Scientists for Global Responsibility

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Promoting ethical science and technology

Cleaner technologies: a positive choice

By Dr Tim Foxon

A Scientists for Global Responsibility briefing

This briefing provides background insight into some of the approaches and technologies that are designed to reduce the impact of human activities and industry on the environment. Readers will gain greater awareness of possible career choices (and a shift in thinking) that can make a positive contribution to sustainable development.

Cleaner technologies: a positive choice is of relevance to students and graduates of:

Aeronautical engineering
Architecture
Biology
Computer science
Chemical engineering
Chemistry
Civil engineering
Design
Economics
Electrical engineering
Environmental science
Geoscience
Mathematics
Mechanical engineering
Physics
Statistics

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This briefing is part of a series entitled ***Thinking About an Ethical Career in Science and Technology***.

Thinking about an ethical career in science and technology

Thinking About an Ethical Career in Science and Technology is intended to give young scientists and engineers an understanding of the wider ethical dimensions of various careers in science and technology. Each briefing focuses on an area in which science and technology can play a major role, either good or bad, and examines the social and environmental controversies in that area. It then gives guidance on how to make an informed, 'ethical' career choice.

Technological change and sustainability

The extraordinary pace of development of science and technology in the last 200 years has resulted in a huge increase in the environmental impacts of human activities. The SGR briefing "Career choice and climate change" describes the damage that human-induced emissions of greenhouse gases are causing, but this is only one aspect. Damage also results from emissions of dangerous chemicals, destruction of forests, excessive waste production and dumping, and so on. These activities have an adverse effect both on the natural world and on human health, especially where vulnerable groups – such as those living in poverty – are concerned.

It has been estimated that technological change accounts for over 40% of economic growth, as conventionally measured [1]. Many of the drivers of technological change can be found within the dominant, 'neo-classical' economic paradigm, which results in the need for existing firms to stay ahead of their competitors and in the opportunity for new firms to exploit opportunities through technological developments – such as the Internet and biotechnology.

Nevertheless, the development of 'cleaner' technologies offers the hope of providing people with the services that they want, with reduced environmental and social impact, and at the same time fulfilling the economic requirements of commercial outfits. As recognition of environmental and social impacts increases, opportunities for employment related to the development and application of cleaner technologies are likely to increase dramatically.

A positive development: cleaner technologies

As noted by Paul Ehrlich [2], environmental impact (I) of human activity is a combination of three factors, population (P), the rate of consumption per person, related to the level of affluence (A), and the environmental impact per unit of consumption, which depends on the technology (T) being applied. This is summarised in the equation, I = P x A x T. Even with concerted action to improve access to birth control and the social and educational opportunities of women, global population is likely to rise from the current level of 6 billion to 9 or 10 billion by 2050. At the same time, as developing countries industrialise and consumption levels in industrialised countries continue to grow, economic growth of 2-3% per year would lead to a quadrupling of consumption levels by 2050. This means that, unless consumption patterns change dramatically, the environmental impact per unit of consumption will need to decrease by a factor of 6 just to keep environmental impacts at current levels, and by substantially more to decrease impacts to a sustainable and equitable level [3].

Tuno Knob offshore wind farm, 2000.
©Greenpeace/Davison

Energy generation

As mentioned in the SGR briefing "Career choice and climate change," to limit the potential environmental impacts of climate change, human emissions of greenhouse gases (GHGs) need to be reduced from current levels by at least 75% over the coming century. Achieving this while still enabling social and economic development in poorer countries will require a massive switch to cleaner technologies for energy generation. These take the form of more energy efficient technologies and practices, and renewable energy generation.

Similar arguments apply more generally across a range of technologies and practices. This can be illustrated by considering the material and resources flows needed to meet human end-use service needs. The average UK private consumption of finished products, including food and materials, is 1 tonne per person per year. To meet this need, around 10 tonnes of raw materials per person per year need to be extracted from the environment. Of the products consumed, 90% of the material is discarded as waste (solid and gaseous) within six months of purchase [4].

Efficient production

The efficiency with which resources are used to meet end-use service needs can be increased by means of three main strategies. The first is to *reduce wastage* at each stage in an energy or material supply chain. This is because high-volume production and supply processes waste large amounts of materials, time and effort. This is due to activities (or inactivities) that do not add to the final value of the product or service.

The second strategy is to *increase the durability* of the service life of products. If products are designed to last longer and engineered in a modular way that permits the replacement, re-use and/or recycling of individual parts, then a reduction in the materials used can be achieved.

The third strategy is to *substitute* current processes by others that do not produce the undesired effects. The most obvious example of this is the substitution of renewable forms of energy generation, such as solar, wind and wave power, which do not produce greenhouse gas emissions in use, for fossil fuel combustion.

Fewer resources

These strategies have one key thing in common: they provide ways of satisfying demand for end-use services using fewer materials and resources. In the first strategy, waste is by definition an unwanted by-product and can be reduced without loss. In the second strategy, the key factor to the user is the service life of the product. People do not want a computer, a photocopier or a refrigerator for its hardware; they want it for the computing, photocopying or refrigeration services that it provides. The third strategy involves the replacement of one technology by another that provides the same end-use service to the user, but without the undesired effects.

A fresh perspective: service provision

The above examples show that the conceptual switch from selling products to selling services is a key aspect of the move towards cleaner technologies. The switch to considering service provision has wide applicability. For example, in the field of energy, the services to be provided are thermal comfort, lighting and cooking. These services can be provided with less primary energy input by the installation of energy-efficient devices, such as compact fluorescent light bulbs or insulating equipment to prevent heat losses. The increased energy efficiency can even be sold in the form of 'Negawatts' – a unit that expresses the energy saved [5].

Of course, technology alone will not solve environmental problems. Supplying services more effectively makes them cheaper and the money saved can be used to fund more consumption. This is not a problem in cases where current service provision is inadequate, for example where the installation of energy efficiency measures enables poor householders to then heat their houses to an adequate level. However, those on higher incomes can use efficiency savings to buy new services, such as an extra holiday, thereby losing many of the environmental benefits of the saving.

Attitude change

However, it is hoped that the technological changes involved in moving towards greater resource efficiency and service provision will help to stimulate some of the changes in attitude and behaviour that are also needed to move towards greater sustainability.

In particular, selling services instead of products could change the dynamic of consumption. Companies could potentially make more profit by selling fewer material products, if they can, at the same time, provide a higher level of service. For example, some companies now sell floor-covering services instead of carpets. The floor covering comes in the form of carpet tiles and the company provides a service contract to replace the 10-20% of tiles that become worn over a period, instead of fitting a whole new carpet. The removed tiles can then be re-used or recycled. The whole process thus provides a better service to the

customer with a much smaller use of physical materials and so a much reduced environmental impact.

Service provision also fits well with moves towards more local consumption, as it could allow additional, 'old-fashioned' benefits such as personal service and community interaction to flourish.

Finally, the idea of selling services might encourage people to ask 'What level of services is sufficient for my needs?' It only needs a combination of people voluntarily deciding to accept a sufficient level of efficiently provided service to make real steps towards both environmental and social sustainability.

Employment opportunities

Many people are committed to achieving greater sustainability and environmental protection, but, for a variety of reasons, will choose to work within the 'mainstream economy' rather than for an environmental pressure group, for example. So, where will the opportunities lie in the new 'service provision' economy?

Clearly, it is important to investigate exactly what a potential employer is selling. Many people will not wish to work for companies in the chemical industry, for example, because of the harmful environmental impacts of some chemicals. However, all products have some environmental impacts associated with the extraction, use and disposal of materials. This is why it is good to seek out and favour employers who take a responsible attitude towards reducing these life-cycle impacts, for example by selling services rather than products. The service idea can be applied in many sectors, including electrical goods, household services, transportation and energy services.

Eco-design

There is a clear need for innovation in the design of product-service systems [6]. This is often known as 'eco-design' and involves a combination of strategies to minimise total environmental impacts over the life cycle of a product. These include:

- the selection of low-impact (e.g. renewable, recycled) materials;
- reducing the weight or volume of materials in the product;
- using cleaner (e.g. less wasteful, polluting) techniques for product manufacture;
- reduction of environmental impacts arising from the packaging and distribution of the product;
- reduction of environmental impacts arising from the use (e.g. energy consumption) and maintenance of the product;
- optimising the life of the product (e.g. by creating durable, 'classic' designs); and
- potential for re-use, re-manufacture or recycling of the product.

The most progressive companies are likely to have codes of practice implementing these principles in the design of their product-service systems. Many companies also now produce corporate environmental or sustainability reports, which can provide useful information on their activities and motives, if read with a critical eye. Check these aspects before applying: does the company unambiguously state its policies? Does it have quantified targets (e.g. an x% cut in emissions of y in the next z years)?

Energy technologies

There are so many clean technology developments in the energy sector geared towards reducing waste and pollution – specifically greenhouse gases (GHGs) – that it is worth focusing on this area in more detail.

Efficiency options

When it comes to producing energy there are some far-reaching efficiency options being explored. Some of those with the greatest potential for GHG reduction are combined heat and power plants (CHP, also known as cogeneration); hybrid and fuel cell engines for automobiles; and energy-efficient building design.

CHP plants use fuel (fossil fuel, biomass or waste) to produce electricity, but also harness the waste heat from that process and use it to supply heat to industry or hot water for domestic use. The efficiency of such plants is more than double that for those that produce electricity alone and CHP plants are increasingly used across Europe. The UK has been lagging behind in this area but interest from the electricity industry is growing.

Hybrid engines use both petrol and electricity to drive the vehicle. At low speeds, the petrol engine switches off and the car simply runs off battery power. As the car accelerates, the petrol engine switches back on, charging the battery at the same time. Fuel consumption can be reduced by 50%. The first hybrid cars have just gone on sale in the UK, e.g. the Toyota Prius and the Honda Insight. All the major car manufacturers are involved in developing such vehicles but some manufacturers are taking more of a lead in this area.

Fuel cells are more advanced and more environmentally friendly but not as close to commercialisation as hybrid engines. They simply convert a hydrocarbon such as petrol to hydrogen and use this to generate electricity to drive the car. The only waste product is water vapour, which, although a GHG, is not persistent like CO_2.

Working in a career that contributes to these technologies will make a contribution to sustainable development.

Installing photovoltaic cells, Silvertown, London, 1997
©Greenpeace/Beere

Building design

Designing and constructing energy-efficient buildings and improving existing ones can also save energy. Design options – like the use of high insulation materials and south-facing aspects to maximise natural heating and lighting – can contribute to considerable reductions in the energy use (and thus GHG emissions) of buildings. Architects and engineers may find they are able to make a positive contribution by seeking out building projects with these objectives.

Renewable energy

While energy-efficiency improvements are important for tackling GHG emissions and pollution, long-term success can only be achieved by a large-scale shift to renewable energy generation. By definition, renewable energy is that which is replenished as fast as or faster than it is depleted. The main such types are solar (direct heating and photovoltaic), wind, biomass, hydro-power and geothermal energy (tapping into the heat from sub-surface rocks).

UK government research has recently concluded that the accessible potential of renewable energy for the supply of electricity is considerably larger than current usage [7]. Less than 1% of electricity is currently supplied from renewable sources in the UK; the government has already set a target of 10% by 2010 and an increase in this target is currently under discussion.

Employment opportunities in the solar power area are increasing quickly. Production of solar photovoltaic (pv) cells for electricity production has been doubling every 5 years, whilst the cost has fallen by 75% over the past 20 years [8]. The trends are set to continue.

Perhaps unsurprisingly, the world's two largest companies involved in pv manufacture are the multinational oil companies, BP-Amoco and Shell. Given the environmental and social record of these companies, many people will object on ethical grounds to working for them.

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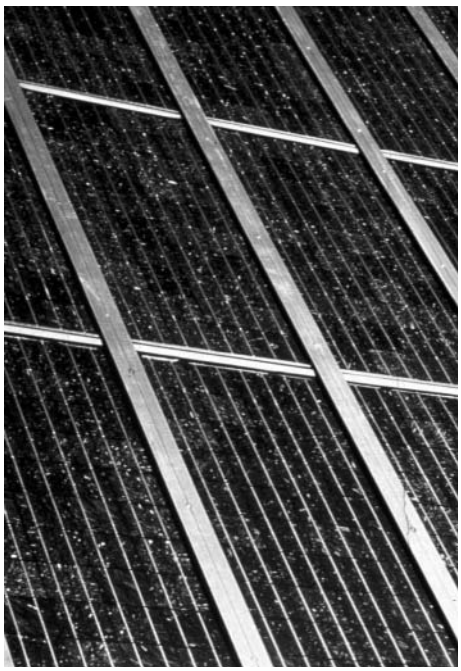

Close up of photovoltaic cells on the side of Rappeneck Hof, Germany.
©Greenpeace/Bond

There are two views: it could be argued that helping a major fossil fuel producer develop its renewable energy business will speed the demise of fossil fuels, but on the other hand, by doing so you are also helping to keep profitable a company that continues to make a major contribution to environmental degradation. A further issue is whether it is in society's best interests to continue to allow our supply of energy to be controlled by large undemocratic companies. This is an issue that cannot be resolved here but merits some thought.

The UK has the highest wind resource in Europe: roughly a third of the total. Onshore wind energy is already commercially viable. However, the largest potential is in offshore wind farms, sited just off the coast. Pilot offshore wind projects are currently being built. Hence the employment potential in this area is large and growing, in technology optimisation, construction and operation.

Biomass energy, from the controlled combustion of crops or wood fuel, is another growing technology. It can be classified as renewable so long as trees and/or other crops are grown to replace those burned. Much research and development is being carried out in this area, for example on the type of crops suitable for combustion, the growing conditions, the combustion processes themselves and the control of pollutants.

Large-scale hydro-power is well established as an energy source but there is growing concern about the damage caused to local ecosystems and the displacement of human communities by the requisite flooding for the reservoir. Further, there is doubt over whether it really is a GHG-free source of energy, due to methane and carbon dioxide releases from rotting vegetation in the flooded area. Run-of-the-river hydro and small-scale hydro offer a growing alternative: the former does not require a reservoir, whilst for the latter any reservoir is small and can be more sensitively located.

A number of pilot geothermal energy projects already operate around the world, including one in Southampton. However, large-scale commercial development is only just beginning. The process offering the greatest potential resource is 'hot fractured rock' (also known as 'hot dry rock') technology. This is where water is pumped down through boreholes to geologically heated rocks, then emerges either as hot water or steam and is used to generate electricity. Many of the larger companies involved in development are, not surprisingly given their geological expertise, large oil companies. Note that strictly speaking, geothermal energy is not renewable since it is not replenished naturally. However, it is generally classified in this way because the time scales over which it can last are very long.

A further, much neglected technological option is that of 'intermediate technology'. This is where attempts to supply energy or produce goods are carried out using simpler, cheaper technology. It is particularly useful in developing countries where the infrastructure to support high technology does not exist. A leading organisation in this field is Intermediate Technology Development Group (ITDG) based near Rugby.

Summary

In order to work towards achieving sustainable development, a massive increase is needed in the efficiency with which we use resources to provide the services that people need or want. This will require fundamental changes in the way that we design, produce and implement the products and services to meet those needs and wants. There is therefore likely to be many opportunities for knowledgeable and committed individuals to work to produce these changes.

Of course, technological changes alone are unlikely to be sufficient to achieve sustainability. This is because, as noted above, at least some of the savings to customers

resulting from resource efficiency improvements may be taken back in the form of increased consumption. For this reason, moves towards resource efficiency need to be complemented by moves towards ecological tax reform (taxing resource use and waste rather than jobs and income) and investments in maintaining natural capital - the living systems that provide the ecosystem services of freshwater, fertile soil and nutrient and resource cycles.

Finally, we all need to take a holistic viewpoint and to reduce our environmental impacts, both in the course of our work and as consumers of products and services, so that we contribute to the sustainable production and consumption of a sufficient level of services to meet our real needs.

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SGR promotes ethical science and technology, i.e. that which contributes to peace, social justice and environmental sustainability. Our work involves research, education, lobbying and providing a support network for ethically-concerned scientists. Founded in 1992, we are an independent UK-based membership organisation.

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