieved by EGI-ACE partners in pursuit of that goal during the project.
- Liaise between complementary GC activities in other projects.

6.3 Task Force composition and organisational aspects

Respondents to the Green Computing practice surveys (see 4.1.1) were sent invitations to join the Task Force. There is no limit on the number of members of the Task Force and more are expected to join by the end of the project.

Appropriate Terms of Reference[19] have been available, an online space has been created for the Task Force[20] and a mailing list has been configured.

Regular virtual TF meetings are taking place every 8 weeks with communications via a mailing list whenever necessary, also TF members are encouraged to attend the regular T7.2 meetings where a dedicated GC slot is a permanent item on the agenda.

6.3.1 Organisations represented in the taskforce

The organisations initially represented in the task force were:

[19] https://documents.egi.eu/document/3848
[20] https://confluence.egi.eu/display/EGIBG/Green+Computing+Task+Force

- CNRS *(co-chair)*
- CSIC *(co-chair)*
- UKRI-Jisc *(co-chair)*
- EGI-Foundation *(support)*
- CESGA
- CESNET
- CYFRONET
- GRENA
- IFCA
- IMCS-UL
- INFN
- IISAS
- LIP
- SRCE
- SURFsara BV
- TUBITAK
- UKAEA
- UKRI-STFC
- Univ de Lille

There is an open invitation for other organisations to join the taskforce.

6.4 Relevant activities

The task forces responsibilities mirrored those of the 7.2 working group. Particular initiatives included:

- The survey on GC software practices (software optimisation for energy efficiency (see 4.1.3) targeted at developers of Platform Services (WP4) and Thematic Services (WP5).
- Contributions to contributed to the "How Green Is My Infrastructure" webinar[21] in the form of 'lightning' talks.
- The workshop on Green Computing[22] at the EGI Conference 2022[23] (see 5.3).

The Task Force has met regularly (and continues to meet)—every 8 weeks—since December 2021.

[21] https://www.egi.eu/event/webinar-how-green-is-my-infrastructure-march-30th-2022
[22] https://indico.egi.eu/event/5882/sessions/4852
[23] https://www.egi.eu/event/egi2022

7 Impact Metrics and Key Performance Indicators (KPIs)

Three types of metrics are defined in EGI-ACE: KPIs, Impact metrics and Communication metrics.

7.1 Impact metrics for the task

The Green Computing aspects within the project are tracked by two impact metrics meant to measure the progress of the project impact.

They are:

- Number of providers tracking green computing metrics and
- Number of centres that have assigned a Green Computer officer role (with a mandate that is not limited to EGI-ACE)

and they are based upon the responses to the surveys on GC practice across EGI-ACE.

Table 1: The evolution of Impact metrics

Impact indicator	Frequency	M10	M20	Target
No. of providers tracking green computing metrics	Every 10 months	9	14	14
No. of centres that have assigned a GC officer role	Every 10 months	3	7	10

We plan to add to these initial sets of responses with a further email campaign in M30 focused entirely on these two fundamental issues.

7.2 Internal KPIs

Also based on the surveys outcome we were able to propose a category of internal KPIs that potentially can be used to reduce the ICT footprint of activities within the EGI Federation and within the computing infrastructure of EOSC in general beyond EGI-ACE.

These internal KPIs include:

- Number of respondents—sites aware of and interested in implementing GC
- Number of partners actively becoming 'green'—sites with GC policies or GC awareness programmes, sites using 'green' clauses for procurement or decommissioning, sites using 'green' energy suppliers or 'green' power initiatives
- Number of partners planning to become greener. Those who are becoming involved sites planning to do something in near future.
- A measurable increase in ‘green’ activities

Table 2: The evolution of internal KPIs.

Metric	Survey 1	Survey 2	Overlap
No. of respondents	16	14	7
No. of partners becoming 'green'	11	11	6
No. of partners to become involved	9	8	1

It should be noted that, based upon the definitions we've used, a responding organisation could be both 'becoming greener' and 'becoming involved' in that they plan to expand upon their current green activities (as opposed to planning to start their green journey).

8 Conclusion and Recommendations

There are pockets of good practice amongst the partners. However, although those individuals with an interest in 'Green' issues are very engaged, overall engagement amongst partners is low with 'Green' seen very much as a secondary issue when it comes to provision of services. For instance, even when green energy is available, it's not seen as a priority to use it. Less than 2/3rds of the respondents who had green power available were actually using it (reasons ranging from "no incentive" to "not a priority").

In addition, the engaged practitioners are not those in a position to force the issue.

It is for this reason that we recommend a multi-faceted approach, one that combines both reward and compulsion alongside enabling activities/policies. Broadly speaking this could be expressed as:

- Build upon the current knowledge sharing activities.
- Facilitate the adoption of green initiatives and practices.
- Incentivise the adoption of green initiatives and practices.
- De-incentivise non green activities and non-adoption of green initiatives and practices.

8.1 Knowledge sharing

The Task Force and Working group have already introduced a signposting web site. Apart from changes to formatting and the presentation of the information this needs to be built upon by encouraging partners to publish existing good practice / policy / strategy. Ideally this would be on their own sites (which would facilitate keeping the materials up-to date and current) and linked to from the signposting site. Alternatively, in cases where the relevant resources are publishable, but not publicly accessible, they could be hosted on the signposting site. In the short term the Task Force needs to follow up on offers of sharing. In the medium to long term ALL partners need to be canvassed regularly for contributions.

Training opportunities are few and far between. Many of the partners have expressed a willingness to train, especially if training were available. We recommended that appropriate training be commissioned and made available to all partners.

The Task Force and Working group have undertaken several other awareness raising activities already (webinars, conference workshops, etc.) These activities need to continue. We recommend a further webinar before the end of the project and additional appropriately pitched activities at all future EGI-ACE events.

8.2 Adoption of green initiatives and practices

The project as a whole suffers from lack of a centralised, coordinated coherent Green policy/strategy. The few existing strategies are not harmonised across the partners and differ widely in terms of what they cover and the level of detail (assuming they exist at all). There needs to be a top-down initiative to address this. For this reason, we recommend the appointment of an EGI Green computing officer. This individual would be responsible initially for creating a cascading Green strategy for EGI-ACE and partners and guiding it through a

formal adoption process. Information from partners with existing Strategies/policies could be used as the starting point.

We acknowledge that there are widely different requirements and expectations within the project. A cascading policy and strategy set the core principles at the top level. These can be adapted into more detailed policies and strategies appropriate to each element of the project, and, in turn, be adopted and built upon by partners. Those without policies and strategies will have a comprehensive starting set. Those with existing policies and strategies will have the opportunity to harmonise them with those of their peers.

Why is this needed? Quite apart from the harmonisation and the filling of the gaps mentioned above, Policy drives Strategy and Strategy drives Budgets. Once a policy is adopted a strategy can be created to implement that policy. This in turn leads to the development of initiatives/projects/process to fulfil the strategy. At that point budgets can be formulated, underpinned by a comprehensive and justified business case.

Green initiatives, although cost effective in the long term—reduction in energy use automatically has a carbon reduction side effect as well as a financial benefit, particularly in this era of high energy costs and shortages—can cost significant sums to set-up. There is an argument that the set-up costs at least should be centrally funded. The Policies, strategies and budgets feed into the argument for any such central funding. We recommend that budget be sought to initiate green initiatives across the project partners.

8.3 Incentivising and facilitating Green

A significant number of respondents to the survey indicated that they would use 'Green' energy if it were a) available, and/or b) incentivised in some way. Individually, the project partners are not sufficiently influential to demand green power sources. Even as a group EGI do not form a sufficiently influential block—they're not large enough consumers individually and, due to their unavoidable geographically dispersed nature, they do not address a sufficiently centralised supplier base to lobby for green power. However, the EC is in such a position.

We recommend that initiatives be undertaken to make the purchasing of green energy easier / cheaper, not just for the EGI project, but Europe wide. There needs to be additional centralised infrastructure investment and capacity building to facilitate this.

Related to this, incentives to make the energy consumed go further (such as waste heat initiatives) will also reduce the negative impact of EGI. We recommend that funding be sought to initiate such reuse projects and/or improve/widen existing projects where they exist already.

One of the points of note arising from the surveys was the lack of relevant certifications amongst partners. We recommend that all suppliers be encouraged to undertake certification and that financial support be sought to facilitate this. It should be noted that certifications (and the independent audits that form part of certification) are, along with standards (mentioned later in this section) an essential component of trust and transparency. Partners need to not only to be 'Green', but also be seen and trusted to be 'Green'.

8.4 De-incentivisation

The alternative to incentivising green, imposing penalties, would probably not have the desired effect, especially if it were undertaken without first implementing initiatives to encourage/subsidise 'Green' take-up. It would also disproportionately impact less well-off partners.

However, there are more subtle (and potentially cheaper) ways to approach this the opposite side of the equation. For instance, although EGI can't insist that all hardware purchased by partners is 'Green' labelled[24] , it should be possible to require compulsory green procurement clauses be built into contracts, and compulsory 'Green' reporting[25] etc. Such clauses would have little or no infrastructure overhead, and should be a cheap, easy win.

With this in mind, we recommend that the investigation of and rolling out of 'Green' procurement clauses and other related imperceptible drivers be undertaken by the EGI Green computing officer mentioned earlier.

8.5 Miscellaneous

One factor that is hampering the adoption of green is that of standardisation. There are many competing ways to measure and/or express an organisation's "Greenness" and this leads to confusion and inappropriate/incomprehensible/unjustified comparisons and claims. Until such time as there is an agreed set of measurement and reporting standards adopted across the board this situation will continue.

The measurement problem is exacerbated by the lack of coherent Green related information for some of the second order or indirect[26] Green and Carbon. These include especially embedded carbon; total lifetime carbon; cost/impact of infra structure; energy use of applications; etc. These are not trivial things to calculate.

For this reason, we recommend that an R&D activity be commissioned to investigate and set the relevant standards (those mentioned above and others) and then provide appropriate measuring, monitoring, and reporting tools. This activity should include further investigation of initiatives around cloud computing and virtualisation and their potential positive impact on carbon reduction.

Later in this report there is a brief discussion around the pros and cons of implementing a "Compute brokerage" (see Appendix 5: Brokering strategies). It is clear that some form of strategy is required going forward, but it is also clear that it is not a trivial task to implement a fair strategy. For this reason, we recommend that an R&D activity be commissioned to investigate and implement an automated compute brokering strategy that facilitates green job provisioning and avoids the identified potential negative impacts (for instance defining a weighting logic and enriching the GODCB/VAPOR with Green computing related information). It is likely that additional negative impacts will be identified as part of this activity. Obviously, these should be minimised as well.

[24] E.g., Energy star compliant.
[25] E.g., require the use of smart PDUs to accurately measure, monitor and report power draw on a node by node basis.
[26] It should be noted that although they are indirect, they may indeed be the larger of the cost/impact factors when it comes to total green/carbon cost.

9 References/Bibliography

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Appendices

Appendix 1: Partner survey questions

Many questions in the surveys were dependent upon previous answers. Where possible, this has been indicated with [*text in brackets*]. Some questions have been paraphrased to fit a document format.

A1.1 Green Computing Survey 1

Introduction

General questions

Full Name

Email

Organisation

What is the size of your organisation in terms of staff and collaborators (e.g. students)?

Please indicate the type of organisation.

Please indicate the country in which your organisation is based.

Green Computing Practice

Metrics

Does your organisation track any Green Computing metrics?

[*If tracking*] What do you track? [Select from list—Power usage effectiveness (PUE); CO_2; Water usage; Other]

[*If Water use*] Water Use (and embedded energy) [Select from list—Closed circuit cooling; Open circuit cooling; Reused; Other]:

[*If Other*] Please tell us about your "Other" water use.

What do you track and not in the list above?

Please share any figures you can

What do you do based on those metrics? [Select from list—Publish; Undertake comparison with peers; Initiate measures to improve; Something planned; Other]

Can you give details (re: something planned)?

[*If Other*] Can you give details (re: other)?

Green Role

Does your organisation have a role that is responsible for green activities (policies, monitoring, enforcement etc.).

What is their job/role title? (e.g. Green Computing Officer, Environment Officer, etc.)?

Policy

Do you have a Green Computing policy?

[*If Policy*] Are you prepared to share it?

Training

Do you have an institution wide Green Computing related awareness raising / training programme?

[*If Course*] Is it a mandatory course?

[*If Course*] What are completion figures?

If Course] Would you be prepared to share it?

[*If Course*] Is there a plan to introduce one?

[*If no Course*] Would you introduce one if it were provided to you?

Impact minimisation

Do you plan your work / systems to optimise / minimise green computing impact?

Is there any form of incentive to do so?

[If no Optimising] Are you planning to adopt one?

Green Power

Is there a green power supplier available to you?

[An energy supplier is considered 'green' if one or more of their tariffs are supplying energy from renewable sources (wind farms, hydroelectric power stations or nuclear-free)].

Do you use a green energy supplier?

[*If no Supplier*] Would you use a green supplier if one were available?

Do you use any green power initiatives?

[*If Initiatives*] What do you have? Is it local to you, national, or international?

[*If no green power use*] Why?

Certifications

Do you have any related certifications (individual or at organisation level)?

[*If Certifications*] Which? (ISO 9000, ISO 14000, ISO 50000 etc.)

[*If no Certifications*] Do you plan to get certified (what, when)?

Green labelled hardware

Do you proactively try to source **Green Labelled** hardware?

[**Green Labelled** hardware is designed to reduce energy expenditure and reduce the impact that computers have on the environment. It can bear various ratings, evaluations and certificates such as **ENERGY STAR**, **EPEAT**, **TCO Certified**.]

How do you decide what is 'green'?

Will you be sourcing **Green Labelled** hardware in the future?

Were you aware of **Green Labelled** hardware?

Green decommissioning

Do you use 'green' decommissioning services?

Is this primarily due to legislation or voluntary?

Green purchasing

Does your organisation include 'green' clauses in your standard contracts and procurement processes?

Do you make purchasing decisions based on the lifetime power / carbon costs of equipment?

[*If green clauses*] Would you be prepared to share typical procurement / requirement clauses?

Carbon trading

Do you participate in any form of carbon credit trading?

Waste energy

Do you utilise waste energy for other uses?

[*If Waste Energy is used*] Please specify

[*If Waste Energy is not used*] Any specific reason why not?

Other

Is there anything else not covered by this survey that you would like to provide as input? Please add below!

A1.2 Green Computing Survey 2

Introduction

General questions

Full Name

Email

Organisation

What is the size of your organisation in terms of staff and collaborators (e.g. students)?

Please indicate the type of organisation.

Please indicate the country in which your organisation is based.

This is the **second** iteration of the EGI-ACE T7.2 Green computing survey. Did you or your organisation respond to the first iteration?

Green Computing Practice

Metrics

Does your organisation track any Green Computing metrics?

[*If tracking*] What do you track?

Water Use (and embedded energy) - Is your usage:

[*If Other*] Please tell us about your "Other" water use.

What do you track and not in the list above?

Please share any figures you can!

What do you do based on those metrics?

[Publish; Undertake comparison with peers; Initiate measures to improve; Something planned; Other]

Can you give details (re: something planned)?

[*If Other*] Can you give details (re: other)?

Green Role

Does your organisation have a role that is responsible for green activities (policies, monitoring, enforcement etc.).

What is their job/role title? (e.g. Green Computing Officer, Environment Officer, etc.)?

Policy

Do you have a Green Computing policy?

[*If Policy*] Are you prepared to share it?

Training

Do you have an institution wide Green Computing related awareness raising / training programme?

[*If Course*] Is it a mandatory course?

[*If Course*] What are completion figures?

If Course] Would you be prepared to share it?

[*If Course*] Is there a plan to introduce one?

[*If no Course*] Would you introduce one if it were provided to you?

Impact minimisation

Do you plan your work / systems to optimise / minimise green computing impact?

Is there any form of incentive to do so?

[If no Optimising] Are you planning to adopt one?

Green Power

Is there a green power supplier available to you?

[An energy supplier is considered 'green' if one or more of their tariffs are supplying energy from renewable sources (wind farms, hydroelectric power stations or nuclear-free)].

Do you use a green energy supplier?

[*If no Supplier*] Would you use a green supplier if one were available?

Do you use any green power initiatives?

[*If Initiatives*] What do you have? Is it local to you, national, or international?

[*If no green power use*] Why?

Certifications

Do you have any related certifications (individual or at organisation level)?

[*If Certifications*] Which? (ISO 9000, ISO 14000, ISO 50000 etc.)

[*If no Certifications*] Do you plan to get certified (what, when)?

Green labelled hardware

Do you proactively try and source **Green Labelled** hardware?

[**Green Labelled** hardware is designed to reduce energy expenditure and reduce the impact that computers have on the environment. It can bear various ratings, evaluations and certificates such as **ENERGY STAR**, **EPEAT**, **TCO Certified**.]

How do you decide what is 'green'?

Will you be sourcing **Green Labelled** hardware in the future?

Were you aware of **Green Labelled** hardware?

Green decommissioning

Do you use 'green' decommissioning services?

Is this primarily due to legislation or voluntary?

Green purchasing

Does your organisation include 'green' clauses in your standard contracts and procurement processes?

Do you make purchasing decisions based on the lifetime power / carbon costs of equipment?

[*If green clauses*] Would you be prepared to share typical procurement / requirement clauses?

Carbon trading

Do you participate in any form of carbon credit trading?

Waste energy

Do you utilise waste energy for other uses?

[*If Waste Energy is used*] Please specify

[*If Waste Energy is not used*] Any specific reason why not?

Changes

[*If Previous survey*] You indicated that you and/or your organisation took part in the previous survey. Have you made or are you planning to make any changes to your green computing practice as a consequence?

[*If changes*] Please tell us the changes you've made.

[*If planned*] Please tell us the changes you've planned.

Other

Is there anything else not covered by this survey that you would like to provide as input? Please add below!

A1.3 Green Software Survey

Introduction

General questions

Full Name

Email

Organisation

What is the size of your organisation in terms of staff and collaborators (e.g., students)?

Please indicate the type of organisation.

Please indicate the country in which your organisation is based.

Green Software Practice

Programming Languages

Which programming languages are being used for research in your cluster?

Please order the following criteria for choosing a programming language

[Inheriting Legacy Code / Historic Reasons; Ease of use; Performance; Energy Efficiency; Availability / Compatibility / Vendor lock

Programming considerations

Have you considered energy efficiency when programming?

[*If no consideration*] Any reasons why not?

Would you change your programming practices and/or programming language for greater energy efficiency?

Software efficiency

Do you use software that has been optimised for energy efficiency?

[*If using optimised software*] Examples

[*If using optimised software*] Reasons

Do you develop software that has been optimised for energy efficiency?

[*If developing optimised software*] How, details, reasons

[*If not developing optimised software*] Any reasons why not?

Do you measure the efficiency gains in any way?

[*If measuring*] Please describe how?

[*If not measuring*] Any reasons why not?

Procurement

Do you consider energy efficiency as a criterion when procuring software?

[*If energy efficiency considered*] What is the weight in the decision process?

[*If energy efficiency not considered*] Any reasons why not?

Power consumption

Do you monitor power consumption of your clusters?

[*If monitored*] For what reasons?

[*If monitored*] How are you doing it?

Are you measuring energy consumption for your applications?

[*If measuring*] How?

Do you utilise energy capping on your systems?

[*If Energy capping*] Please choose

Are you aware of Power Usage Effectiveness (PUE)?

GPU

Are you using GPU technologies to accelerate your tasks?

[*If using GPU*] Which GPU enabled libraries and frameworks are you using?

[*If using GPU*] How do you use it?

Which of the following libraries and frameworks are familiar with you?

Other

Is there anything else not covered by this survey that you would like to provide as input? Please add below!

Appendix 2: Survey responses

Note: These survey responses have been redacted/anonymised.

Note: Survey questions (rows) with no responses are not shown.

A2.1 Green Computing Survey 1

	Respondent #															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
General Questions																
Size of your organisation in terms of staff and collaborators	1,001 to 10,000	101 to 1,000	Up to 100	Up to 100	101 to 1,000	101 to 1,000	101 to 1,000	101 to 1,000	101 to 1,000	More than 10,000	101 to 1,000	101 to 1,000	101 to 1,000	Up to 100	Up to 100	1,001 to 10,000
Type of organisation	Research Infrastructure; eInfrastructure; Research Institute; Computing Centre	Research Infrastructure; eInfrastructure; University; Research Institute; Computing Centre	eInfrastructure; Research Institute	Research Infrastructure	Research Infrastructure; eInfrastructure; NREN; NGO	eInfrastructure; University; Computing Centre	Research Infrastructure; eInfrastructure; NREN; Government department / agency; Library; Archive; Computing Centre	Research Infrastructure; eInfrastructure; Computing Centre	Research Institute; Computing Centre	University	Research Infrastructure; Research Institute; Computing Centre	eInfrastructure; Research Institute	Research Institute	Research Infrastructure; Computing Centre	NREN	Research Institute
Base country	Italy	Poland	Slovakia	France	Czechia	Croatia	Turkey	Netherlands	Spain	France	Latvia	Portugal	France	Spain	Georgia	United Kingdom
Metrics																
Does your organisation track any Green Computing metrics?	Yes	Yes	No	Don't know	No	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes
What do you track?	Power usage effectiveness (PUE); Other	Power usage effectiveness (PUE); Water usage				Power usage effectiveness (PUE); Water usage			Power usage effectiveness (PUE)		Power usage effectiveness (PUE)	Power usage effectiveness (PUE)	Power usage effectiveness (PUE)	Power usage effectiveness (PUE)		Power usage effectiveness (PUE); CO2; Water usage
What do you track that's not in the list above?	Energy consumption per rack															
Water Use		Closed circuit cooling; Reused (e.g. district heating)				Closed circuit cooling										Closed circuit cooling; Open circuit cooling (extracted from the environment cold, returned warm)

	Respondent #															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Please share figures		Two datacenters ~2MW each, mix of closed cold aisle air cooled racks (PUE ~1.3) and liquid cooled servers (PUE 1.05-1.08).														On site data centre efficiency - PUE ~1.02 Offsite computing - Number 3 on Green 100 (Jul 2021) Organisation has halved its CO2 footprint since 2015
What do you do based on those metrics?	Publish; Undertake comparison with peers; Initiate measures to improve; Something planned	Initiate measures to improve				Initiate measures to improve			Initiate measures to improve		Initiate measures to improve		Undertake comparison with peers; Initiate measures to improve	Publish; Undertake comparison with peers; Initiate measures to improve		Initiate measures to improve; Other
[What do you do based on those metrics? Other] Can you give details?																Report to funders
Green Role																
Does your organisation have a role that is responsible for green activities	No	Don't know	No	Don't know	No	No	No	Yes	Yes	No	No	No	No	No	No	Yes
What is their job/role title?								CSR Policy Advisor								Health Physics Group Manager
Policy																
Do you have a Green Computing policy?	No	No	No	Don't know	Yes	No	Don't know	No	No	Don't know	No	No	No	Yes	No	No
Are you prepared to share it?					Yes									Yes		
Training																
Do you have an institution wide Green Computing related awareness raising / training programme?	No	No	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No
Is it a mandatory course?													No			
What are completion figures?													Don't know			
Would you be prepared to share it?													Yes			
Is there a plan to introduce one?	Yes	No	No	Yes	No	No	No	Yes	No	No	No	No		No	No	No

	Respondent #															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Would you introduce one if it were provided to you?	Yes	Yes	Yes	Yes	No	Yes		Yes	Yes	No	No			No	Yes	No
Impact minimisation																
Do you plan your work / systems to optimise / minimise green computing impact?	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Is there any form of incentive to do so?	No	Don't know	Don't know			No	No	No	No	Don't know	Yes	No	No	No	No	
Are you planning to adopt one?				Don't know	Don't know											Don't know
Green Power																
Is there a green power supplier available to you?	Yes	Yes	Don't know	Don't know	Yes	Yes	Don't know	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes
Do you use a green energy supplier?	Yes	No			Yes	Yes		Yes				No	No	No	Yes	No
Would you use a green supplier if one were available?									Yes	Yes	Yes					
Do you use any green power initiatives?	Don't know	No	Don't know	Don't know	Don't know	No	Don't know	Don't know	No	Don't know	No	No	No	No	Don't know	Don't know
What do you have? Is it local to you, national, or international?																
[If no green power use] Why?		No incentives, increased price which would not be compensated							We do not directly manage the power supply contracts		not a priority	More expensive	We do not have the ability to choose our power provider			
Certifications																
Do you have any related certifications?	No	No	No	No	No	No	No	No	Yes	No	No	No	No	Yes	No	Yes
Which?									ISO 9000, ISO 27000 (undergoing)					ISO 50001		ISO14001
[If no certifications] Do you plan to get certified?		Not in a foreseeable future	do not know					no		No	probably not	No	I would like		No for near future	
Green labelled hardware																
Do you proactively try and source Green Labelled hardware?	Yes	No	Don't know	Don't know	No	Don't know	Don't know	Yes	Yes	No	No	No	Yes	No	No	Yes

	Respondent #															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
How do you decide what is 'green'?								Energy efficiency, Energy Star/TCO, responsible use of resources,					Better recycling, less power consumption, EPEAT GOLD label			Energy Star rating
Will you be sourcing Green Labelled hardware in the future?		Don't know			Don't know					Don't know	Don't know	Don't know		Don't know	Yes	
Were you aware of Green Labelled hardware ?			Yes	Yes		No	Yes									
Green decommissioning																
Do you use 'green' decommissioning services?	Don't know	Yes	Don't know	Don't know	Yes	No	No	Yes	Yes	Yes	No	No	Yes	No	No	Yes
Is this primarily due to legislation?		Due to legislation			Due to legislation			Due to legislation	Voluntary	Voluntary			Due to legislation			Voluntary
Green purchasing																
Does your organisation include 'green' clauses in your standard contracts and procurement processes?	Yes	No	Don't know	Don't know	Don't know	No	No	Yes	Yes	Don't know	No	No	Yes	Yes	No	No
Do you make purchasing decisions based on the lifetime power / carbon costs of equipment?	No	No	No	Yes	No	Yes	Don't know	No	Yes	Don't know	No	No	Yes	Yes	Yes	No
Would you be prepared to share typical procurement / requirement clauses?				No		No			No				Yes	Yes	No	
Carbon trading																
Do you participate in any form of carbon credit trading?	No	No	No	Don't know	No	No	No	No	No	No	No	No	No	No	No	No
Waste energy																
Do you utilise waste energy for other uses?	No	Yes	No	Don't know	No	No	Don't know	Don't know	Don't know	No	Yes	No	No	No	No	No
Please specify		Heat re-use for the purpose of office heating during winter, plans to expand re-use in the near future									we use servers' heat to warm building in winters					

	Respondent #															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Any specific reason why not?					We rent most of our facilities, it's outside our scope to furbish for heat reuse.					The datacentre was not designed for.		Not efficient for our power consumption			Not available	Cost of putting in infrastructure into older buildings
Other																
Is there anything else not covered by this survey that you would like to provide as input? Please add below!	There must be a distinction between "Institution" and "Data Centres", missing here. For example, INFN is a single nation-wide organization that has more than 10 large data centres, and while there is central coordination for what regards computing topics (including some that are green computing related), different INFN data centres have different technical characteristics and therefore may provide different answers to some of the questions of this questionnaire.	It would be good to get some templates/best practices of RFPs which take into consideration power efficiency, which are in line with the European public procurement law. They need to be adjusted anyway to be in line with the local law, but it'd be a good start.	We plan to use some automatic dynamic cluster size management tool.					Yes, we are actively working on co-implementing a framework for energy management & accounting on the national supercomputer "Snellius". This framework apart from providing accurate energy consumption info at the job level should also help in tuning the hardware depending on application characteristic.				Our focus is mainly on power consumption and efficiency. Regarding hardware we select the equipment based on the best ratio of power consumption / performance. We also specify efficiency for the power supplies.			No	

A2.2 Green Computing Survey 2

Note: These survey responses have been redacted/anonymised.

Note: Survey questions (rows) with no responses are not shown.

	Respondent #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
General questions														
Size of your organisation in terms of staff and collaborators	Up to 100	101 to 1,000	Up to 100	1,001 to 10,000	Up to 100	101 to 1,000	Up to 100	1,001 to 10,000	Up to 100	101 to 1,000	1,001 to 10,000	1,001 to 10,000	101 to 1,000	More than 10,000
Type of organisation	Research Infrastructure	eInfrastructure; Computing Centre	Research Infrastructure; eInfrastructure; NREN; Government department / agency; Computing Centre	Research Infrastructure; eInfrastructure; University; Research Institute; Funding agency; Computing Centre	Research Institute	Research Infrastructure; eInfrastructure; NREN	Research Infrastructure; eInfrastructure; University; Research Institute; Computing Centre	Research Institute; Government department / agency; Funding agency	Research Infrastructure; Computing Centre	Research Institute	Research Institute	Research Infrastructure; eInfrastructure; Research Institute; Government department / agency; Archive; Computing Centre	Research Infrastructure; eInfrastructure; University; Computing Centre	Research Infrastructure; eInfrastructure
Base country	Portugal	Croatia	Turkey	Italy	Italy	Netherlands	Italy	United Kingdom	Spain	Bulgaria	Germany	United Kingdom	Poland	France
Did you or your organisation respond to the first iteration of the survey?	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Don't know	Don't know	Yes	Yes
Metrics														
Does your organisation track any Green Computing metrics?	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
What do you track?	Power usage effectiveness (PUE); Water usage	Power usage effectiveness (PUE); Water usage		Power usage effectiveness (PUE)	Power usage effectiveness (PUE)	Other		Power usage effectiveness (PUE); Water usage	Power usage effectiveness (PUE)	Power usage effectiveness (PUE)	Power usage effectiveness (PUE); Water usage	Power usage effectiveness (PUE); CO2; Water usage	Power usage effectiveness (PUE); Water usage	Power usage effectiveness (PUE)
What do you track that's not in the list above?						application energy use (per job)								
Water use	Closed circuit cooling	Closed circuit cooling						Open circuit cooling (extracted from the environment cold, returned warm)			Closed circuit cooling; Open circuit cooling (extracted from the environment cold, returned warm)	Closed circuit cooling	Closed circuit cooling; Reused (e.g. district heating)	
Please share figures								Average PUE is about 1.04	PUE 1.49 in 2021				PUE is measured on various levels, as pPUE per system (range 1.05-1.35 for HPC systems) and total PUE for the DC buildings (1.2-1.6).	

	Respondent #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
What do you do based on those metrics?	Initiate measures to improve	Initiate measures to improve		Publish; Undertake comparison with peers; Initiate measures to improve	Undertake comparison with peers; Initiate measures to improve	Something planned		Initiate measures to improve	Publish; Undertake comparison with peers; Initiate measures to improve; Something planned	Initiate measures to improve	Initiate measures to improve	Initiate measures to improve	Undertake comparison with peers; Initiate measures to improve	Undertake comparison with peers; Initiate measures to improve
[What do you do based on those metrics? Other] Can you give details?						We are working on a visualization interface the energy usage (for a user) and then suggest a user how to tune their application.			Monitoring and take measures to continue improvement and detect anomalies, failures, detect main energy consumption sources and deviations					
Green Role														
Does your organisation have a role that is responsible for green activities?	No	No	No	Yes	No	Yes	No	Yes	No	No	Yes	Yes	No	Yes
What is their job/role title?				green computing task force to provide guidelines during the current energy crisis		CSR Policy Advisor and a program manager		Environmental officer			sustainability officer	Estates		Environment Officer
Policy														
Do you have a Green Computing policy?	No	Yes	No	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	No	No
Are you prepared to share it?		Yes		Yes	No			No	Yes		No	Yes		
Training														
Do you have an institution wide Green Computing related awareness raising / training programme?	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Is there a plan to introduce one?	No	No	No		Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Would you introduce one if it were provided to you?	No	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Impact minimisation														
Do you plan your work / systems to optimise / minimise green computing impact?	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Is there any form of incentive to do so?	Yes	Yes	No	No	No	No		No	Yes	Yes	Yes		No	No

	Respondent # 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Are you planning to adopt one?							Yes					No		
Green Power														
Is there a green power supplier available to you?	Yes	Yes	Don't know	Yes	Yes	Yes	Don't know	No	Yes	Don't know	No	Yes	No	Don't know
Do you use a green energy supplier?	No	Yes		Yes	Yes	Yes			Yes			Yes		
Would you use a green supplier if one were available?								No			Yes		No	
Do you use any green power initiatives?	No	No	Don't know	Don't know	Don't know	Yes	Don't know	Don't know	No	No	Don't know	Yes	No	Don't know
What do you have? Is it local to you, national, or international?						We are leasing a windmill						Solar panels throughout campus (locally)		
[if no green power use] Why?	More expensive								Our power provider issues certificate on green energy	It is in the plan, but our scale is not big enough.			Our energy is bought in a big group of institutions and we have limited influence on the kind of energy provided, cost is the key factor for most stakeholders	
Certifications														
Do you have any related certifications?	No	No	No	No	No	No	No	No	Yes	No	No	No	No	No
Which?									ISO 9000, ISO 50000					
[If no certifications] Do you plan to get certified?	No		Don't know.					Unsure			planned, no details yet	No	There is no plan yet.	
Green labelled hardware														
Do you proactively try and source Green Labelled hardware?	Yes	No	No	Yes	No	Yes	No	No	No	Yes	Yes	No	No	Yes
How do you decide what is 'green'?	By the certifications and announced efficiencies					Energy efficiency, Energy Star/TCO, responsible use of resources,					Label			We are selecting hardware with ecolabel
Will you be sourcing Green Labelled hardware in the future?		Yes	Don't know		Yes		Yes	Yes	No			Don't know	Don't know	

	Respondent #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Green decommissioning														
Do you use 'green' decommissioning services?	Yes	Yes	No	Don't know	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Is this primarily: to legislation?	Voluntary	Voluntary				Voluntary		Due to legislation		Due to legislation		Voluntary		Due to legislation
Green purchasing														
Does your organisation include 'green' clauses in your standard contracts and procurement processes?	Yes	No	Don't know	Yes	No	Yes	Don't know	No	Yes	No	Yes	No	Don't know	Yes
Do you make purchasing decisions based on the lifetime power / carbon costs of equipment?	No	Yes	No	No	Yes	No	Don't know	No	Yes	Yes	No	Yes	Yes	Yes
Would you be prepared to share typical procurement / requirement clauses?		No			No				Yes	No		No	Yes	Yes
Carbon trading														
Do you participate in any form of carbon credit trading?	No	No	Don't know	No	Yes	No	Don't know	No	No	No	No	No	No	No
Waste energy														
Do you utilise waste energy for other uses?	No	No	No	No	Yes	No	Don't know	No	No	No	Don't know	No	Yes	No
Please specify					Tri-gas generators outputs reused for cooling ICT room, and heating during winter department building.								One of our HPC systems is used to heat office space in the DC building, an ongoing investment is currently in the tender process for the modernization of one of the older DCs to allow heat reuse from a 3 MW HPC system.	
Any specific reason why not?	Not efficient for the amount of dissipated energy	Not enough budget for it	Our building infrastructure doesn't allow waste energy from the system rooms to be shared/transferred into them.			We don't own the datacentres		Too expensive to integrate into existing infrastructure		It was expensive when we considered the question for the first time.		Not feasible		Need important modification of the building and heat system.

	Respondent #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Changes														
You and/or your organisation took part in the previous survey. Have you made or are you planning to make any changes to your green computing practice as a consequence?	No	Not yet, but changes are planned	No		Yes, but changes were planned anyway			Yes, but changes were planned anyway	No				Not yet, but changes are planned	Yes
Please tell us the changes you've made.					using free cooling in the data centre.			In the process of integrating environmental impact and ethics into procurement. More training on green it and impact of computing on the environment.						
Please tell us about the changes you've planed.		New HPC resource will be more green.											We are putting more focus on heat reuse and including more TCO-oriented metrics in the tenders for bigger systems, there is still no plan to introduce a green computing policy at the organization level.	

	Respondent #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Other														
Is there anything else not covered by this survey that you would like to provide as input? Please add below!				There must be a distinction between “Institution” and “Data Centres”, missing here. For example, INFN is a single nation-wide organization that has more than 10 large data centres, and while there is central coordination for what regards computing topics (including some that are green computing related), different INFN data centres have different technical characteristics and therefore may provide different answers to some of the questions of this questionnaire.								Net zero policy: the entire organisation aims to be carbon neutral by 2040 We have several current and future green computing initiatives, the most prominent is Net-Zero DRI (see https://zenodo.org/record/7016952)		

A2.3 Green Software Survey

Note: These survey responses have been redacted/anonymised.

Note: Survey questions (rows) with no responses are not shown.

	Respondent # 1	2	3
General questions			
What is the size of your organisation in terms of staff and collaborators	Up to 100	101 to 1,000	101 to 1,000
Please indicate the type of organisation.	Research Infrastructure; eInfrastructure; Computing Centre	Research Infrastructure; eInfrastructure; NREN	Research Infrastructure; Research Institute
Please indicate the country in which your organisation is based.	Portugal	Netherlands	Netherlands
Programming languages			
Which programming languages are being used for research in your cluster?	R; C/C++; Python	R; C/C++; Python; Rust; FORTRAN	C/C++; Python
Please order the following criteria for choosing a programming language	Performance; Ease of use; Inheriting Legacy Code / Historic Reasons; Energy Efficiency; Availability / Compatibility / Vendor lock	Availability / Compatibility / Vendor lock; Performance; Ease of use; Inheriting Legacy Code / Historic Reasons; Energy Efficiency	Availability / Compatibility / Vendor lock; Performance; Inheriting Legacy Code / Historic Reasons; Ease of use; Energy Efficiency
Programming considerations			
Have you considered energy efficiency when programming?	Yes	No	No
Any reasons why not?			Challenges for improving science output, including quality, processing efficiency, and reducing data volumes have received precedence for the available programming resources. NB Performance optimisation as well as data compression does result in reduction of required compute and storage reources, which likely will have a beneficial effect on energy consumption.
Would you change your programming practices and/or programming language for greater energy efficiency?		Yes	Yes
Software efficiency			
Do you use software that has been optimised for energy efficiency?	No	Yes	No
Examples		Software that uses EAR	
Reasons	We just support the execution of software that the users require to be executed, we don't choose the software, it might or might not have been optimised.		See reason provided for (so far) not considering energy efficiency.
Do you develop software that has been optimised for energy efficiency?	No	No	No

	Respondent # 1	2	3
Any reasons why not?	We don't generally develop software as INCD is an infrastructure. We do develop some tools for management or to assist users but the performance/CPU consumption requirements of those are usually very low.		See reason provided for (so far) not considering energy efficiency.
Do you measure the efficiency gains in any way?	No	Yes	Yes
Please describe how?		how the software interacts with the systems. We measure the most efficient use.	The computational resources needed for data processing pipelines are characterized.
Any reasons why not?	Is not easy to measure the gains, sometimes we do benchmark and measure the server power consumption but requires fully dedicated servers and time to obtain meaningful results.		
Procurement			
Do you consider energy efficiency as a criterion when procuring software?	No	No	No
Any reasons why not?	Not easy to measure with precision, all our tenders use precise tangible metrics.		The software we procure in general does not have high demand on energy consumption.
Power consumption			
Do you monitor power consumption of your clusters?	Yes	Yes	Yes
For what reasons?	Energy Consumption Optimization, Cost	billing	Cost
How are you doing it?	PDUs with meters available over the network Measurements units attached to the switchboards Server monitoring when the information is provided by the BMC	prometheus. EAR on Snellius Some PDU's. Rack based energy number provided by DC	Provided by data center (power usage per rack)
Are you measuring energy consumption for your applications?	No	Yes	No
How?		EAR	
Do you utilise energy capping on your systems?	No	Considering	No
Are you aware of Power Usage Effectiveness (PUE)?	Yes	Yes	No
GPU			
Are you using GPU technologies to accelerate your tasks?	Yes	Yes	Yes
Which GPU enabled libraries and frameworks are you using?	nVidia CUDA; TensorFlow; PyTorch; The applications I use already support direct execution	nVidia CUDA; AMD ROCm; TensorFlow; PyTorch	nVidia CUDA; TensorFlow
How do you use it?	Depends highly on the application usually one or more GPUs per job/task.	facilitating scientific research	No overall strategy. GPU's are in general used to optimize performance of computational tasks and specific applications depend on the task to be performed.
Which of the following libraries and frameworks are familiar with you?	Tensorflow; cuBLAS; numPy; Cython	Tensorflow; Eigen; libFlame; cuBLAS; numPy; Cython	Tensorflow; numPy

Appendix 3: Survey analysis

A3.1 Overview

T7.2 conducted an initial survey (Survey 1[27]) on Green Computing practice in Q3 2021. The second survey (Survey 2[28]) on GC practice was conducted approximately 12 months later. The Green Computing practice Survey 1 and Survey 2 were to all extents and purposes identical to allow for meaningful comparisons (baseline to 12 months on). However, a few additional questions were added to Survey 2 to capture any explicitly observed changes. In particular to measure any progress made by partners regarding a) becoming aware of green issues and mitigations, and b) changes made to the operation of their data centres to reduce their carbon impact.

A total of 21 different respondents from 15 countries[29] participated in at least one survey. They were members of organisations part of Research infrastructures, Research institutes, Data centres, NREN, e-Infrastructures. In the context of EGI-ACE the breakdown was as follows:

- 12 from WP3 (6 of them also in WP4)
- 1 from WP5
- 6 from WP7
- 2 outsiders (University of Lille, GSI Germany)

Some from WP3 and WP7 were also part of WP5 (four) and WP6 (one).

For the analysis we identified respondents that participated in both surveys and respondents who participated in only one survey (first or second). In the findings and conclusions presented below we are assuming that the Green Computing status at sites that responded only to Survey 1 remained unchanged 12 months later. Apart from general trends, the 9 respondents that participated in both surveys allowed us to draw some definitive conclusions relating to changes related to Green Computing over the year.

A third survey on Software Efficiency[30] was also conducted during Q3 2022.

A3.2 Detailed findings

See Appendix 1: Partner survey questions and Appendix 2: Survey responses for details of the questions asked and the responses received.

[27] Appendix A1.1 Green Computing Survey 1
[28] Appendix A1.2 Green Computing Survey 2
[29] Bulgaria; Croatia; Czechia; France; Georgia; Germany; Italy; Latvia; Netherlands; Poland; Portugal; Slovakia; Spain; Turkey; United Kingdom;
[30] Appendix A2.3 Green Software Survey

Area of interest	Findings Survey 1	Survey 2	Notes
Respondents	16 respondents from 13 countries active in organisations part of Research infra, Research institutes, Data centres, NREN, e-Infrastructures	14 respondents from 11 countries active in similar type of organisations as Survey 1	
Tracking Metrics	9 tracking GC metrics PUE - 9 Water usage - 3 also CO2, energy consumption per power rack	12 tracking GC metrics PUE - 11 Water usage - 6 also CO2, application energy use (per job)	
Tracking motivation	Initiate measures to improve - 8 comparisons with peers - 3 to publish - 2	Initiate measures to improve - 11 comparisons with peers - 5 to publish - 2	
Green role	3	6	
GC Policy	2	7	2 shareable from Survey 1 4 shareable from Survey 2
GC training programme?	Available – 2 Plan to introduce - 3 Would introduce if provided - 8	Available – 0 Plan to introduce - 8 Would introduce if provided - 11	1 shareable
Work planned to minimise GC impact	13	12	
Green power	Available – 10 Used – 5 Would use if available – 3 Using green power initiatives – 0 Not using green power initiatives - 7	Available – 7 Used – 6 Would use if available – 1 Using green power initiatives – 2 Not using green power initiatives - 5	Reasons for not using green power: no incentives, costly, not a priority, no ability to choose energy provider
Related certifications	3	1 Planned - 1	ISO 9000, ISO 27000, ISO 50000, ISO 50001, ISO 14001
Procurement	Sourcing Green Labelled HW - 5 Will source - 1 Aware of Green Label – 3 Green clauses in contracts – 5 Lifetime carbon taken into account when purchasing - 6	Sourcing Green Labelled HW - 6 Will source - 4 Green clauses in contracts - 6 Lifetime carbon taken into account when purchasing - 7	3 sets of green contract clauses shareable
Carbon credit trading		1	
Green Decommissioning	7 Due to legislation - 4 Voluntary - 3	7 Due to legislation - 3 Voluntary - 4	
Waste Energy reuse	2	2	Reuse - office/building heating in the winter Reasons for not reusing - rented facilities, not available, not feasible, important modifications needed, not efficient, DC not designed for this, costs
Changes made or planned since Survey 1		4	

A3.3 Key computing survey findings

A3.3 1 Green computing (GC) status within EGI-ACE (condensed)

Topic	Sites responding YES			
	Survey 1	Survey 2	Overall status	Notes
GC metrics tracking	10	4	14	
GC role	5	2	7	
GC policy	5	3	8	5 to share
GC awareness programme	2	0	2	9 plan to introduce
Plan to minimise GC impact	13	4	17	
Green power supplier avail	10	2	12	
Use of green energy supplier	5	3	8	other 4 would use if avail
Green power initiatives	0	2	2	
Sourcing of Green Labelled HW	5	3	8	other 5 would do in the future
Use of Green decommissioning services	7	4	11	
Green clauses included in procurement processes	5	2	7	3 shareable
Purchase decision based on carbon costs of equipment	6	4	10	
Participate in a form of carbon credit trading	0	1	1	
Waste energy for other uses	2	1	3	

A3.3 2 Recorded progress in Green Computing area

From a total of 21 different institutions that responded to at least one survey, 9 of them responded to both surveys. This allowed us to identify any progress made in the Green Computing area by these organisations during an interval of approximately 12 months. Significant findings that we can highlight:

- one started to track Green Computing metrics
- Green Computing related roles have been created at two partners.
- Green Computing policies have been defined at three places, two available for share
- 3 institutions were planning to introduce Green Computing related awareness raising (or a training) programme particularly if it were provided to them
- one is planning work/systems to optimise process so that green computing initiatives have minimal impact on their throughput
- one started to use a green energy supplier[31] (that issues certificates on green energy)
- one started to use green power initiatives (windmill lease)

[31] An energy supplier is considered *green* if one or more of its tariffs are supplying energy from renewable sources (wind farms, hydroelectric power stations or nuclear-free)

- one started to proactively try and source Green Labelled[32] hardware, by the certifications and advertised efficiencies
- 2 respondents commenced to use 'green' decommissioning services
- one organisation included 'green' clauses in the standard contracts and procurement processes
- one respondent began to make purchasing decisions based on the lifetime power / carbon costs of equipment being prepared to share the typical procurement / requirement clauses

A3.3 3 Software efficiency within EGI-ACE

Although the survey on software optimization for energy efficiency recorded a low number of respondents, the answers were similar enough to allow us to extrapolate and make a first evaluation of existing levels of awareness on Green Software.

Amongst the main findings of this survey, we can list and comment:

- C/C++ and Python chosen as main programming languages used, because of their performance and availability/compatibility; no energy efficiency criterion was considered;
- software that uses EAR[33] (an Energy Management Framework) is being considered and the way the software interacts with the systems is measured to identify the most efficient use;
- energy efficiency is not yet considered a criterion when procuring software;
- nVidia Cuda, TensorFlow and PyTorch are most used GPU frameworks used, with a focus on optimising the performance of the computational tasks;
- the energy consumed by the clusters is measured at sites mainly for cost management purposes, but also to optimise it.

[32] *Green Labelled* hardware is designed to reduce energy expenditure and reduce the impact that computers have on the environment. It can bear various ratings, evaluations and certificates such as ENERGY STAR, EPEAT, TCO Certified.
[33] https://www.bsc.es/research-and-development/software-and-apps/software-list/ear-energy-management-framework-hpc

Appendix 4: EGI-ACE VA sheets

A4.1 VA centres of WP3

% of energy price in one unit

- CESNET: 1,000,000 CPUh = 1,000,000 unit; in total: 200,000 EUR out of which 30,000 EUR → 0.2 EUR / unit → out of this energy is 15%

WP3 member	PUE	Energy % on a per-unit basis	Processor	Country	% of renewable energy*	g CO_2e/ kWh§
CESGA		not known		ES	43.2	177
CESNET	1.6	27% (Storage), 25% (GPU), 34% (CPU)	Intel Xeon Processor (Skylake, IBRS)	CZ	12.7	389
CSIC		not known	Intel(R) Xeon(R) CPU E5-2670 0 @ 2.60GHz	ES	43.2	177
CYFRONET		not known	Intel Westmere E56xx/L56xx/X56xx (IBRS update)	PL	17.9	711
DESY		29%	Intel Xeon Processor (Skylake)	DE	43.7	313
GSI		4%	Intel Core Processor (Skylake, IBRS)	DE	43.7	313
IFIN-HH		not known	AMD EPYC Processor (with IBPB)	RO	44.0	254
IISAS		15%	Intel Westmere E56xx/L56xx/X56xx (IBRS update)	SK	23.8	104
IN2P3-IRES		5% (Storage), 8% (CPU)	AMD EPYC Processor (with IBPB)	FR	23.5	60
INCD	1.45	not known	AMD EPYC Processor (with IBPB)	PT	56.7	200
INFN-CLOUD-BARI		not known	AMD Opteron 63xx class CPU	IT	41.7	215
INFN-CLOUD-CNAF		6% (storage), 12% (GPU), 18% (CPU)	AMD EPYC-Rome Processor	IT	41.7	215
SCAI		24%	Intel Xeon Processor (Cascadelake)	DE	43.7	313
SURF	1.22	23% (dCache)		NL	26.7	332
TUBITAK		5% (Storage), 28% (CPU)	AMD Opteron 23xx (Gen 3 Class Opteron)	TR	41.8	375

* see IRENA stats in 2022[34]

§ see European Environment Agency data in 2022[35]

[34] https://www.irena.org/Publications/2022/Jul/Renewable-Energy-Statistics-2022
[35] https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of-1

A4.2 Non-WP3 members

(via the survey)

Organisation	PUE	Country	% of renewable energy*	g CO_2e/ kWh§
STFC	avg 1.04	UK	43.9	233[36]
CESGA	1.49 (in 2021)	ES	43.2	177
CYFRONET	1.05 to 1.35 per HPC system	PL	17.9	711
	1.2 - 1.6 per DC building		17.9	
UKAEA		UK	43.9	233[36]

* see IRENA stats in 2020[34]

§ see European Environment Agency data in 2020[35]

[36] Source: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020

Appendix 5: Brokering strategies

There are a number of potential brokering strategies that could lead to a reduction in energy/carbon consumption. Broadly speaking, they can be considered to be one or other of the following types:

1. Send jobs where the PUE is the best
2. Send jobs where the energy % is the smallest in a compute unit
3. Send jobs to sites with high % of renewable energy

The possibility of implementing brokering was raised in a series of 1-to-1 interviews. The feedback received was as follows:

1. In DIRAC

   Generally, the issue is more political than technical.

   By default, DIRAC is supposed to give equal chances to sites to receive jobs to run. At present the order of sites is random—WeNMR jobs go to all sites. This is inherently less efficient (or 'less green'). In the future any constraints (some 'green' related weighting added to the randomness for instance) will lead to bad and 'polluting' sites staying empty. WeNMR jobs go to the best / most efficient site(s). This is greener, but possibly less politically acceptable.

   DIRAC is able to consume info about PUE[37], or other energy-related % information. It is also able to rank sites. Thus, it can make decisions (i.e. where to send jobs) based on accepted policies.

   Still to do… describe (several) strategies that need to be implemented.

   Still to do… evaluate and implement policies, to incentivise sites, lots of implications.

   Also, procedure to review what sites are reporting and where.

2. In DODAS
   (inconclusive)

3. In Galaxy

   "If I would have this information Galaxy could do all of those, yes."

   "If I would have a formula that can calculate the CO2 consumption of a given job - I could display that very prominently to a user. We do something similar for cost - e.g., this job would cost you on AWS X.Y$. And we could do something similar for CO2."

4. In WeNMR

   [confirmed WeNMR relies on DIRAC for any type of brokering]

[37] Values such as PUE, %'s need to be recorded either in the GOCDB Infrastructure information system or in other registers/aggregators (for example VAPOR). Clear APIs are needed to access these numbers.

A5.1 Green ranking

In order to include information relating to the 'greenness' of a site we need an accepted measure of typical CO_2/energy footprint for that site based upon the typical EGI-ACE workloads. This could be something along the lines of:

- Container execution by 1 user—1 user runs 10 containers, each for 2 days, on X CPUs/GPUs
- Notebooks—1 user in the catch-all installation (10GB storage, 2 CPUs for 10x1h during 1 week → CO2 emission, Energy consumption)
- (WeNMR—using 1 portal by 1 postdoc [how much data transfer, how much CPUh, how much storage → CO2 emission, Energy consumption])

In addition, simulations could model the effect of external factors. For example:

- What if energy price goes up 5x → Impact on total cost of delivery, on usage by platforms?

Questions yet to addressed include:

- What would the consumption by WeNMR look like?
- What is a typical EGI-ACE workload?
- How would consumption shift from one country to another?
- How many tons of CO_2 less we would be emitted.

The pursuit of these answers and strategies falls outside the remit/resources of this group. However, involvement of other work packages / tasks (WP5, thematic service for example) may provide a way forward.