Forse Group

Sustainability Expectations 2026

1 - Introduction

The Forse Group prides itself on its reputation for sustainability, having been the first departmental research group to introduce a sustainability officer, sustainability guide and specific sustainability policy.

The **Royal Society of Chemistry** states that ***"****The chemical sciences will play a pivotal role in solving the challenges associated with sustainability.****"***

As a research group that focuses on understanding materials that can reduce greenhouse gases and tackle the climate-change crisis, this statement is of great relevance to us. We therefore strongly believe in working in a sustainable way that aligns with the goals of our research outcomes.

More broadly, the University is committed to a science-based net-zero target, and research funding bodies have begun to consider laboratory sustainability in funding allocation. The University of Cambridge has also signed the Concordat for the Environmental Sustainability of Research and Innovation Practice.

Sustainability, in all aspects of our work, inside and outside the lab, is therefore one of our group's **core values**. These expectations are also developed based on LEAF accreditation standards. In order to achieve this standard, all lab members must practice sustainable research in line with the LEAF recommendations.

What is the Laboratory Efficiency Assessment Framework (LEAF)?

LEAF is a standard set of actions developed by University College London to improve the sustainability and efficiency of laboratories. More than 85 global institutions are already taking part to help address the climate and ecological emergencies through your science.
Laboratory-based research is essential for advancing society but it is also extremely energy and resource intensive. It's estimated that laboratories are responsible for around 2% of global plastic waste and use 3-10 times more energy per meter squared than a typical office. By joining the LEAF programme, laboratories reduce their carbon emissions and create an environment that supports research quality. Last year, we achieved Gold LEAF status for the first time. We aim to maintain this high standard of sustainable practices in our labs and offices this year, whilst also working with other groups across the Materials RIG to achieve wider LEAF certification.

This Sustainability expectations document will be reviewed and updated by Professor Alex Forse and the Sustainability Officer annually. Items will also be raised in the **Sustainability minute** of weekly group meeting discussions.

2- Sustainability Expectations of group members

2.1 Energy Use

Lab equipment:

Did you know a **fumehood** can use 3-4 times an average U.S. household's annual energy? Harvard University reports fumehoods are responsible for 44% of their lab's energy consumption!

- Keep the fumehood sash lowered whenever not in use
- Remember to switch off equipment when not in use (including portable potentiostats)
- Improve Computational efficiency (see below)
- Share equipment (vacuum lines, glovebox, gas sorption, ovens...) wherever possible

Heating:

The department's biggest direct fossil fuel consumption is on the gas heating so:

- If the windows are open in the room, don't use air conditioning
- turn the thermostat down a few degrees and wear an extra layer

2.2 Food & Travel Policy

The details of the policy can be found in the Group Expectations document

2.3 Equipment Sharing

Using the **google calendars** within the group to book the following equipment. Ask the relevant equipment managers for access.

- Gas sorption
- 3rd floor oven
- Glovebox
- NMR (Juniper & Lossie)
- Portable potentiostats

Within our own lab, **share equipment as effectively as possible** e.g.:

- Collaborate with others to use gas sorption instrument at full capacity
- Willingness to share glovebox with other users
- Adding samples to schlenk lines where vacuum pumps are already switched on

Ensure any **additional equipment procured to the lab** is listed on equipment sharing database - equipment managers responsible for facilitating sharing of equipment with other groups

If there is **excess equipment** within the lab which is no longer needed, ensure a new home is found:

1. Email the department/other groups
2. Use suggestions from the University below:
   a. Use WARPit: a free online tool for exchanging furniture, equipment, and other resources between university departments: www.warp-it.co.uk/cambridgeuni/
   b. List items on the University's 'Science Purchasing' and 'All Company' Yammer platforms to ensure awareness across the University
   c. University Green Scheme is an asset resale service with whom the University has established a longstanding relationship: http://www.unigreenscheme.co.uk/
   d. Science Purchasing Group page: https://www.admin.cam.ac.uk/offices/purchasing/groups/science/
   e. Key Science Purchasing Contact Members: https://www.admin.cam.ac.uk/cam-only/offices/purchasing/groups/science/contacts.html
   f. List on Richmond Scientific

2.4 Procurement

Equipment

When **new equipment** is purchased:

- aim to procure the **most efficient** possible model e.g. A+ rating where available
- Explore second hand options e.g. on Richmond Scientific

Experimental Planning

In accordance with the **12 Principles of Green Chemistry**, where possible aim to do the following in your experiments:

- To **replace hazardous routes** with alternatives where possible
- **Maximise yield** and reaction **efficiency**
- Use **minimal reagents** and solvents
- Use **Greener Solvents:** see **Solvent Selection Guides** for help

Before buying new chemicals:

1. Always check the **chemical inventory**

2. If using a small amount, consider borrowing off another group (use chemical inventory to check as above)

Lab Restock Manager- **Only to buy pipette tip refills** from stores (no new pipette tip boxes, as these are intended for sterile use)

For regularly purchased items: If you notice that certain items are being purchased regularly, and may be beneficial on the departmental click and collect service, please inform the group sustainability officer, or contact chemistry stores directly.

2.5 Reduce & Reuse

A great deal of **non-recyclable single-use waste is avoidable** - read this **Nature article** for an inspiring tale on how labs can reduce it! **Plastic** is the biggest problem, but even biodegradable single-use items are problematic as these usually end up in general waste.

In the lab:

- *Rinse* & *re-use* **glass vials with water & ethanol, replace stock into cupbaord**
- *Re-use* clean weighing boats from e.g. electrode films
- Use ***re-useable*** **glass syringes** rather than plastic
- *Re-use* glass pipettes for water and ethanol
- Re-stock pipette tips using **refills**, rather than buying new boxes, as per procurement policy

Outside the lab:

- Bring your own travel *mug* and *water bottle* to the department

  This will avoid the surplus charge on **disposable cups**; there is a sink in the office to wash up, you can take it home or the cybercafé dishwasher may be used

- Use metal cutlery in cyber café
- At social events with take-away food, bring your own cutlery, plate and cup where possible

2.6 Waste & Recycling

Where items cannot be **re-used**, and waste not **reduced**, the next best efforts are in **recycling responsibly**.

In the lab

Recovery Stream: Almost everything ends up here! **non-hazardous** & dry waste (carbon & small volatile solvent contamination fine)

- Cardboard should be flattened (Consider if cardboard boxes and packaging can be re-used)
- Paper, metal, plastic etc.

Pipette-Tip Boxes are collected for recycling – let the Sustainability Officer know to arrange for this or contact rc643@cam.ac.uk

Chemical inventory manager:

- Any chemicals procured over **4 years prior** should be assessed before the lab group regarding their current use, and advertisement of these chemicals to other research groups should be prioritised over disposal.
- Any further chemicals identified as time-sensitive chemicals should also be assessed.
- Our chemical inventory is viewable to all groups in the department, and sharing of available chemicals should be encouraged.

In the Office

1. **Recovery Stream (General Recycling):** Recycling should be clean & dry, if it's not clean – feel free to wash in the sink in office 110

    - Cardboard & Paper
    - Plastic (including wrapping)
    - Tins & Cans etc.

2. **Food Only:** This waste stream goes for **anaerobic digestion** - do not contaminate with packaging

Other Recycling: Batteries: see **here** for details, **Printer Cartridges**: return to stores

2.7 Sample Storage

Sharing of prepared solvents and electrolytes is heavily encouraged when feasible. When preparing **a solvent** or **bulk electrolyte** often used by other lab users, please refer to the shared electrolytes spreadsheet to verify that it has not already been prepared. Identifying new commonly used solvents to this list is encouraged.

3- Conducting Sustainable Research

3.1 12 Principles of Green Chemistry

During the planning of experiments, keep in mind the **12 Principles of Green Chemistry** (you can find more detail and examples by following the link). In bold are highlighted the principles most relevant to our groups' research.

1. **Prevention (of waste of chemicals and resources)**
2. **Atom Economy (choose the most efficient reaction)**
3. **Less Hazardous Chemical Syntheses (Avoid hazardous chemicals and waste)**
4. Designing Safer Chemicals
5. **Safer Solvents and Auxiliaries (minimise solvent quantities; use greener solvents)**
6. **Design for Energy Efficiency**
7. **Use of Renewable Feedstocks**
8. Reduce Derivatives
9. Catalysis
10. Design for Degradation
11. Real-time analysis for Pollution Prevention
12. **Inherently Safer Chemistry for Accident Prevention (by risk assessment and precautions)**

3.2 Computational Efficiency

Shared Laboratory Code

To maximise efficiency and minimise time spent re-writing similar code, the Forse group maintains a public repository at https://github.com/JackScottTaylor/ECAnalys. The group encourages everyone to use this repository and welcomes any suggestions or collaborations in improving it.

High-performance Computing

Supercomputing considerable resources in both electricity and cost. It is worth considering how to **optimise** the computational credits of the lab. Some rough guidelines

1. Submit non-urgent jobs with **low-level priority**
2. Optimise parameters at lower parameter values
3. **Read up** on how to optimise your calculations:

Ask around for old scripts for similar calculations to get an idea/reference points for your own coding/submission scripts/etc.

Use CSD3 pages for guidance: https://docs.hpc.cam.ac.uk/hpc/index.html

Example reading: **[Parallel Efficiency and Parametric Optimization in CASTEP](#)**
[Parallel in CASTEP](#) - for **CASTEP**:

Number of CPU's should be equal to number of k-points; if this is not possible, have a high common factor between them

- Choose the least number of nodes with sufficient memory; avoid cross-node parallel calculation
- Supercells with cubic symmetry recommended for better convergence and less memory usage
- **KEY POINT:** Increasing the number of CPU's and nodes does not necessarily improve efficiency!

3.3 Life Cycle Assessments (LCA)

It is highly recommended that you take the Life Cycle Assessments for Scientists course to learn how to measure the environmental, resource and health impacts of your research, even in its early stages – look out for these being advertised.

Conducting Life Cycle Assessments at an early stage of research also highlight opportunities to most effectively reduce the negative impacts of your research

3.4 NMR Spectroscopy

Here, we evaluate the energy cost associated with NMR in our group. This focuses on CO2 equivalent for cryogens and compressed gas. This does not include the energy associated with helium extraction, manufacturing of the instrumentation, and energy to run the console/computer electronics, and other environmental impacts. In addition, there are some important considerations about the sustainability of the use of helium as a cryogen, which is dependent on natural gas extraction and geopolitics.

3.4.1 Magnet maintenance

Superconducting NMR magnets require liquid nitrogen and liquid helium.

3.4.1.1 Nitrogen

Juniper is spec'd for 400mL/h of liquid nitrogen, or 0.323kg/h (assuming 0.807 kg/L density). There is no data for Lossie, but we can expect to be the same.

The ideal energy cost to liquefy 1 kg of nitrogen from ambient temperature is:

$$Q = c_p \cdot (T_{\text{initial}} - T_{\text{boil}}) + \Delta H_{\text{vap}} = 1040 \cdot (298 - 77.36) + 199000 = \mathbf{428.5}\,\text{kJ/kg}$$

This corresponds to 0.119 kWh/kg. In 2023, the average UK electricity grid carbon intensity was approximately 238 g CO_2e/kWh, therefore. This assumes 100% liquefaction efficiency, which is not realistic. Industrial nitrogen liquefaction systems typically operate at 30–50% efficiency. Therefore, a spectrometer uses 0.323 kg/h *24h*0.119kWg/kg /30% = 3 kWh/day, which is 732 g CO2e/day in liquid nitrogen, i.e. 0.26t CO2e/year

3.4.1.2 Liquid helium

Helium can reach ultra-low temperatures essential to sustain superconductivity at high fields. It is not a renewable resource as commercial helium is extracted from natural gas when the helium concentration is above 0.3%. Once helium is released in the atmosphere, it will continue rising until it escapes into space, making it the only truly unrecoverable element. Helium in recoverable quantities is found in only a few locations around the world, and these sources are being rapidly depleted. https://www.acs.org/green-chemistry-sustainability/research-innovation/endangered-elements/helium.html

The production of liquid helium uses 2kWh/L, which is about 0.5kg CO2e/L (https://pubs.aip.org/aip/ltp/article/49/8/967/2905263/Carbon-footprint-of-helium-recovery-systems). This does not count the liquefaction of 1900 m^3 of natural gas required to produce it (at 440 kg CO_2/l for the separation of 1 l worth of liquid helium)

As of 2024, helium in the department is being recovered directly from the spectrometers and being compressed to gas cylinders, and sent to the physics department for reliquefaction. The current recovery rate is about 80%. Juniper uses 0.5L/day of liquid helium, and Lossie 0.350L/day. Therefore this implies an annual carbon footprint of 0.114 t CO_2e/year and 0.79t CO2e/year, which does not include environmental cost of this extracting natural gas.

3.4.2 MAS NMR:

Solid-state NMR spectrometers are connected to the department’s high-pressure nitrogen (N_2) gas line. Nitrogen is used for fast magic-angle spinning (MAS) and provides dry, inert conditions that prevent icing and minimize sample oxidation.

In this setup, nitrogen gas originates from liquid nitrogen (LN_2) stored in a tank outside the building. The tank is refilled daily by a tanker from a local liquefaction facility. To produce 1 standard litre (SL) of nitrogen gas at 20 °C and 1 atm, the equivalent mass of gas must be cooled to –196 °C (77 K) and liquefied for transport, before being warmed back to ambient temperature via heat exchangers at the point of use.

A spectrometer spinning a 4 mm rotor at 14 kHz typically uses 55 SL/min of nitrogen gas (i.e., the mass equivalent of 55 L of ambient-pressure, 20 °C gas per minute). 1kg nitrogen = 800L of nitrogen gas at standard temperature/pressure. This corresponds to: 4.125 kg/h of nitrogen, or 1.77 MJ/hour or 0.492 kWh/hour (i.e., 492 W) or 0.492 kWh x 238gCOe/kWh = 117g CO2e/h. It uses 80SL/min for a 1.3mm at full speed, i.e. 170g CO2e/h.

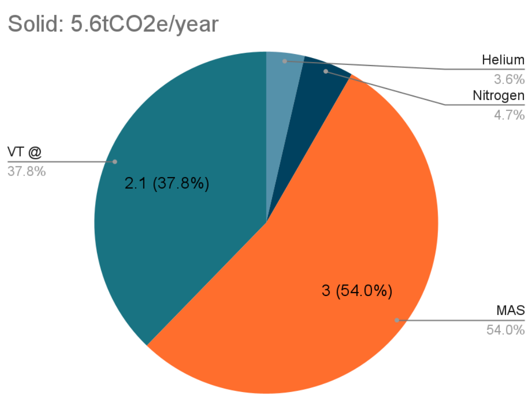
However, this assumes 100% liquefaction efficiency, which is not realistic. Industrial nitrogen liquefaction systems typically operate at 30–50% efficiency. Assuming 30% efficiency and ignoring transportation costs, the actual emissions may be conservatively estimated at:

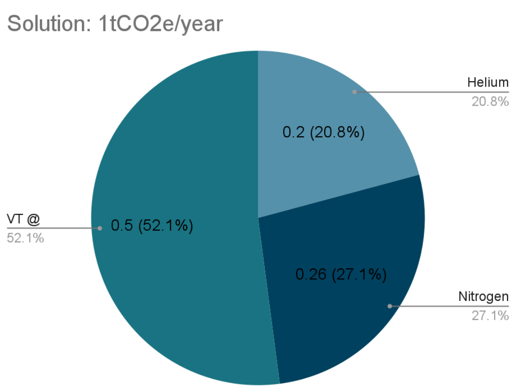
0.35-0.5kg CO2e/h, or 3-4.3 tons CO2/year (assuming 24/7 operation)

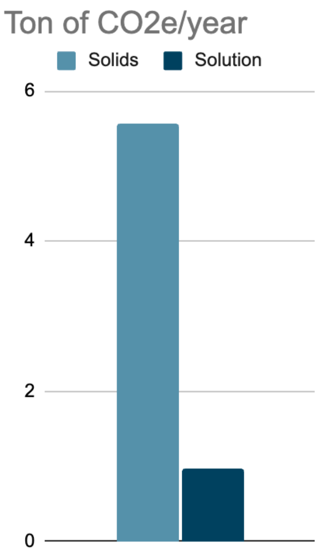
3.4.3 VT NMR:

Variable temperature (VT) operation in solid-state NMR experiments can require up to 1600 standard litres per hour (SL/h) of nitrogen gas, cooled to –80 °C to prevent sample heating. In typical setups, this gas originates from a liquid nitrogen (LN_2) supply, and the associated thermal pathway includes three energy-intensive steps: (1) liquefaction of nitrogen from ambient temperature (298 K) down to its boiling point (77 K), (2) vaporization and warming to room temperature (298 K), and (3) final re-cooling of the gas to –80 °C (193 K). The total ideal energy cost for these processes is approximately 0.673 kJ per standard litre of nitrogen gas, combining the latent and sensible heat removal during liquefaction (~0.536 kJ/SL) and subsequent gas cooling (~0.137 kJ/SL). At a flow rate of 1600 SL/h, this corresponds to an ideal energy consumption of 1077 kJ/h, or 0.299 kWh/h. Using the 2023 UK average grid carbon intensity (238 g CO_2e/kWh), this results in a theoretical minimum of 71 g CO_2e per hour. Accounting for the limited efficiency of industrial refrigeration systems (coefficient of performance ~0.3), the effective energy use increases to ~1.0 kWh/h, with a carbon footprint of ~236 g CO_2e/h, or approximately 2.1 t CO_2e per year for continuous operation.

3.4.4 Conclusion







MAS NMR can use up to 8 tons CO2e/year. **As a result: avoid leaving samples spinning unnecessarily and use VT only if necessary**. Do not use extreme MAS or VT conditions. Plan experiments ahead of time and be careful to optimise experiments to ensure the spectrometer is most efficiently used.

Some equipment can be shared with other NMR groups in the department to get access to additional probes and resources:

Grey Group:
https://www.ch.cam.ac.uk/group/grey/research/nuclear-magnetic-resonance-magnets
contact lab manager Chris O'Keefe co402@cam.ac.uk

Duer Group: https://www.ch.cam.ac.uk/group/duer/ssnmr-facility, contact Melinda Duer mjd13@cam.ac.uk

NMR Service: contact Duncan Howe, Andrew Mason & Pete Gierth
https://nmr.ch.cam.ac.uk/ - nmr@ch.cam.ac.uk

3.5 Technical Support

- Can always seek support from laboratory technicians: floor2tech@ch.cam.ac.uk , who can also provide advice when it comes to implementing more sustainable solutions
- Information on other departmental services available here: https://www.ch.cam.ac.uk/intranet/services-0

4- Supplementary Information

4.1 Carbon Reduction Fund

The Carbon Reduction Fund is available for projects which reduce carbon emissions within the University, including projects within labs. More information can be found here: https://universityofcambridgecloud.sharepoint.com/sites/UoC_EnvironmentalSustainability/SitePages/Carbon-Reduction-Fund.aspx

4.2 Royal Society Chemistry Sustainable Research Grants

In September each year, the Royal Society Chemistry opens a grant of up to £10,000 for improving sustainability in laboratories. If you have ideas on how sustainability in the lab could improve, consider applying.

It's especially helpful if you've done the LCA training above to mention the predicted outcomes of your proposal in your application.

Find out more here:
https://www-rsc-org.ezp.lib.cam.ac.uk/prizes-funding/funding/find-funding/sustainable-laboratories-grant/

The aims of the grant scheme:

- Advancing understanding of environmentally sustainable laboratory practice
- Increasing the take-up of environmentally sustainable laboratory practices in the chemical sciences
- Facilitating sharing of best practices

Guidance for applicants to consider for future Sustainable Laboratories Grant applications:

- Make it clear in your application how your project meets the aim of the scheme to make research practice in the chemical sciences more environmentally sustainable.
- Clearly articulate the wider benefits that would result from your work beyond your immediate lab, group or department (e.g. giving quantitative estimates, where relevant).
- Consider how you might quantify the environmental outcome of your project.
- Make sure you include information addressing all of the selection criteria which will be used to assess the applications. Decisions can only be made based on the information provided in your application. See the grant webpages for selection criteria.
- Write for a general chemistry audience. Our peer reviewers and decision panel members have a wide range of expertise but may not have specific knowledge on the project area.

4.3 Social Events

The Forse group actively promotes a **healthy work-life balance** with regular group social events. The **environmental and ethical impacts** of these events are carefully considered.

As such events:

- Are as **local** as possible, with **public transport** used as necessary
- **Minimise waste**: food and single-use items
- Favour supporting independent, local businesses
- Follow our **sustainable food policy**

Examples of previous social events:

- Plant-Based Yuletide dinner at Jesus College, and previous Christmas meals at Thrive café
- 5-year group anniversary celebration at the Museum of Technology with catering from Vegan Bites
- Visits to the **Botanic Garden**
- Punting and picnic in **Grantchester** and a **board games café trip**

4.4 Want to do more?

Contact **sustainability@ch.cam.ac.uk** to join the **departmental sustainability committee** or for more information.

Outside of research, you could also join a University **climate society or campaign**, or make a **personal commitment** to make your own lifestyle more sustainable.

If you would like to do more, help the lab improve its sustainability or have any questions or suggestions please contact Alex or the group Sustainability Officer.

For general reading see the Chemistry World Article: **How to run a sustainable chemistry lab**