

Giving Voice to, and Empowering Stakeholders of UKRI DRI: A Net Zero Workshop Series (Go Zero)

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Executive Summary

The UK and other countries face major challenges in transitioning to climate safe levels of fossil-fuel use over the coming decades, with climate science indicating an urgent need to make the biggest reductions in oil, gas, and coal consumption as soon as possible. The UK Research and Innovation (UKRI) organisation has begun the process of transitioning its digital research infrastructure (DRI) to Net Zero carbon and could be expected by many to set an example to other sectors.

The Go Zero project was created to engage with the diverse community of UKRI DRI policymakers, service providers and service users on the subject of the Net Zero transition. The project ran a series of three workshops in the Autumn of 2022 which considered different aspects of the challenge, allowing participants to discuss and share their expertise and ideas and giving them a voice in shaping future policies. In each workshop, expert speakers gave short but informative talks, and the participants worked together in small groups to explore a series of questions around a common theme.

The workshop themes covered the energy consumption and energy efficiency of the DRI, how yet unavowed carbon emissions could be managed, and how individuals and groups can put together action plans for Net Zero transition. The participants filled out surveys before and after each workshop which allowed the team to monitor that the workshops did effectively engage, inform and enthuse attendees. Participants also shared their Net Zero action plans that they had developed in the final workshop.

Transcripts from the workshops were thematically analysed to group together findings and arrive at some practical recommendations for strategies and projects that could be adopted by the UKRI in future. Recommendations fell into several broad areas, including (i) the development of new systems for operating and monitoring DRI resources, (ii) the building of communities and skills around Net Zero and energy efficiency and (iii) refinements to UKRI policymaking which will assist the transition to Net Zero. The project has delivered a web-site (<https://dri-gozero.co.uk/>) to disseminate a summary of the workshop series and its conclusions. The project has also developed a toolkit to provide a base for running future workshops on Net Zero transition and some advice on how to effectively run such workshops. Preliminary findings were presented at the *STFC in Conversation: Net Zero* workshop on November 24th 2022.



This project has received funding from the National Centre for Atmospheric Science, through the Natural Environment Research

1. A Net Zero Workshop Series (Statement of the Problem & Objectives)

The UK scientific Digital Research Infrastructure (DRI) community is facing a daunting challenge in the need to help the country reach net zero carbon. On the one hand, the quantities of data available, the range of processing algorithms and the important uses to which scientific DRI can be applied, are increasing. Conversely, everyone must play their part in reducing the carbon footprint of these activities. Other sectors facing similar challenges, whether in the government sector or in business and industry, will look at the approaches that we, as responsible scientists and researchers, have taken in our own sector.

The different stakeholders within our UKRI DRI community need help to understand and plan for meeting these challenges so that current and anticipated future scientific workloads can continue whilst we reduce our carbon footprint. Many of the skills and knowledge that will be needed to solve these challenges already exist within the community, but we lack mechanisms for sharing them and enabling behaviour change. Without adopting community-driven approaches, individual stakeholders may feel isolated and uncertain about how to play their role in solving these complex problems. They will need help and support to take their first practical steps on the journey to increasing energy efficiency, and to start to develop plans for the remainder of the journey.

Stakeholders across our community are currently lacking ways for their voices to be heard but they need to be at the heart of our discussions about reaching Net Zero. Without their inputs, we will struggle to discover where future investment should be directed to develop new technologies, processes and policies to increase energy efficiency and balance demand with the supply of DRI resources. We need to find a way to connect and enthuse our community in order to meet the net zero challenge. In doing so, our project developed a Net Zero workshop series.

Through a series of sequential participatory workshops (Ws) with stakeholders of UKRI DRI, we aimed to answer three research questions:

- (W1) Where does the energy consumption come from and how can it be made more efficient (including, for example, choice of infrastructure/software/workflow)?
- (W2) What to do with the fossil fuel left over/how to limit unavoids emissions and what behaviour change solutions exist to meet climate targets?
- (W3) What are key actions (by 2025, 2030, 2035, 2040) to meet net zero targets?

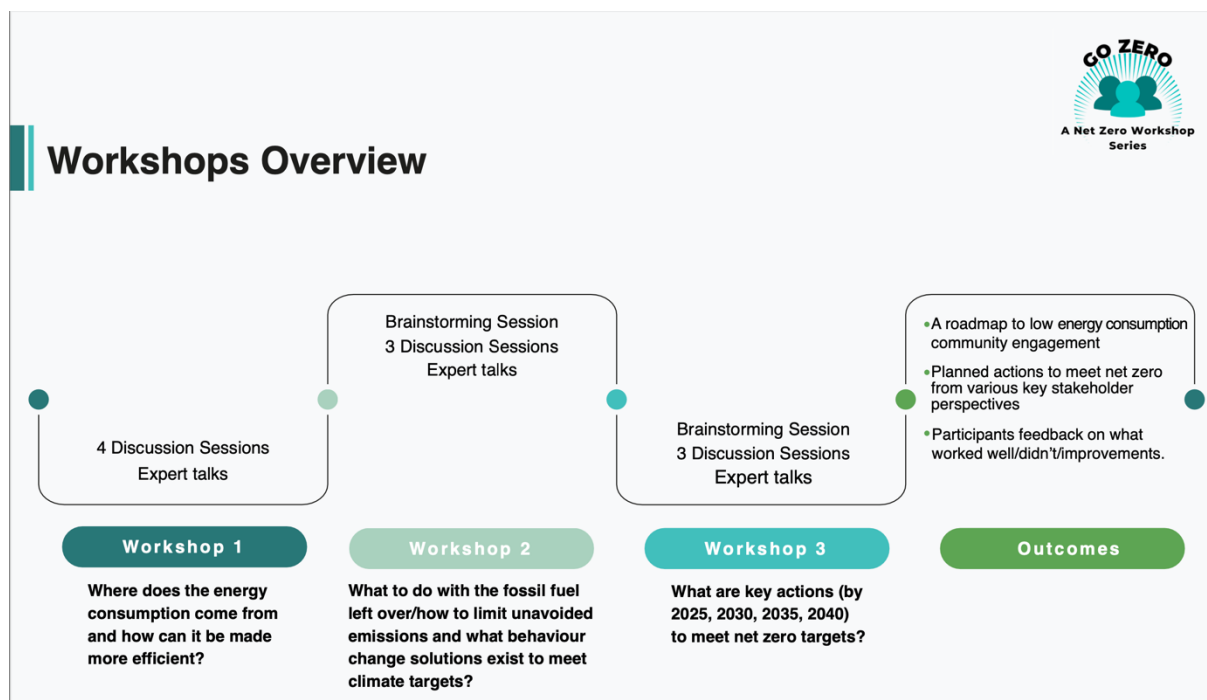


Figure 1. Workshops Overview.

Solutions co-designed with audience representatives contribute to consensus creation, build trust between different stakeholder groups, and can transform behavioural, policy and social outcomes. Hence, it was vital to take stakeholders with us on our Net Zero journey via our participatory design. The workshops were designed to empower all DRI stakeholders to take ownership of the path to Net Zero. The stakeholders invited were from all nine research councils: computing infrastructure providers and experts; application developers; (scientific and business) users of the software and/or high performance computing (HPC) resources; funding and data providers; users and providers of digital repositories, and technology designers. We were able to get good representation of these stakeholders within our workshops (see section 2.1 for more discussion).

The planned outcomes of our workshops were as per the below, which were fully achieved:

- a) a roadmap to low energy consumption community engagement (i.e., we have developed a toolkit for running workshops, building communication bridges between communities, and developing net zero action plans);
- b) planned actions to meet net zero from various key stakeholder perspectives i.e., a set of recommendations that arose from our workshops AND a net zero recipe book comprising examples of communities' net zero action plans from workshop participants; and
- c) participant data via before and after workshop online surveys providing statistical evidence of the effectiveness of such workshop series in advancing DRI net zero

knowledge/awareness, which have an impact on intentions; along with identifying challenges and opportunities including what worked well/didn't/improvements.

2. Methodology and Results

2.1. Methodology, Recruitment and Sample Size

The sequential workshops were conducted online to promote net zero targets (rather than contradict our values with workshops in a physical location that required travel for participants) and ensure a good geographical spread nationally and internationally. They enabled the co-creation of solutions by giving voice to the needs, perceptions and intentions of stakeholders. They were recorded and transcribed via Zoom (so that they could be thematically analysed afterwards), while breakout rooms were used to enable interactive participation in smaller groups. After each discussion session in breakout rooms stakeholders were brought back all together for cross-fertilization of ideas. Each workshop lasted four hours, which included a 30 min break, and the sequential workshops were followed by a two week gap between each other, to allow participants to fill in online surveys and reflect on previous discussions prior to the next workshop. This gap between workshops also allowed the project team to analyse findings and provide a short summary of these to participants in the following workshop, before addressing the new set of discussion questions.

A concrete agenda with a set of aims, exact timings and discussion questions were developed in advance of all workshops. This was essential for the management of the workshops on the day but also to ensure that our aims were achieved. An overview of our main discussion sessions in each workshop can be seen below, while the exact set of agendas for each workshop with timings, can be found in Appendix A. In addition, a set of slides was developed for each workshop, which defined terms prior to discussions, enabled participants to be reminded of the main discussion questions during breakout sessions and beyond, as well as provided a platform for expert guest speakers to communicate their views. The slides for all workshops can be seen in Appendix B, along with definitions of key terms within our slides. However, expert guest speakers' slides are not provided within.

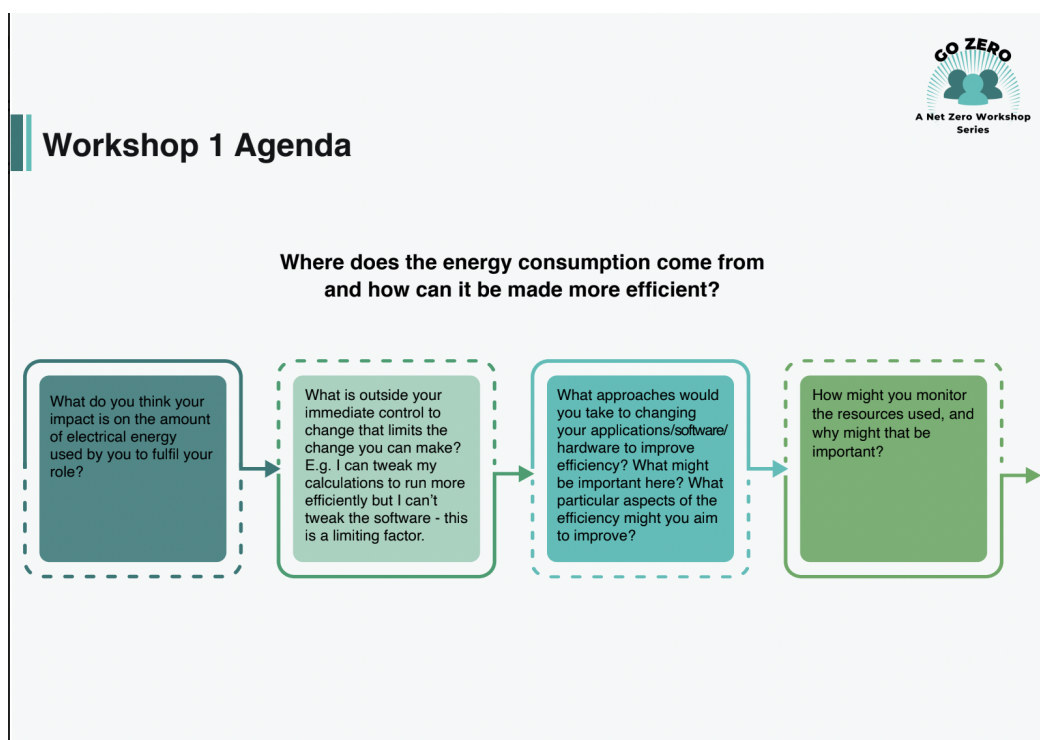


Figure 2. Workshop 1 agenda.

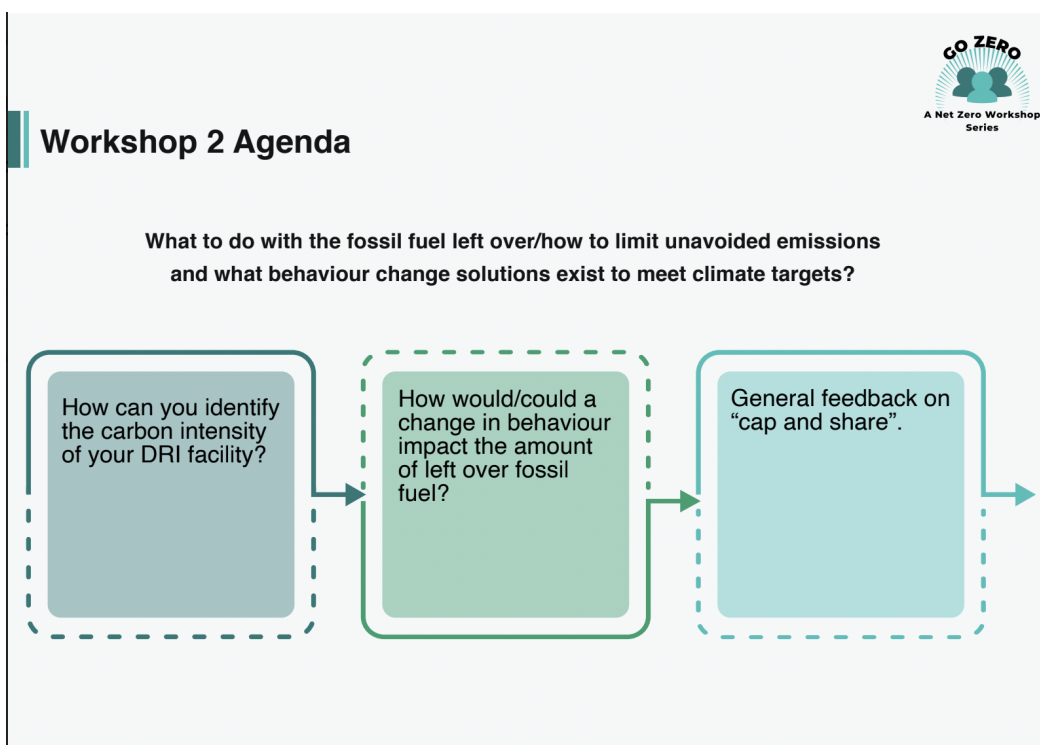


Figure 3. Workshop 2 agenda.

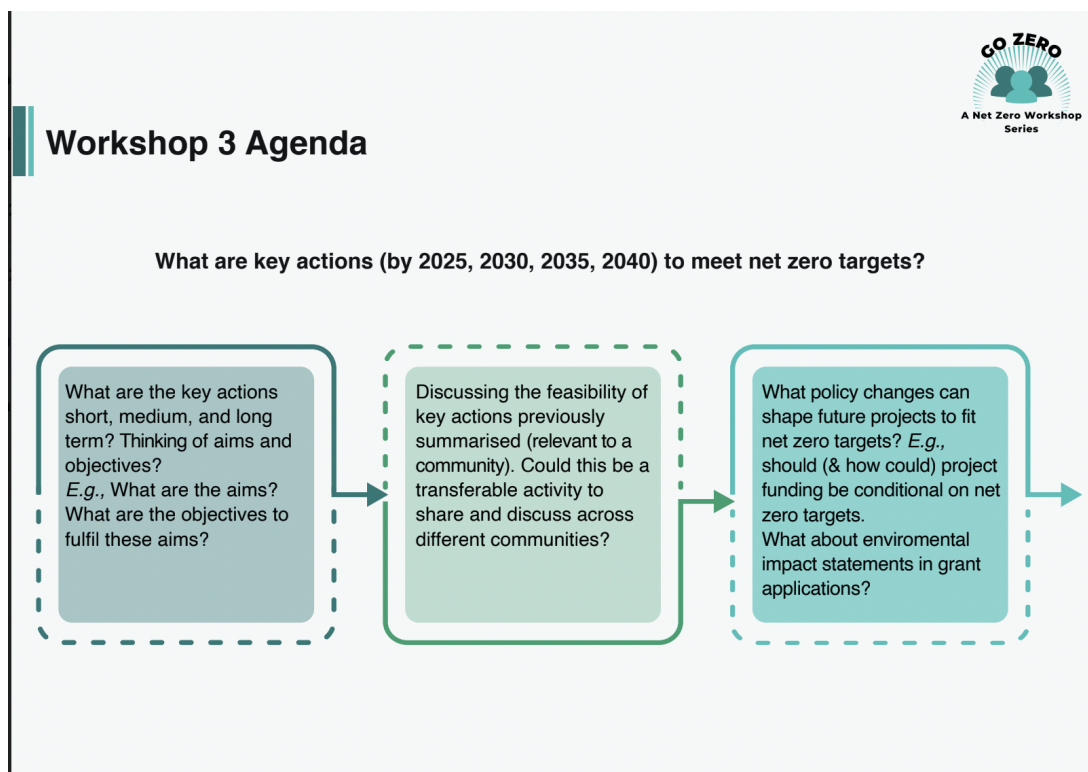


Figure 4. Workshop 3 agenda.

Participants for the sequential workshops were recruited utilising snowball sampling techniques starting with the UKRI DRI Sandpit participants, JISC DRI community, the STFC contact list, and personal contacts from across UKRI councils. An advert (see below) along with a website (by the scoping team: <https://net-zero-dri.ceda.ac.uk/go-zero/>) were created for recruitment of participants, which asked potential interested stakeholders to complete an online expression of interest (i.e., our online pre-workshops survey designed via Qualtrics). A set of participant incentives (choice of Unicef gift, Ecologi donation, Lifestyle voucher) were utilised for the promotion of our workshops. It should be noted that ethical approval was provided by Brunel University London (38244-A-Aug/2022- 41238-1) prior to any data collection from potential participants and advert dissemination. In accordance with our ethical approval, anonymity of participants was ensured with only the PI and RAs within Brunel having access to names and email addresses, which were deleted at the end of the project. The recordings and transcripts were also anonymised, including the action plans as much as possible before results were included in this report. Consent forms were signed by all participants and expert guest speakers before participation in our workshops. These have been stored by the PI in accordance with our ethics approval requirements.

Join our “Go Zero” online workshops targeting the UK research community

What?
The online workshops are designed to **connect and enthuse the UK Research community** in order to meet the net zero challenge and empower stakeholders to take ownership of the path to net zero. Join us and benefit from a chance to share the future of UKRI's net zero work, give your views, receive up to £190 of incentives, and network with others!

Who?
UK Research community across the nine councils, computing infrastructure providers and experts; application developers; (scientific and business) users of the software and/or high performance computing (HPC) resources; funding and data providers; users and providers of digital repositories, and technology designers.

When?
We will give priority to those who can attend all three workshops, but understand that unexpected things may come up.

5th October 2022	19th October 2022	2nd November 2022
Wednesday 13:00- 17:00	Wednesday 13:00- 17:00	Wednesday 13:00- 17:00
Click here for Agendas	Click here for Agendas	Click here for Agendas

If you have any questions, please email us at:
go.zero.ukri.dri@gmail.com

Interested in such discussions?

“What approaches would you take to changing your applications/software/hardware to improve work-related energy efficiency?”

“I can tweak my calculations to run more efficiently but I can't tweak the software.”

Express your interest [HERE](#) by 14/09/2022. Selected participants will join the workshops and receive up to **£190** of incentives for workshops attendance and surveys completion (Choice of: Lifestyle vouchers, Ecologi donations, Unicef Gifts).

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Figure 5. Net zero workshop series promotional flyer.

Each of the workshops was originally planned to include 60 participants, and 4 invited expert speakers (low energy practice champions). However, due to the passing of Her Majesty the Queen, our recruitment endeavours had to pause for a bit, which resulted in recruiting fewer participants overall; in addition to the significant time commitment from participants for our workshop series (i.e., 3 workshops x 4 hours = 12 hours in total). Overall, we still believe we were able to achieve the objectives of our project with the recruited participants as can be evidenced below (see findings, conclusions and recommendations).

Out of 26 expressions of interest (via an online pre-workshops survey), Workshop 1 was attended by 25 participants, 3 expert guest speakers, 1 participant/expert guest speaker (i.e., served as both for W1), and 6 project team members (Total attendees: 36). Workshop 2 was attended by 18 participants, 3 expert guest speakers, and 7 project team members (Total attendees: 28). Workshop 3 was attended by 11 participants, 3 participant/expert guest speakers, and 7 project team members (Total attendees: 21). As expected for sequential workshops, given the demand on attendees' time i.e., 3 days x 4 hours, attendance dropped from one workshop to the next. In total, 14 participants attended all sequential workshops. The workshops lasted for 12 hours in total. Each workshop included 3-4 main discussion sessions via 3 breakout rooms (i.e., participants were split equally as much as possible between breakout rooms). These main

discussions for each workshop lasted between an hour to two-hours and twenty-five minutes. In total, 137,343 words were transcribed from the audio-recording of the workshops and later thematically analysed. The transcripts can be found in Appendix C.

The same happened with participation in the online surveys in between workshops. We started with 60 prospective participants who started the expression of interest to join the workshops via the pre-workshops online survey, but only 32 of them completed the entire survey. Out of the 32 one was a duplicate and hence we ended up with 31 unique expressions of interest and one participant was also later added. Hence the total of expected participants and those invited to join the workshops based on the pre-workshops online survey (i.e., expression of interest) was 32 participants. Out of the 32 participants, workshop 1 was attended by 25 participants, so some of those who said they would attend did not (only one of them gave prior notice). With respect to the online surveys, we had 31 pre-workshops expressions of interest, 29 attendees (excluding the project team members but including both participants and expert guest speakers) completed the after-W1 online survey, 16 completed the after-W2 online survey, and 10 completed the after-W3 online survey. Only 8 participants completed all online surveys and attended all sequential workshops.

The aim of the online surveys was to collect expressions of interest for participation, select diverse participants and collect key information on them, identify potential expert guest speakers, monitor/evaluate each sequential workshop, and compare and contrast from one workshop to the next and overall: participants' comfort levels in engaging with the UKRI DRI community, the perceived level of net zero importance for UKRI and participants' job role, participants' perceived knowledge on the topic of net zero DRI, control and intentions to take action to meet net zero targets. The online surveys used can be seen in Appendix D.

2.2. Descriptive Information on Participants

Below, in the Table 1 provided, we indicate some descriptive key information on the participants of Workshop 1 (total 26 participants that attended W1). Most participants/attendees were affiliated with NERC, STFC and EPSRC as expected due to the nature of the project. Their areas of interest ranged from data centres, software development, HPC infrastructure, training skills, and hardware. There were 14 males and 10 females, with the majority coming from the 41 to 50 years old group (10 participants), and some from 51-60 years old group (5 participants) and 21-40 years old group (8 participants). No participants were above the age of 60. Participants mostly came from the UK, with also two from France, one from China and one from Poland. The majority of participants had jobs at senior levels (16 participants), with 7 having worked 15+ years in their current role or less than 10 years (16 participants). Lastly, participants were asked to select an incentive of their choice. The majority picked an altruistic incentive not connected to net zero/project (i.e., Unicef Gift), followed by an egoistic gift (i.e., Lifestyle voucher), and lastly

an altruistic incentive connected to net zero/project (Ecology donation). More details on the results of each online survey can be found in section 2.4.

Table 1. Descriptive Information on Participants based on Workshop 1

Council Affiliations for Participants*		Areas of Interest*		Gender	
<i>Councils</i>	<i>Number of participants</i>	<i>Area</i>	<i>Number of participants</i>		
AHRC	1	HPC Infrastructure	12	Males	14
BBSRC	2	Data Centre	17	Females	10
EPSRC	5	Software Development	16	Prefer not to disclose/Missing	1
ESRC	3	Hardware	8	Age Category	
Innovate UK	1	Training Skills	11	21-30	4
MRC	0	Other	3 (all the above, Research data and achieving)	31-40	4
NERC	9	Highest Education Level		41-50	10
Research England	1	High school diploma	1	51-60	5
STFC	6	UG degree	4	61+	0
Central UKRI	1	Masters degree	5	Prefer not to disclose/Missing	1
None of the above	8	PhD ongoing	1	Country of Residence	
Other	University funding, BEIS, Code carbon, Digital Humanities Climate Coalition, Software Development Organisation	PhD degree	13	UK	22
Job Role		Years in current role		China	1
Junior	6	< 5 years	9	France	2
Senior	16	5-10 years	7	Poland	1
Top Management	1	10-15 years	1	Incentive Choices	
Other	1 (e.g., Junior pay but senior responsibility)	15+ years	7	Ecology donation (altruistic incentive connected to net zero/project)	6
				Unicef gift (altruistic incentive not connected to net zero/project)	11

				Lifestyle Voucher (Egoistic incentive)	9
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Notes: * participants could select more than one category; Total may or may not add up to 26 in total, due to some missing info from participants.

2.3. Sequential Workshops' Findings

As noted earlier the sequential workshops had clearly defined aims, and discussion sessions. Below we describe each workshop and its findings, as well as a visual representation of the findings in the form of ppt slides can be found in Appendix E.

Workshop 1 aimed to develop workshop participants' knowledge and understanding on the challenges surrounding the transition of UKRI DRI to Net Zero. The workshop opened with presentations to introduce the terminology and concepts. The main body of the workshop was discussion based in 3 breakout groups. The guided discussions focused on 4 themes; electricity consumption and the role of the individual, factors beyond a person's control in achieving net-zero goals, approaches for improving energy efficiency, and how individuals might monitor the resources used, and why that might be important. The outcomes by question will now be summarised.

Discussion on electrical consumption and individuals role was broad including topics on the way data are stored, how online portals are managed, HPC infrastructure, how code is run and user behaviour. The concept of embodied carbon versus the operational carbon use was first introduced when considering data storage where power draw is very low for storage, but there is an embedded carbon footprint in the manufacture of storage systems. The concept of data triage and the choice of storage media (data versus tape) were identified as potential energy efficiency savings. Online portal architecture should also be reviewed in the context of Net Zero e.g. the use of databases and methods for making queries more efficient such as cached search histories. High performance computing (HPC) services will need to be more energy efficient in future so users will have less freedom when using these services. It may be more efficient to use a central computing resource. The relative impact of HPC with scope two emissions (embodied costs of equipment) was raised with ARCHER 2 at peak capacity emitting far less than a transatlantic flight, UKRI policy and ethical research mean the topic should still be considered though. User behaviour is crucial in achieving Net Zero with improvements needed to how code is produced, reviewed, tested, deployed and run to make processing more efficient. Policies on HPC may become less free with more planning of compute to target times when the energy grid has a lower carbon intensity. Human behavioural change is difficult with training of the user community on carbon usage is required to achieve user behavioural changes.

For factors beyond a person's control in achieving a Net-zero goals introduced carbon intensity, usage and monitoring entered into the discussion. Knowledge of the carbon intensity of electrical supply is required with procurement frameworks not currently including carbon impact.

Procurement of HPC also needs to include carbon impact both in terms of embedded carbon and auxiliary equipment such as cooling systems. Including the carbon impact should be a factor when scoping the replacement of systems potentially increasing the lifetime of hardware. Optimising the maintenance of HPC systems may also extend their lifetime. The environmental sustainability of research could be added as an element of funding proposals. The concept of monitoring energy usage is key in influencing user behaviour of DRI with discussion highlighting that it needs to be in terms people can understand. Monitoring is covered in more detail in question 4.

The next question in workshop 1 looked at approaches for improving energy efficiency. A green computing campaign would potentially be an effective method to highlight the carbon impact of computing to encourage all researchers to think before deploying their codes. Achieving the user culture to shift away from running code as fast as possible towards understanding of the need for efficiency, increasing renewable penetration and its capacity. Rationing of compute resources was discussed with monitoring and assessment of usage to regulate the policy. Improving research software engineering (RSE) skills is needed to evolve software development to increase job efficiency by both improving code, development operations and approaches for running code. Pressure could be applied from funding bodies to request an assessment of carbon impact for each proposal and to perform life-cycle analysis. Funding councils could ask proposals to consider efficiency and plan for reducing the carbon footprint.

The last question considered how might users monitor the resources used, and why might that be important? The use of monitoring equipment with dashboards for servers and nodes with meaningful metrics for users was proposed. In turn, people will innovate and they will become competitive about how much they have reduced their carbon impact. This monitoring data should help to build a green computing community, sharing ideas driven by the monitoring data, re-using results to save power. Thus, supporting the development of environmentally friendly software and codes based on users' choices. Data centre schedulers could decide when the jobs should run. Lastly, encouraging people to see if they can re-use data that has already been generated, this approach would leverage the difference in power draw between storage and compute.

Workshop 1 findings are summarised below, along with a word cloud based on the most frequently used words during W1.

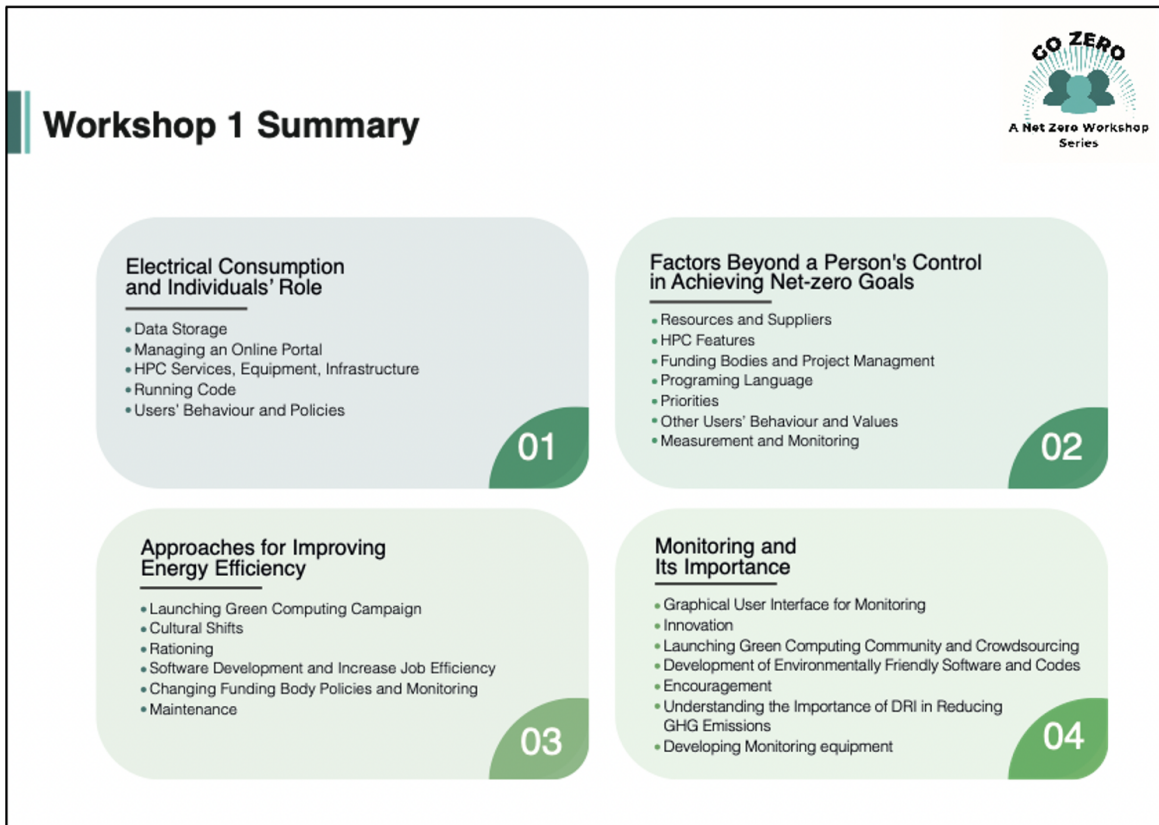


Figure 6. Summary of workshop 1 findings.

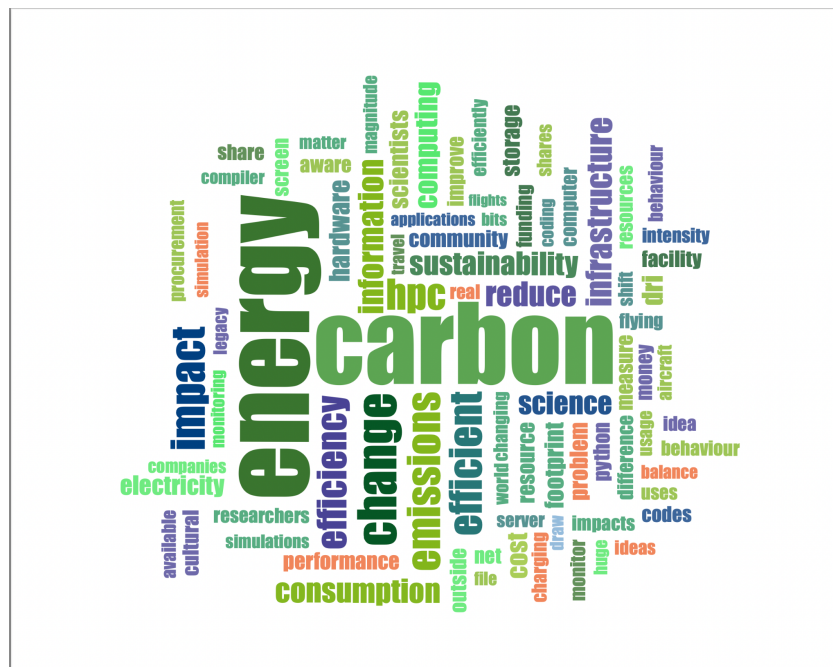


Figure 7. Word cloud: Workshop 1

Workshop 2 aimed to answer the question “What to do with the fossil fuel left over/how to limit unavoided emissions and what behaviour change solutions exist to meet climate targets?”. The first breakout session was dealing with the identification of the carbon intensity of a DRI facility. The participants were asked to discuss where the carbon emissions come from exactly and how the carbon intensity can be determined. The need for a *global criteria for carbon intensity* was highlighted. The criteria should incorporate the necessary granularity of the different sources of emissions (embedded emissions, operational emissions, emissions from cloud applications), and a generalised unit of reference (i.e., emissions per research paper, per operation, per facility). This will help to gain an overview of the DRI system to estimate the impact of emission reduction measures. In order to achieve this carbon intensity metric, the implementation of a *carbon intensity policy* is needed to ensure standardisation across facilities. This enables transparency and community coherence but also responsibility in analogy to health and safety workplace policies. The lifetime embodied emissions of hardware components need to be considered; their utilisation should be maximised as well as their lifetime through improved maintenance to reduce the overall emissions from hardware in DRI. In order to implement the policy, *user training* will be essential to train the community on how to use new tools.

The second breakout session was discussing the impact of behaviour change on the left over fossil fuel and yet unavoided emissions. The need to *change grant policies* has been highlighted. Allocating research grants with the premise to stay within a certain carbon budget could act as a demand-push policy. This includes procurement and usage. Predicting the carbon consumption of a project might not be as straightforward as financial budgets, especially as the carbon intensity of whole systems changes continuously. The development of a tool to facilitate the estimated carbon budget will be helpful. Stakeholders should be able to roll-over unused budget when a resulting reduction in emissions is justified. Similarly, spending unused budget on other emission reduction measures should be facilitated. A change in behaviour towards the *development of efficient codes and infrastructure* can be achieved through competitions (i.e., hackathons) and careful considerations of architecture procurement and usage. Efficient jobs could be upweighted. Setting up a *database for green computing* that consists of detailed documentation about what has been done to increase energy efficiency in past projects will support DRI stakeholders. This goes beyond data repositories in the appendices of publications today. It would give DRI stakeholders the option to save time for their own code optimisation. Similarly to an ethics review or animal use review in research applications, this database would need to be consulted in an application process to show that applicants are familiar with established measures to decrease the footprint of their intended computations.

The third breakout session was dealing with the concept of a “green scheduler” as the realisation of a cap and share system. In general, such a system would allow an improved approximation of DRI activity to renewable energy fluctuations to both increase the utilisation of renewables and decrease the need for fossil-fuel energy. A “green scheduler” could support the realisation of a *carbon budget allocation* in grand allocation. The basis of such a system would be a standardised and transparent *resource monitoring* that accounts for the spent carbon budget of a certain job. An *intelligent scheduler* would need to incorporate both the operational emissions and the embedded hardware emissions, resulting in a multi-criteria optimisation for the decision making of the

scheduler. The pressing question is how stakeholders will be able to organise around a certain budget (“cap”), which highlights the need for a suitable interface of the scheduler. This raises the urge to make this a *community-driven development* to increase the trust in such a system compared to sole top-down decision making.

Workshop 2 findings are summarised below, along with a word cloud based on the most frequently used words during W2.

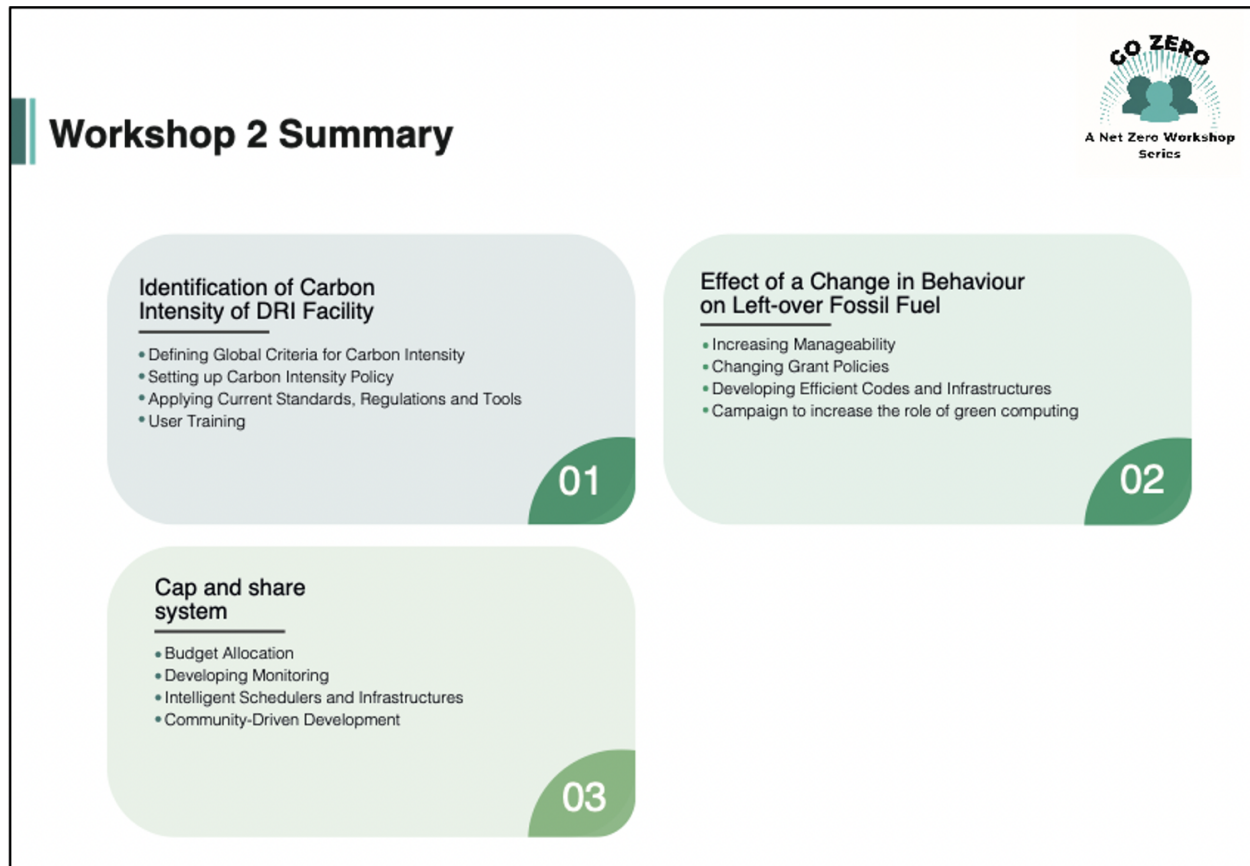


Figure 8. Summary of workshop 2 findings.



Figure 9. Word cloud: Workshop 2

Workshop 3 dealt with actions and recommendations to be taken by UKRI on the route to net zero. We organised three breakouts plus a fourth one to allow participants to write their own organisational net zero action plans/recipes.

The first breakout asked participants about the key actions to achieve Net Zero targets, focusing on the short-, medium- and long-term time scales. Moratoriums emerged as important, identifying highly polluting activities that are too complex to solve in the short term with a focus on reducing energy usage. Trying to reduce demand for new hardware should be part of a clear definition of procurement and maintenance policy, addressing institution hardware's replacement cycles and complex mechanisms of procurement/provider policies, equipment security and business policies. Cultural changes will affect other activities, as will travel policies, sometimes ignored today in terms of public transport usage. The participants were clear that some of the changes must be community-led, with groups coming together to plan to make short-term savings. Individuals and communities need the time and space to explore what is possible, as this can drive the less motivated and build capacity and momentum. Finally, it is critical to embed an environmental impact carbon footprint assessment on every research proposal with clear criteria, mandatory reporting, and auditing of the entire process.

The second breakout session focused on the feasibility of the key actions. Participants prioritised people involvement through well-defined communication activities that will create synergies between actions, giving communities tools and the motivation needed to push actions. A big part of the UKRI DRI drive and motivation must be targeted funding for Net Zero projects, as those are already driving behavioural change in parts of the community, proving that this incentive is effective. But as important as the funding is, common terminology, standards, frameworks,

education, and training are required, to bring the community to a collective understanding from the grassroots to the senior level.

Breakout three focused on the policy changes to shape future projects to fit net-zero targets. Most of the thinking from previous sessions was repeated; in addition there could be systems to reward work that reduces carbon footprints. These systems should be clear at the time of awarding funding, UKRI should do a carbon-based assessment rather than money-based. UKRI must develop tools to allow applicants a transparent and clear carbon content assessment of their proposals and projects. Finally, green schedulers should be developed and used to adapt to different patterns in the future - allowing intensive computing when the energy supply is greener.

The final part of the workshop focused on developing net zero recipes; participants were provided with a template and worked individually on them. Finally, the recipes were shared among the groups to debate them. Participants have shared their recipes with the Go-Zero team to be provided as part of the project deliverables.

Workshop 3 findings are summarised below, along with a word cloud based on the most frequently used words during W3.

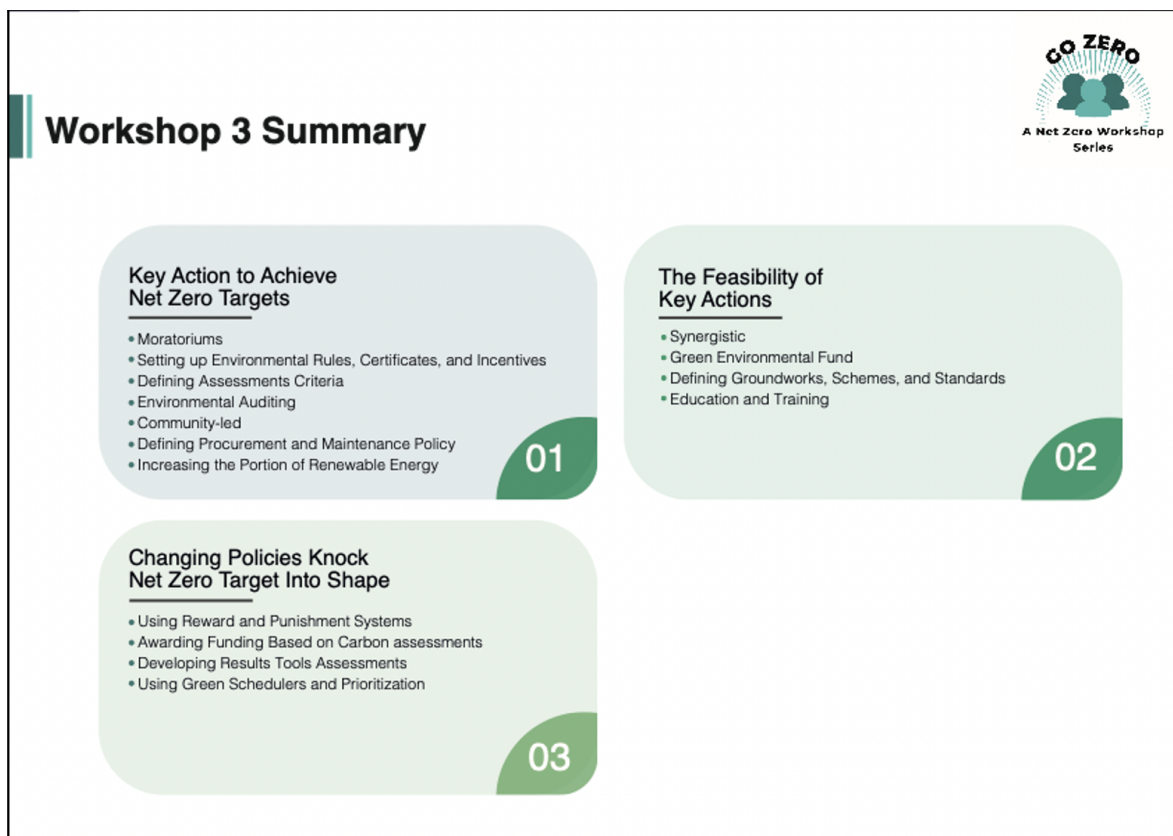


Figure 10. Summary of workshop 3 findings.



Figure 11. Word cloud: Workshop 3.

Based on these findings, a set of recommendations were put forth (see section 3.1).

2.4. Online Surveys' Findings

One of the aims of the online surveys was to compare and contrast from one workshop to the next and overall: participants' comfort levels in engaging with the UKRI DRI community, the perceived level of net zero importance for UKRI and participants' job role, participants' perceived knowledge on the topic of net zero DRI, control and intentions to take action to meet net zero targets. This is because our project conceptualisation incorporated the hypothesis that the sequential workshops themselves – as part of community engagement – would enhance participants' knowledge and intentions to take action to meet net zero targets. This was tested by measuring the same constructs with likert scale items ranging from 1 to 10, four times across each participant: before the workshops, after W1, after W2 and after W3. Table 2 below provides an overview of the means (and standard deviations) for each construct across these 4 online surveys (please note that the total number of participants in each online survey differed and hence we cannot test for statistical significance, hence these results should be interpreted with caution.

Table 2. Means and Standard Deviations for Main Survey Variables

Construct	Pre-workshops survey <i>M (SD)</i> N=26	After W1 survey <i>M (SD)</i> N=25	After W2 survey <i>M (SD)</i> N=15	After W3 survey <i>M (SD)</i> N=10
Workshop evaluation	n/a	8.48 (1.56)	8.53 (0.83)	8.70 (0.95)
Comfort level for engaging with DRI stakeholders	8.25 (1.51)	7.60 (2.22)	8.27 (1.58)	9.00 (1.55)
Importance of net zero to UKRI	9.63 (0.92)	9.68 (0.63)	9.73 (0.59)	9.80 (0.42)
Importance of net zero to Job Role	8.62 (1.34)	7.88 (2.22)	8.67 (1.05)	9.20 (0.79)
Knowledge	5.92 (2.34)	6.52 (2.26)	7.40 (1.68)	8.70 (1.16)
Control	6.29 (1.94)	5.56 (1.94)	6.87 (1.36)	7.00 (1.76)
Intentions	8.50 (1.35)	8.60 (1.47)	8.93 (1.22)	9.50 (0.71)

Note: all means based on a 10-point likert scale; results do not show whether the differences are statistically significant.

However, we were able to test for statistical significance across the online surveys for all constructs based on the 8 participants that completed all online surveys and attended all workshops. Based on these 8 participants, we found that our sequential workshops were effective in advancing knowledge, but not intentions to take action. More specifically, we conducted a t-test and found that knowledge significantly improved from the pre-workshops survey to after the sequential workshops [$t(14)=-2.42$, $p<.05$; Mean before workshops = 6.13 out of 10 (SD=3.28); Mean after workshops = 9.00 out of 10 (SD=1.07)]. This proves that sequential workshops as a community engagement mechanism can help DRI stakeholders build and advance knowledge which later in turn could potentially influence their intentions to take action to meet net zero targets (based on prior research knowledge can influence behaviour - but also there is caution against assuming that knowledge always leads to behaviour change).

In addition, another aim of the online surveys was to receive feedback from participants in regards to the sequential workshops. Below the word clouds, summarise open-ended comments provided for the three sequential workshops; which indicate their positive impact and important terms and ideas at each stage.



Figure 12. Word clouds: Feedback and thoughts before and after each workshop collected via online surveys.

2.5. Action Plans: Recipes

During Workshop 3, participants had time to develop their own net zero action plans. An action plan is an outline or list of all the tasks that need to be completed to achieve a goal (Boutros, n.d.). Put most simply, an action plan is a list of the steps or tasks that need to be completed to reach a goal or to complete a job (Frese, et al., 2007).

A common technique for simple and effective guidance is the 5W technique (i.e., what, who, when, where, why), which creates a step-by-step roadmap that is a sequence of questions to understand the issue being evaluated and help develop an action plan that can be used for various types of situations (Hernandez, 2020). These typical 5W questions are commonly used for action plan

development and design (Šormaz, 2020). To use the 5W technique, we asked the following questions in our action plan: **What** aspects of your work are related to net zero targets? **Who** needs to take action to meet these net zero targets? **When** will these targets be achieved? **Where** can these changes be implemented? And **Why** would these methods/approaches work, or are there any barriers?



Figure 13. Developing a net zero action plan by using 5W technique.

By designing a table to answer these 5 W's, we could develop a strategy in which the participant could identify their potential net zero targets and the capacity of their organisation to reach this goal. By answering who needs to get involved, we could broaden the vision of all the possibilities of utilising human resources and management to achieve mutual goals towards net zero. By asking the key milestones, or the 'When' question, we could encourage the participant to draft a set of key milestones for the specific aspects they listed regarding their net zero targets; doing so, the participant could gain a vision of whether each element could be reached in the short, medium or the long term, and what possible time steps each aspect would require. By asking the participant where these changes can be implemented, we wanted to look into different sectors of their organisation or broader company involvement to see how widely these changes could affect net zero goals and the community/sector/group these changes will affect. By asking the participants why they think this could work, we could get them to think about the opportunities that could help achieve net zero, all the possibilities, and the limitations and barriers they feel can affect their goal

of reaching net zero. By identifying the prospects, opportunities and obstacles, the participants could construct a broader vision of getting their net zero targets and what challenges they anticipate in this path.

From the action plans developed within the Go-Zero workshop series, a recipe book has been put together as example action plans for achieving net zero. These can be seen in Appendix F. For example, points were made on implementing carbon-aware strategy for hardware replacement, implementing IT infrastructure for using power monitoring, presenting power consumption data to users for spreading awareness of their HPC jobs, using RSE to review codes and workflows, and also to provide HPC users with carbon estimates to help them understand their emissions and highlight the importance of reducing their emissions. Furthermore, within the 5Ws method, applicants could identify who needs to take action, whether it is team experts implementing monitoring, infrastructure managers or team developers and communications staff. Also, important awareness was raised on the ‘why would these methods work’, whether because of the concrete set of effective actions or the importance of using hyperscale data centres because local clusters are rarely as efficient. And also to identify some barriers such as resistance to change from users due to possible extra work, finance required for new hardware or research software optimisation and the cost difference of more power-efficient hardware (Go-Zero Workshop series, 2022).

An example net zero action plan can also be seen below.

Go Zero Action Plan



What are your work-related net zero targets?	Who needs to take action to meet these net zero targets?	By When? Key milestones: 2025, 2030, 2035, 2040
<p>System:</p> <ul style="list-style-type: none"> - Establish robust monitoring of energy usage, and develop understanding - Implement "carbon aware" strategy for hardware replacement - Develop and roll-out tools to enable users to evaluate carbon impact of workflow options (e.g. storage "just in case" vs re-run on demand) <p>Users:</p> <ul style="list-style-type: none"> - Raise awareness of carbon costs for work and encourage users to consider options for designing work in advance - Ensure workflows / software are optimised to minimise carbon impact <ul style="list-style-type: none"> - Staff member in place to support community in doing this - Users actively manage their data, including tidying up post-project, and making good use of tape <p>Others:</p> <ul style="list-style-type: none"> - Carbon aware procurement process - Use of green energy 	<ul style="list-style-type: none"> - Team experts to implement monitoring - Infrastructure manager and procurement team - Team developers, and communications staff - Communications and training team members, consortium managers - Users, and team to support - Director, with Research Council - Consortium managers, with support from the team - Procurement process owners; we need to advocate - STFC; we need to advocate 	<ul style="list-style-type: none"> - 2025 – tools should be well established - 2030 – awareness sooner, but needs procurement process on board - 2030 – needs tools in place and reliable first - 2030 – needs tools to be able to accurately assess - 2025 – can start optimising workflows immediately; needs carbon cost tools to fully implement - 2025 – asap! - 2025 – should be doing this anyway! - 2030 – might be ambitious! But replacement timescales for hardware are long. - 2030 - might also be ambitious
Where change can/ will be implemented?	Why would this work? (+ any barriers to change)?	Other Notes
<p>System changes – within the remit of the HPC team</p> <p>User changes – needs community buy-in, then changes to community practice</p> <p>Others – needs government / organisational change</p>	<p>System changes – provide the tools needed to be able to have authoritative conversations with users. Necessary to make progress (though not necessarily sufficient!).</p> <p>User changes – if we can get the community on board, these changes can have a big impact through the accumulation of small changes across a large community. Need to be aware of the risk of increasing demand through releasing capacity, which would counteract benefits.</p> <p>Others – may be tricky! But these are big impact changes needing high level leadership.</p>	

Figure 14. Example of a net zero action plan.

3. Conclusions and Recommendations

3.1. Recommendations

A total of 12 recommendations have been synthesised from the three workshops, which are summarised below.

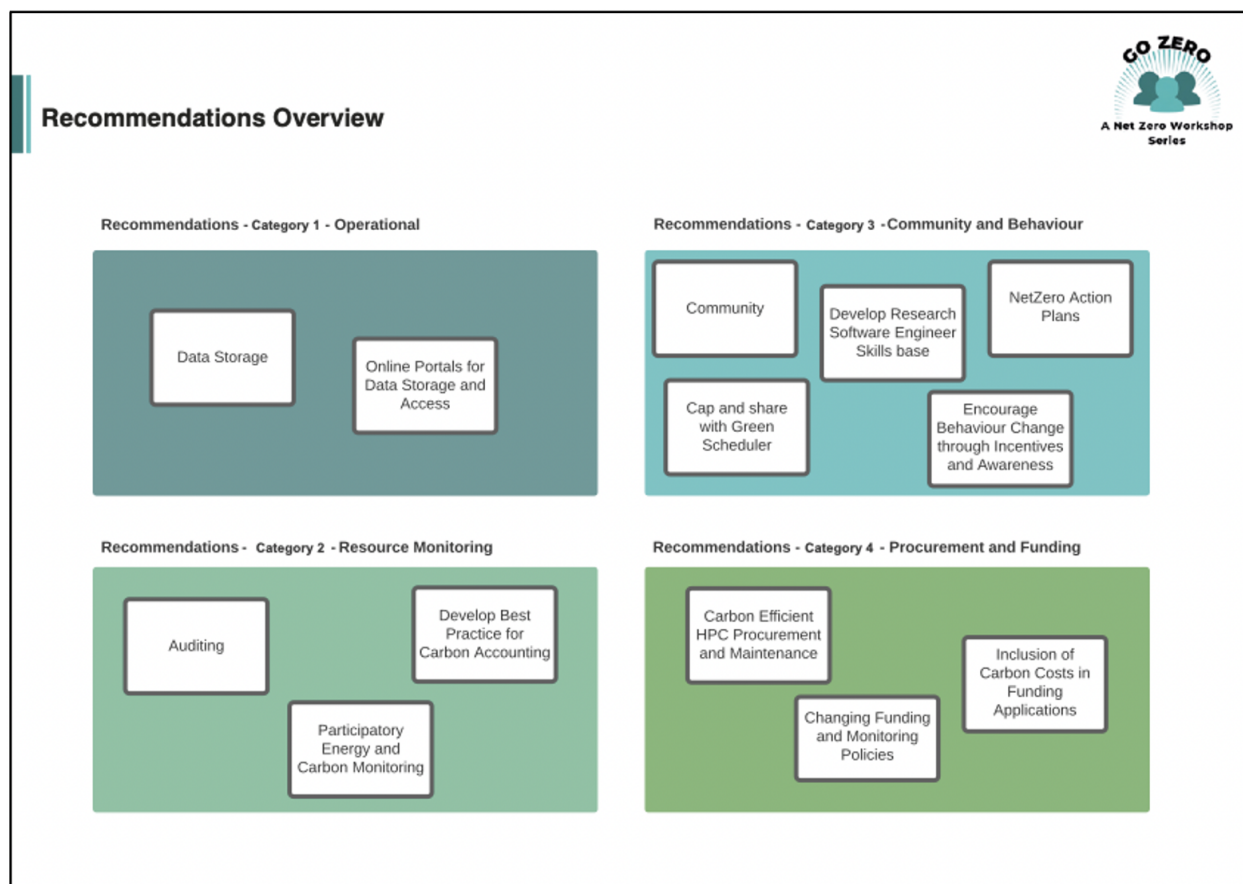


Figure 15. Overview of recommendations.

These recommendations can be broken down into 4 different groups; operational, resource monitoring, community & behaviour, and procurement & funding recommendations. Operational recommendations consider aspects of energy efficiency for data storage through software and hardware. Information is key for net zero actions, which is being considered by resource monitoring techniques. This goes beyond general energy auditing and carbon accounting, towards the need for novel ways of monitoring operational carbon emissions. This will allow DRI stakeholders to understand how their behaviour impacts carbon emissions from DRI use. The community and behaviour aspects range from the general need to form a community, to specific recommendations around participatory methods to reduce carbon emissions such as green schedulers. The key to enabling behaviour change in the community is to provide sufficient information and the right infrastructure to allow a change in behaviour. Another main concern was the need to change the financial policies. Currently, carbon does not play a major role in procurement and funding which could be overcome by including carbon budgets in applications.

Both the embedded carbon in hardware and the operational carbon emissions from electricity need to be considered.

A more detailed overview of how our recommendations map against our workshops' findings can be seen in Appendix G, along with our excel file recommendations in detail.

3.2. Online Workshop Toolkit for Community Engagement: Guidelines based on lessons learned

The below guide is provided on how DRI researchers and other stakeholders could run additional online workshops for community engagement; and the valuable lessons our team learned based on this project.

3.2.1. Thinking and Planning

Think and plan ahead and allow even more time for thinking and planning:

Why run a workshop? You are asking people to give-up their time to attend an event you are running, ask yourself 'What would motivate me to give up my time?' 'What will the participants gain from attending the workshop?' 'What do I want to achieve from running the workshop?' Focus on, and address these questions first because you might find a workshop is not the best format (e.g. a survey might achieve what you want).

Structure of the workshops Ok, so a workshop it is. A single or multiple event? How long should it/they be? If multiple, the commitment expected from participants and their motivation to attend needs to increase - you will need to generate this motivation - is that feasible?

Participant availability Think of your audience -what sector do they belong to? Does this impact when they have availability to attend? (E.g. teaching academics might have a common time free per week). Enquire through your and colleagues' networks. Be prepared to adapt the workshop structure and times to suit your participants (e.g. evening/weekend events).

Workshop Content This is reverse-engineered from your aims and objectives -what you hope to achieve from the workshop, examples:

1. If you want a list of ideas about subject X, then you will need to include plenty of time for idea generation built around a discussion that is seeded by a question/topic of your own. So: ask a question about subject X, generate a discussion, develop ideas, list them → workshop objectives achieved!
2. If you are gathering opinions around a specific subject for a report from diverse communities, decide if you want cross-community interaction and/or specific community focus, divide the participants accordingly, outline the subject area, break it down into sub-sections, and build a discussion around the participants' answers to specific questions. Compile the report from the answers and discussion.

3.2.2. Include a variety of speakers

Include a variety of speakers where relevant (e.g. domain specialists) to ensure a variation in the pitch and tone of content delivery; include interactive activities where relevant to engage the participants but don't panic if no-one steps forward to contribute especially during the first activity, instead, ensure that organisers other than the convenor are ready to contribute.

Workshop Resources What format does your institution use (e.g. Zoom, Microsoft Teams, Google Meet)? Does this match the most familiar format for your participants? Don't use something niche unless you are confident your participants already use it. Does the format offer the functionality that you want, e.g. break-out rooms, whiteboards and/or a shared and interactive editing space, recording, subtitling etc.? If not, do you need to use multiple formats, e.g. an external interactive space such as [Mural](#), [Miro](#), another means of recording e.g. smart phone, live subtitling and/or sign language?

Numbers of participants and organisers How many participants do you want? Accept about 20% more than this number to allow for no-shows, cancellations and drop-outs. If using break-out rooms cap the number of participants per room at ten, and **allow three organisers per room**: one to run the technical controls and keep to time, one to convene and facilitate the meeting, and one to take notes, help out with the interactive function and contribute to the discussion or task during long silences or moments when the participants are struggling to contribute. Do not underestimate the effort required by the convenor to build and maintain momentum especially when the participants are brought together for the first time.

Practise, practise, practise! Do not assume the technical side of the workshop will run smoothly, try and think of all the ways it might go wrong and test the system to breaking point - do this as a team of people (drag along some 'volunteers' to help out if necessary) to include as much variation as possible in human decision making when using the workshop platform.

Recruiting participants When you've nailed the workshop content and structure plan how to recruit participants. Do they need to be motivated to apply? What form will this motivation take (e.g. financial incentive, the promise of community-building around a shared passion?) How will the workshop be advertised? Do applicants need to complete an application or registration form? How will it be monitored and who will respond to any queries that arise? Do you need a workshop-specific email address and website? What is the most appropriate social media to use? Ensure the chosen or registered participants are made fully aware of the following:

1. The timeline - when they will receive information, e.g., the finalised agenda, joining instructions etc.;
2. The workshop format, structure and content;
3. What is expected from them as participants;
4. How the workshop output (e.g. recordings, transcriptions etc.) will be used;
5. The workshop's GDPR compliance;
6. If they need to reply with their signed consent to participate;

7. When appropriate, full and extensive joining instructions.

Recruiting domain specialist speakers Depending on the format you've chosen, you may want some domain specialist talks to set the scene, helping participants to get a better understanding of the problem at hand. Domain specialists can be renowned in their field, early careers or even members of the organising team, but in any case, you will need to contact them in advance, checking their availability and willingness to participate. You will need to clearly tell them what you want from them; is it a high level overview or a very detailed presentation on a single issue?. Tell the domain specialists how long the presentation should be and give them a deadline to send you the slides in advance. Remember to always include the titles of their presentations in the agenda.

3.2.3. Ethical approval

Before starting inviting participants to workshops, and collecting data, it is essential to seek ethical approval from an institutional body (e.g., university). Ethical approval committees would review the plan and provide early feedback, which is imperative in this process. These committees also would have their own institutional guidelines in terms of anonymity, how long data will be retained, and other processes involved in running workshops and data collections and dissemination. The ethical approval committee will also provide researchers with institutional insurance in case something goes wrong with the workshops and/or participants. This cover is essential when collecting data from human subjects.

3.3 Conclusion

Based on the aforementioned, our project delivered the output agreed and more importantly was a positive mechanism in engaging DRI stakeholders, enhancing their knowledge on the matter, and promoting net zero within this community. Our team also provided a set of recommendations, along with a guide on running online workshops in the future, and action plan recipes.

Our team also developed an open-access project website, where all material, including this report can be found: <https://dri-gozero.co.uk/> The website hosting has been paid for 12 months. After that Brunel University London (PI's institution) will pay for the availability of the website for another 2 years given that we were unable to pre-pay it from now. All workshop participants were also sent a link to this website, as part of our dissemination endeavours and we hope to use it to further publicise our work and findings.

Findings were also presented on the 24th Nov 2022, at the *STFC in Conversation: Net Zero* workshop [Invited presentation ('UKRI Net Zero Scoping Project Overview and the Go Zero Project')]. The event engaged businesses and researchers around the Net Zero agenda to

understand potential opportunities to collaborate, and to inform the development of an STFC Net Zero seed fund.

It should be also noted that due to the short timeframe of this project (6 months) we were unable to spend our entire dissemination budget by December 2022. Future dissemination activities include a series of presentations in conferences; and a planned academic journal publication, while working with our institutional media/communications teams to raise awareness of these. Funding for such activities, if needed, needs to be further discussed.

4. References

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