The Green Laboratories Manual

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ABOUT THIS MANUAL

In response to the report by the Higher Education Academy 'Sustainable Development in Higher Education, Current Practice and Future Developments' [1] the Institute of Biological Sciences (IBS) at the University of Aberystwyth (AU) proposed the practical implementation of sustainability into the curriculum and delivery of education across the Biological Science sector. The project was funded by the Centre for Bioscience's Departmental Teaching Enhancement Scheme and entitled **"Towards Sustainable Teaching of Biosciences"**. Initial research[2,3] highlighted that a lack of relevant information was a limiting factor in implementing sustainability into the working practices of Bioscience Departments. The **'Green Laboratories Manual'** was therefore designed to address this problem.

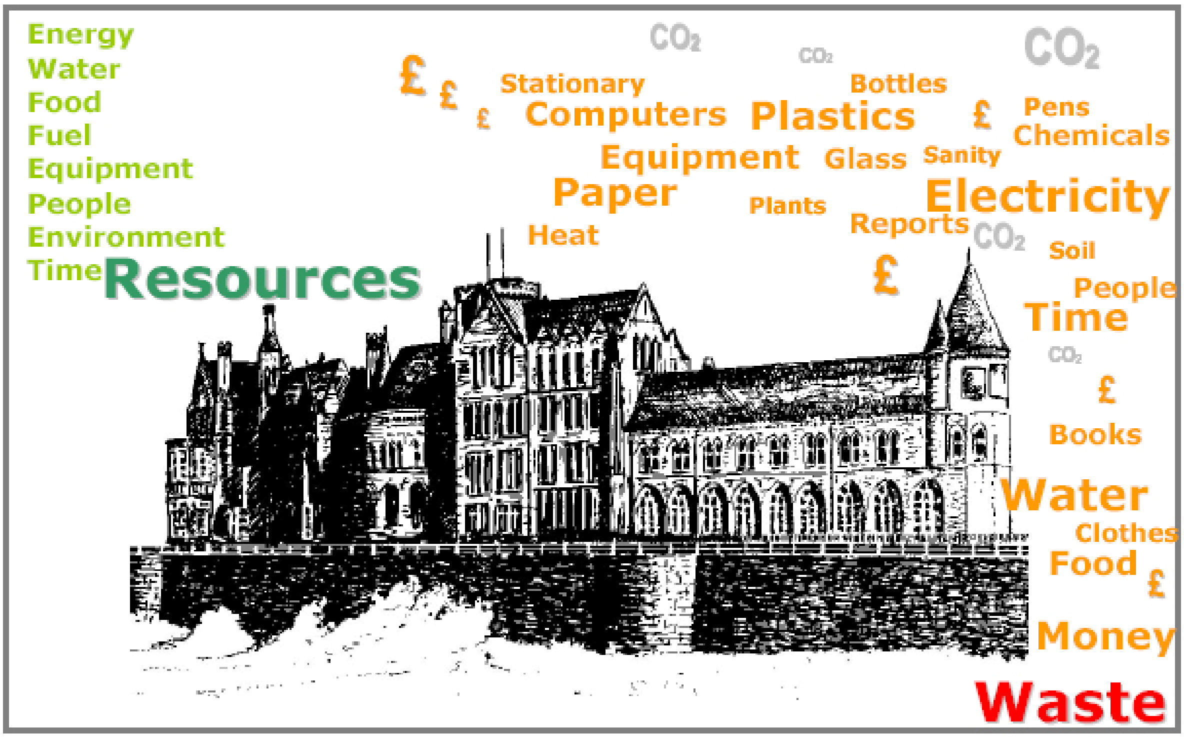
This guide has been prepared as a general reference and starting point for laboratories wishing to move towards sustainable practices. It does not constitute technical guidance, and is not a substitute for appropriate professional advice on the subject matter being discussed.

SUSTAINABILITY

The concept of sustainability has become central to environmental debates around the world and has been taken up by all sectors including government, business and non governmental organisations. The 1987 Brundtland report first defined sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' [4]. This report set out the guiding principles for sustainable development as it is generally understood today. In order to achieve a sustainable world and minimise environmental degradation, a transition in resource use and waste management must occur locally, nationally and globally. Reducing carbon dioxide and other greenhouse gas emissions is now a high priority as global climate change has been clearly linked to human activity[5].

WHY SUSTAINABLE LABORATORIES?

Scientific laboratories are complex environments and consume high quantities of resources; the typical laboratory can consume four to five times the energy used by comparable commercial spaces[6]. The use of disposable plastics and experimental kits leads to high wastage and it is unfeasible to re-use much of this due to contamination with potentially dangerous substances and non-compliance with health and safety legislation. Solutions and reagents are often wasted due to inappropriate labelling or lack of communication. Many of the waste streams are inbuilt into the laboratory environment but there are others that can be improved through behavioural changes and small alterations in infrastructure.

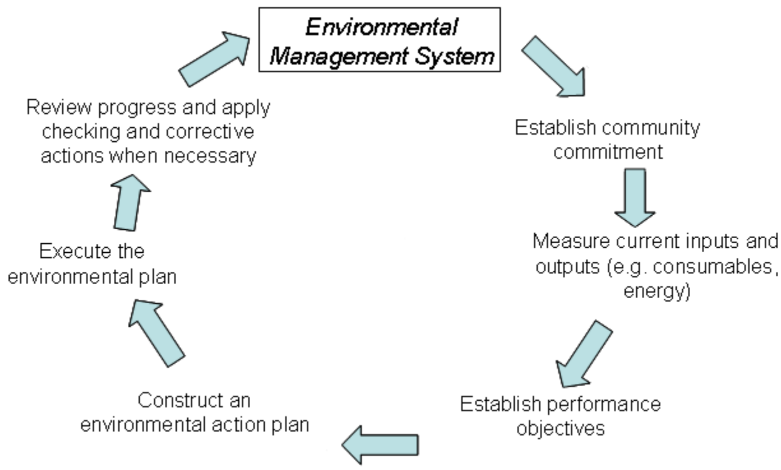


The leaky boat scenario - Sustainability is about finding creative ways to plug the leaks which cause waste by reducing, reusing and recycling resources.

The potential for educational institutions to lead the way in promoting sustainable education and research is now being recognised. The challenge for higher education is to provide all students with an in-depth understanding of sustainability and environmental issues; creating a new generation of 'sustainability literate' graduates. As well as teaching sustainability by theory, there is the opportunity for universities to 'walk the walk' by demonstrating sustainability through their practices. This will provide students with a platform to integrate sustainability into their own lives and future careers.

Environmental management systems

An Environmental Management System is a management approach which enables an organisation to identify, monitor and control its environmental aspects. An effective Environmental Management System can reduce expenditure on materials, waste and energy, ensure compliance with legislation, help to maximise market and investment opportunities and boost staff morale.



Key questions in establishing an Environmental Management System:

- Which resources are being used (what are the inputs in terms of energy, water and materials)?
- Where do the resources come from?
- Where do the resources end up after use?
- How much is used and how much does it cost?
- How much is wasted (how much does not end up in the final 'product')?
- What is the environmental impact?
- Why is so much used / wasted?
- What can you do to reduce the quantities used, waste produced and environmental impact?
- How will you do it (Action Plan)?
- Has it made an impact?

There are some Environmental Management Schemes that can help you to gain recognition for your achievements: Green Dragon, IS0 14001, EMAS (refer to the **Useful Links** section).

IMPLEMENTING SUSTAINABILITY

Many tertiary institutes do not have the initial capital available for costly environmental changes; especially where the payback period is lengthy. Finding practical low cost environmental measures is therefore imperative. An entire group of sustainability initiatives can be formed by changing the sub-optimal behaviour of laboratory occupants. Changing staff behaviour can be a low cost way of reducing the environmental impact of research and any monetary savings made can be used to fund larger, more costly, changes. While some policies will require committees, meetings and funding, others are as simple as reusing envelopes for internal mail. If you have financial or time constraints focus initially on the cheaper, low input, solutions before implementing sustainable solutions requiring higher inputs.

REDUCING ENERGY CONSUMPTION – It is essential to cut energy use, both for environmental and economic reasons. Electricity is a vastly undervalued resource and is taken for granted until there is a power cut.

Short term solutions

- Conduct an energy audit of your laboratory (consider what is on when and why)
- Make a policy to turn off all equipment when not in use – don't rely on the standby facility
- Switch laboratory lights off when not in use
- Use natural daylight where possible
- In the laboratory environment do not place a fridge adjacent or too close to an oven
- Fill your empty freezers with old plastic bottles filled with water to reduce energy use.
- If you use growth cabinets maintain background room temperature at an ambient temperature that maximises energy efficiency
- Choose energy efficient equipment when replacing and fit energy saving light bulbs
- Fit an Electrisave power monitor to office/laboratory equipment to reduce consumption
- Consider energy metering for individual departments or laboratories but <u>do not</u> constrain or penalise research / teaching requirements but reward good practice
- At Institutional level consider change to a green energy supplier
- When replacing equipment, purchase energy efficient (A star) substitutes

Long term solution

- Consider solar or wind power (more cost effective in long-term, new build)

WATER CONSERVATION METHODS – Even in areas with high rainfall, the consumption of clean drinking water should be reduced. The environmental impact of cleaning water to drinking standard is relatively high and yet we use this resource to flush our toilets.

Short term solutions

- Develop an agreed policy to minimise water wastage in laboratories
- Choose water saving devices when replacing equipment
- Fit flow control to taps
- Fit low flush toilets (or Retrofit water saving device to toilet cisterns e.g. brick)
- Consider water metering for individual departments or laboratories but do not constrain or penalise research / teaching requirements, instead reward good practice

Long term solution

- Rainwater collection from buildings

HEATING AND COOLING – Having a good working temperature is essential but many large institutions fail to provide staff with a comfortable temperature range. By implementing simple measures it is possible to improve this at the same time as improving working conditions.

Short term solutions

- Audit room temperatures in various laboratories
- Turn heating down by a few degrees
- Fit temperature controls in each room for radiators
- For items of equipment that produce heat constantly (e.g. ovens) consider using the heat to good effect
- Share ovens/fridge/freezer space between laboratories to minimise use
- If you install equipment that works on the principle of heating or cooling (e.g. freezer, growth cabinet) place it in the optimum position for the highest energy efficiency (e.g. place a freezer in a cooler place)
- Where possible, open windows to reduce the temperature thereby reducing reliance on air conditioning

Long term solutions

- Passive cooling systems
- Double or triple glazed windows (unless in place)
- Insulation
- Solar water heating (good return over time)

REDUCING / RECYCLING WASTE – Reducing laboratory waste poses very particular problems, there are strict regulations on certain wastes and very stringent sorting is needed.

Short term solutions

- Re-use envelopes for internal mail
- Recycle printer cartridges
- Try to use non-disposable plastics/glassware
- Wash and re-use wherever possible
- Recovery of solvents (re-distil)
- Preferential use of least toxic options
- Making solutions and buffers in-house in bulk but balance your options as pre-made kits can sometimes reduce waste and minimise exposure to harmful chemicals
- Use clear and easy to follow notices if you develop a recycling system to reduce waste through confusion
- Plastic, paper, glass and organic recycling in the laboratory
- Engage students and staff in tidying and recycling activities
- Consider setting up a composting scheme if you have appropriate organic waste
- Use environmentally consumable suppliers, which are committed to package reduction
- Do a 'chemical stock take' to minimise inefficient ordering. Chemicals no longer required by research groups may be suitable for teaching or vice versa

THE PRACTICAL ENVIRONMENT

- Consider whether the resources used justify the exercise
- Are resources being used to maximise the benefits?
- Can you reduce wastage?
- Try to seek out practical options that have a low environmental impacts and minimise the use of toxic substances
- Maintain larger laboratory classes at lower temperatures during Autumn and Spring as body temperature will raise laboratory temperature, you may even able to turn off heating
- Schedule practicals during daylight hours to maximise the use of natural light
- Use equipment and consumables for purpose – it is often possible to develop effective practicals using locally sourced food grade chemicals
- If you are collecting material from the natural environment for a practical (e.g. invertebrates; plant material) ensure that you do not denude the local area
- Consider your biological waste, if you have waste plant material why not compost it?
- Make students aware that resources are valuable
- Involve students in tidying up but only do this if you have complete organisation of the situation as poorly organised tidying can lead to chaos
- Use bulk loads for dishwashing or autoclaving
- Consider a laboratory recycling scheme but organise it well (good signage and instructions) as poor information can lead to problems

THE DISSERTATION

Many students join a laboratory and conduct either field work or laboratory work in the Biosciences

- Make students aware that you are operating a sustainable environment
- Make students aware of time as a resource, ask them to note consumables used as part of their learning exercise (one way to achieve this is to assign a research budget that they must manage)

- Good experimental design is imperative (both too few or too many replications are wasteful)
- Poorly designed experiments without outcomes (significant or non-significant) are the most wasteful of all
- Get students to consider experimental inputs and outputs (consumables and waste)
- Financially penalise students who do not use materials propagated / provided (e.g. growing of plant materials for experiments that they did not harvest)
- Try to develop a culture of resourcefulness (some students consider that using new consumables delivers the best outcomes, good experimental design and practices override everything)
- Make students aware in any experiment of when they should or should not change consumables (e.g. pipette tips in an assay or gloves in the laboratory environment)
- Operate a one glove policy (One glove for carrying toxic materials and the other glove off for opening doors) or arrange laboratories to minimize the need to transport such materials
- Consider whether you can use re-use something for research purposes (e.g. waste paper can be used for making bags for drying plant material)
- Group student projects so that they share facilities (e.g. it is more effective to set up a growth cabinet for several students rather than one)
- If students are conducting field work group them for lift share and for health and safety issues
- Reward resourceful students (some students complete excellent research outcomes from limited resources others join laboratories and achieve greatness through resource availability and support)
- If research is well conducted maximise the outcomes and develop output from the research (primary publications; Departmental news; local (home) newspapers)

TRAVEL – The impact of individual travel to work/study can be reduced by promoting sustainable alternatives to driving. For example, setting up a staff lift share scheme, increasing charges for parking and providing incentives to travel by public transport.

- Car share
- Incentives for staff and students to take public transport
- Good facilities for cyclists (places to lock bikes, showers, etc.)
- Good information on public transport and safe cycling/walking routes
- Implement a system which only allows the most fuel efficient vehicle suitable for the field work to be booked.

FIELD STUDY – Studying the natural environment is a key part of research in the sciences, but taking these observations can have a damaging effect[8]. Environmental impact should be minimised as much as possible

- Reduce travel by studying local habitats
- Take public transport to sites (avoid flights)
- When at a selected field site follow good environmental practice and avoid unnecessary disturbance and trampling of site
- Ensure that the research does not denude the field site of Biodiversity

SOURCING MATERIALS – Buying locally and reducing transport is very important. In addition, the environmental credentials of all suppliers should be considered. You might buy locally but producers may source products from all over the world. Consumer choice is a powerful tool in encouraging manufacturers to comply with environmental regulations.

- Buy local
- Audit your suppliers
- Use suppliers with sound environmental credentials
- Source refurbished, recycled or ethical products (you can buy old laboratory equipment on e-Bay but ensure that the seller has receipts or proof of purchase)

INITIATING CHANGE

Changing researcher behaviour within the laboratory is a fast and inexpensive way to reduce the environmental impact of biological experiments. However, altering behaviour is not an easy task and attempts to promote environmentalism in the workplace are often met with resistance. Nevertheless, appropriate access to useful information, such as that depicted in table 1, can facilitate behavioural change by increasing experimenter awareness of potential waste streams in the laboratory [(6)].

Equipment[a]	**KWh overnight**[b]	**KWh Per year**[d]	**kg CO_2 overnight**[c]	**kg CO_2 per year**[c,d]
Small desktop centrifuge	0.054	19.71	0.023	8.40
Electronic balance	0.056	20.44	0.024	8.76
Bench autoclave	0.552	201.48	0.237	86.51
PCR machine	0.420	153.30	0.180	65.70
pH meter	0.012	4.38	0.005	1.83

Table 1. Examples of overnight energy wastage in the laboratory through an inappropriate use of the standby facility.

[(a)]All values for equipment energy use are taken from Wright *et al.*, (*in prep*) [(b)]Overnight figures are based on a 12 hour period. [(c)]CO_2 conversion is based upon official UK data from the Department of Environment, Food and Rural Affairs, revised March 2001. [(d)]Yearly values assume a daily value of 12 hours energy wastage for 365 days of the year.

What does this mean in real terms? To correctly appreciate the energy wastage shown in Table 1, it is necessary to make comparisons with common forms of energy usage. According to DEFRA guidelines (2005), 2.30kg of CO_2 are emitted per litre of petrol used (1 litre = 0.2612 gallons). According to the National Travel Survey, the average petrol car has a fuel consumption of 30 miles per gallon. Thus, leaving a small bench autoclave on overnight, for a year, emits the same mount of CO_2 as driving about 300 miles in an average car.

How significant is the problem? A typical, medium-sized department will have at least 12 small bench autoclaves. Thus, an inappropriate use of the standby facility in bench autoclaves, in this

Department, could lead to CO_2 emissions equivalent to driving around 3500 miles per year. The problem is further exacerbated when considering the extensive range of other scientific apparatus currently at use in the Institute of Biological Sciences.

HOW CAN WE REDUCE OUR IMPACT? Highlighting the potential for energy wastage in the laboratory can lead to reductions in environmental impact. Indeed, simple behavioural changes such as a reduction in the use of the standby facility are not only cost effective but energy efficient. Moreover, where appropriately applied, they require no extra time to complete a project and do not cause a reduction in research quality.

BARRIERS TO CHANGE

Tackling a change of teaching methods in order to facilitate a move towards sustainable teaching of biosciences then raises many other issues. Information about sustainability does not necessarily lead to behavioural change. An integrated approach is needed that tackles the reasons for unsustainable behaviour. Some of the problems that teachers and technicians have cited as limiting their ability to work sustainably are summarised below.

- **Time** – implementing new structures and practices difficult when added to a full workload
- **Resources** – financial constraints often limit new developments
- **Tradition** – there can be strong resistance to changing teaching practices
- **Information** – there is a lack of easy to use guidelines for sustainable practice
- **Motivation** – sustainability issues may not seem relevant to the individual, or they may feel that it is not their role to be teaching it
- **Curriculum** – there are particular constraints in teaching biosciences, students need to be taught methods relevant to future employment

FINDING SOLUTIONS

To move towards sustainable teaching in bioscience, strategies that involve students and university staff at all levels are required. There is potential for the department to lead by example by implementing a strong environmental policy that guides the University towards a low impact learning environment. With escalating energy costs, and forthcoming regulatory requirements, it is essential that higher education rises to meet these challenges.

USEFUL LINKS

General

University of Aberystwyth environment page www.aber.ac.uk/ensus

Labs21 UK www.labs21.org.uk

Higher Education Academy, education for sustainable development webpages
www.heacademy.ac.uk/sustainability.htm

Environment Association for Universities and Colleges (EAUC) www.eauc.org.uk

Technical guidance and consultancy

The Centre for Alternative Technology for free information on all topics relating to sustainability and a consultancy service for bigger projects www.cat.org.uk

Dulas Ltd. They design and install a range of renewable energy technologies including: wind, hydro, solar, and biomass wood energy. www.dulasltd.co.uk/default.asp

Environmental Management Systems (certification schemes)

- Greendragon www.greendragonems.com
- Eco-Management and Audit Scheme www.emas.org.uk
- ISO 14001 www.iso14000-iso14001-environmental-management.com
- Envirowise www.envirowise.gov.uk

For further sustainability links relating to Climate change, Greening the Office, Transport, Water, Waste, Energy, Biodiversity, etc. go to the University of Wales Aberystwyth Environmental Sustainability pages: **www.aber.ac.uk/ensus/resources**

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