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the Contentious Issue

Bringing air and light to contentious issues

Over the years, environmental scientists have probably been exposed to more than their fair share of controversy. Perhaps this should be expected: we are the canaries in the scientific coalmine, playing the part of an early warning system on behalf of the planet, raising the alarm when the unpredicted consequences of humanity's various technological, industrial and other evolutions become apparent.

While the benefits of such progress are vital and not in dispute, the multifaceted ways in which they have irrevocably altered environmental systems can no longer be denied. This is largely due to the rigour that environmental scientists have applied in their work and the courage they often show in speaking out. For many years, those with the integrity and nerve to urge caution, or even just debate, were derided, dismissed or chastised as doomsayers rather than celebrated for their foresight and acumen.

Rachel Carson surely springs to mind as one of the first courageous canaries, speaking passionately and poetically about the dangers of DDT. She was not in fact the first to do so: nature writer Edwin Way Teale was amongst those who expressed concern nearly 17 years earlier, when DDT was first released onto the market. But he lacked the evidence base it took Carson four years to compile.

This served her well: as the Natural Resources Defence Council explain — when *Silent Spring* was first published the reaction from the chemical industry included remarks such as:

"If man were to faithfully follow the teachings of Miss Carson, we would return to the Dark Ages, and the insects and diseases and vermin would once again inherit the earth."

Chemical giant Monsanto also published a parody of Carson's book entitled *The Desolate Year*: "relating the devastation and inconvenience of a world where famine, disease, and insects ran amuck because chemical pesticides had been banned".

President Kennedy took *Silent Spring* seriously, however, and commissioned further research into the issues Carson had raised. The manuscript had been peer reviewed by several experts, and so it was perhaps unsurprising that the President's Science Advisory Committee vindicated her resoundingly. As we now know, this ultimately led to the banning of DDT in the USA and beyond, as well as to the birth of the modern environmental movement.

Although this is a historic example, the echoes resonate today: environmental scientists still endure scepticism and encounter controversy in relation to climate change, genetically modified organisms, hydro- and geo-engineering, overpopulation, food security, and more local issues such as badger culling. But some of these are amongst the most important of our time, and the fact that we are the ones asking the difficult questions – of ourselves as much as others – should be a source of pride rather than cause for caution.

As such, I encourage all environmental professionals to embrace this contentious issue of the environmental SCIENTIST and share whatever opinions or reactions it provokes. Doing so can surely only strengthen the evidence base and arguments that are part of our critical role as canaries in the coalmine.

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Wicked problems

Steve Rayner explains how environmental problems have become more complex.

Half a century ago, environmental problems seemed quite straightforward. They were mostly recognised as falling into two types: nature conservation and pollution control. From the late 19th century, campaigners for national parks had agitated for areas of outstanding natural beauty to be protected from industrial development. Pollution of air and water was a visible threat to health and safety. London was so notorious for its pea-souper fogs (actually smogs) that the Americans named an upmarket brand of raincoat after them. In 1952, those fogs killed 12,000 people. In the USA, the Cuyahoga River in Ohio was infamous for an alarming propensity to burst into flames between 1936 and 1969, due to extensive pollution with volatile chemicals in the water.

The solutions to the challenges of vanishing nature and industrial pollution seemed obvious: legislative restriction of harmful activities such as development in protected areas or of pollutant discharges into air or water. Pollution, in particular, was clearly conceived and effectively dealt with as an 'end-of–pipe' problem by 1960s clean air and clean water legislation in both Britain and the USA.

PROBLEMS OUT OF CONTROL

Half a century later, environmental problems seem a lot less tractable. The attempt to deal with the build-up of greenhouse gas concentrations in the atmosphere as a global 'end-of-pipe' problem through the creation of 'national pipes' subject to a global control regime has signally failed. A host of other environmental challenges, from foetal exposure to endocrine disruptors through to environmental governance of the oceans and atmosphere, seem to defy effective management. Yet, as Michael Shellenberger and Ted Nordhaus argue in their controversial essay 'The Death of Environmentalism'[1], our thinking in many cases has not caught up with the changes in the nature of the problems that we are seeking to tackle. We fail to recognise that the environmental problems of the past were tame problems. What we are now trying to deal with are 'wicked problems', which have also been described as messy problems[2].

Horst Rittel and Melvin Webber[3] first identified wicked problems in the late 1960s, just around the time that the US Congress passed the landmark Clean Air and Clean Water Acts that did so much to improve environmental conditions across the USA. Rittel and Webber were planning professors at the University of California, Berkeley who were concerned about persistent social problems associated with urban development.

They contrasted some of the relatively easy challenges of the late 19th- and early-20th-century planners with the more difficult challenges facing planners at the tail end of the 20th century. They felt that planners and engineers had done the 'no-brainers', like putting sewers underground and piping water into people's homes to avoid water-borne diseases, but were now dealing with qualitatively different problems – for example, the erasure of complete neighbourhoods for urban redevelopment or the problems of designing and siting roads and other transport systems. They also noted that such intractable problems of social policy could not be tackled using straightforward puzzle-solving, characteristic of mathematics and the natural sciences.

The late 1960s also marked the rise of the student movement and anti-Vietnam War protests in Europe and the United States. Rittel and Webber noted that decision-making was being made more difficult by the increasing diversity of political voices in contemporary society and the emerging value conflicts that this implied – particularly the emergence of popular protest against expert formulations of policies being imposed upon populations without their consent.

CHARACTERISTICS

Rittel and Webber listed 10 characteristics of wicked problems. Others have either condensed or expanded the list, but they seem to boil down to the following'.

- They are often symptomatic of deeper problems and frequently display circularity, as in explaining educational problems by poverty, poverty by social class, and social class by educational achievement;
- They offer little room for trial-and-error learning – once a neighbourhood has been demolished it can never be restored;
- They do not present clearly defined alternative solutions; indeed available solutions are often used to define the problem, as in the idea of monetising ecosystem services to address 'market failure' in environmental protection;
- They are characterised by contradictory certitudes, where there is no shortage of incompatible diagnoses and prescriptions; for example, the recent banking crisis has been blamed both on too much and too little regulation; and
- They tend to have redistributive implications for entrenched interests, such as those of the fossil fuel industry in relation to greenhouse gas mitigation.

Recently, some authors[4] have sought to distinguish a more intensely wicked category of problems that they describe as 'superwicked', citing such additional criteria as perceptions of urgency and the lack of any centralised authority to impose a viable solution. However, it is not clear that these criteria define a qualitatively different phenomenon and are really anything more than elaborations of the core idea of wickedness, which is intractability.

Although they have been identified by science rather than being directly sensed like fog and burning rivers, these are not puzzle-solving problems. For example, our ability to identify the problem of persistent organic pollutants is very much a function of our ability to measure incredibly small quantities: parts per trillion of pollutants, which were not even measurable two decades ago.

Not only do contemporary environmental problems look like the social issues that Rittel was talking about, they actually incorporate social issues, so they are no longer just scientific problems. For instance, we now confront the issue of environmental justice, the almost-universal propensity for minority populations and poor people to have to put up with much worse environmental conditions than people who are better off.

CLUMSY SOLUTIONS

So how do we deal with wicked problems? The most obvious urge – although an urge that I shall argue is to be resisted – is to simplify them. US policy guru, Nancy Roberts, has proposed three simplifying strategies: hierarchical, competitive and egalitarian[5].

The hierarchical strategy is the one traditionally adopted by the puzzle-solving scientists and government bureaucracies: you break the problem down into simpler components and apply well-tried decision routines

and decision rules, such as cost analysis. The second strategy is a competitive approach. The idea here is to use individual expertise and craft skills or 'the right stuff' to control resources to bring to bear on the problem. Finally, there is an egalitarian approach where you open up the problem to more stakeholders: "Let's get more and more people involved in discussions about how to do this".

However, each of these responses itself shapes the definition of the problem to the exclusion of the others, and this divergence of perceptions and values is part of what makes problems wicked in the first place. Attempts to simplify a wicked problem in any one (or even two) of these three ways only serves to entrench opposition from those whose perspective is left out. Hence, Cultural Theorists in the tradition of Mary Douglas advocate 'clumsy solutions' (hybrid strategies) in which all of the voices – hierarchical, competitive, and egalitarian – are heard and responded to[6]. As such, clumsy solutions are likely to be emergent from negotiation or conflict rather than being planned.

In the final analysis, wicked problems have no definitive solutions. They can only be managed more or less well through 'settlements'[7] that endure for a while before the problem reasserts itself in a new form that requires renegotiation[8].

The US policy settlement on nuclear energy that endured from the 1980s through the first decade of the 21st century was a clumsy solution to the nuclear power conflicts of the 1970s and 80s. While not the subject of any form of legislation or formal agreement, this amounted to an informal moratorium on the addition of new nuclear generating capacity while permitting continued investment in research and development. While government, industry and the environmental movement accepted the agreement, none of the parties could publicly agree that they agreed as each was reserving its position pending a change in circumstances. At the time of writing, that settlement appears to be under severe strain and the issue on new nuclear is opening up again.

As issues like climate change reveal themselves to be increasingly intractable to elegant solutions such as comprehensive international agreements (a hierarchical strategy), carbon pricing (a competitive strategy) and moral exhortation to change behaviour and lifestyles (an egalitarian strategy), there is a pressing need to explore clumsy solutions. Rather than depending on getting people with different values and priorities to think the same way, clumsy solutions focus on getting the to do the same thing for their own diverse reasons[8]. It requires humility to admit that we cannot definitively solve wicked problems, but can only cope with them with varying levels of success. In the words of the protagonist of Graham Swift's novel *Waterland*:

"It's progress if you can stop the world slipping away. My humble model for progress is the reclamation of land. Which is repeatedly, never-endingly retrieving what is lost. A dogged vigilant business. A dull yet valuable business. But you shouldn't go mistaking the reclamation of land for the building of empires." (Swift, 1983, p336)[9]. ES

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Ecocide and the 'polluter pays' principle: the case of fracking

Karen Hulme and **Damien Short** assess the effectiveness of economic instruments for the prevention of environmental damage.

▲ **Farndon, Chester. Dart Energy drilling CBM well in March 2014. (© Extreme Energy Initiative)**

It seems as though the environment is subjected to attacks on its integrity and its viability on a daily basis. In the 1970s the term 'ecocide' was coined to describe attacks from military sources, such as the use of chemical defoliants in Vietnam. Today, similar levels of harm are more routinely caused in the name of development and the search for cheap energy sources, one example being the scramble for new oil and gas resources. The 1970s notion of ecocide has recently been revived with suggestions of elevating large-scale environmental destruction to the level of an international crime. But how does this notion of holding an individual or company accountable for an environmental crime relate to other mechanisms for holding the polluter to account, such as the economic notion of accountability inherent in the 'polluter pays' principle? According to legal scholar and environmental activist, Polly Higgins, 'ecocide' refers to:

"the extensive destruction, damage to or loss of ecosystem(s) of a given territory, whether by human agency or by other causes, to such an extent that peaceful enjoyment by the inhabitants of that territory has been severely diminished." (Higgins, 2010, p63)[1]

Higgins views ecocide as a potential fifth international crime, after genocide, the crime of aggression, crimes against humanity and grave war crimes. Her notion is intended-as was the original proposal which dates back to the 1970s-to cover times of both conflict and peace, and today she has in mind the environmental destruction that accompanies such extreme energy processes (often called unconventional sources). This includes oil production from tar sands[2], mountain-top removal, deep-water drilling and, potentially, the family of extraction processes involved in the production of shale gas, coal-bed methane (CBM), tight oil and synthetic gas (syngas) known colloquially as 'fracking' (hydraulic fracturing). Could fracking potentially produce ecocides and what is the benefit of criminalising such harm versus the traditional economic method of holding the polluter to account?

'EXTREME' ENERGY TODAY

Today the depletion of conventional oil and gas reserves[3] is leading to increasing pressure to exploit more unconventional sources. Michael Klare[4] coined the term

'extreme energy' to describe a range of new higher-risk unconventional resource extraction processes, which are increasingly being used as the more easily accessible supplies dwindle. Conventional oil and gas reserves are the reservoirs from which the oil and gas emerge under their own pressure once the reservoir has been drilled into. Fracking techniques for shale gas and CBM require greater effort than conventional well drilling, because the gases have to be flushed out of them using directional drilling, high-volume fracking fluid (including toxic chemicals[5]), slick water, multi-well pads and cluster drilling. These have all been used separately in the past, but the practice of using them all together has only developed since 2007[6].

While first used in the USA, where over 45,000 shale gas wells and 55,000 CBM wells have been drilled in the last decade (and the industry is proposing to add a million more), fracking has also been undertaken on a large scale in Canada and Australia, and is expanding across Europe. The effects on the environment and human population from fracking processes are not yet fully known, but numerous reports warn of the possibility of very serious human and environmental impacts, including the potential for causing earthquakes as well as the contamination of water resources[7] and soils due to the creation of millions of litres of waste polluted with heavy metals[5]. The impacts of fracking may, therefore, fit within the definition of ecocide depending upon the scale of harm.

TAX INCENTIVES

While fracking in the UK is still in the exploration stage, the Government recently announced tax incentives for exploration licenses for approximately two-thirds of the UK's land that will be available for fracking licenses[8]. And it is not just shale gas fracking that is proposed. The UK Coal Authority has issued 24 exploration licenses that could permit large-scale production of syngas via underground coal gasification (UCG, a process for exploiting coal that cannot be mined because the seams are too deep, thin or fractured). UCG is considered part of the 'fracking family' as it uses similar drilling technology to get air or water into the coal seam before it is set on fire underground and partially burned to bring gas to the surface. UCG has only been undertaken on a small scale worldwide (usually for testing purposes) and has been beset with considerable waste management and environmental problems. For example, a major test site in Kingaroy, Queensland, Australia, was closed down following benzene groundwater contamination at the site[9]. Even so, the UK Government is proposing an unprecedented level of syngas production at sites near major UK cities. Thus, using fracking as an example, what does it reveal about the crime versus economic approach?

ECOCIDE IN LAW

Although heavily debated in the post-Vietnam War period of the 1970s[10], the notion of ecocide was shelved in the 90s, and thus no crime of ecocide made it into the 1998 Rome Statute of the International Criminal Court. In fact, no notion of company liability or state responsibility was included in the ICC Statute, which refers only to individual criminal responsibility. As for the notion of criminalising environmental harm at the state level, acceptance of the 1998 Council of Europe Convention on the Protection of the Environment through Criminal Law[11] has been extremely poor (only three state ratifications to date) and, thus, at the international level, political will is probably not in favour of such mechanisms.

Uptake in the European Union (EU) has been slightly better, but here the goal is the harmonisation of the environmental regulation of all member states to ensure economic parity across the EU[12]. Environmental crimes at the EU level are largely concerned with the safe transport and disposal of waste and the nuclear industry, but, more relevant to fracking activities, are crimes related to environmental damage caused by the operation of a dangerous activity and significant deterioration of a habitat within a protected site. Far more dominant, however, is the EU's core economic approach to environmental regulation in its adoption of the 'polluter pays' principle[13], which is supposed to be at the centre of any environmental regulation. There are, of course, also the sociological and philosophical perspectives to consider of whether apparently lawful activities, such as resource extraction, are best regulated by the criminal law. Yet, does the prospect of fracking comply with the EU's adopted 'polluter pays' principle?

"What is pivotal to protection of the environment is proper governance"

POLLUTER PAYS

The origins of the 'polluter pays' principle date back as far as the 1920s, but the principle really came into modern parlance when it was included in the 1992 Rio Declaration on Environment and Development as Principle 16[14]. It was viewed as a core tenet of the sustainable development movement, in promoting equity and fairness in the allocation of environmental risks. The principle centres on the economic notion that the full costs of the use of nature and environmental resources should be borne by the person, company, or even the state that uses those resources. In this way the principle has two core dimensions: first, that the polluter will pay the full cost for the use of, or harm to, such resources and will therefore seek instead to more efficiently internalise those costs through more environmentally sensitive practices, and second, that the polluter will be held liable when environmental damage is caused[15].

While there are many mechanisms for the second dimension, of compensation or liability for environmental damage, even including the criminalisation of environmental harm, the real point of environmental protection is surely for the prevention of harm in the first place. And it is here that the economic roots of the polluter pays' principle reveal that principle's main limitation, notably, that if the polluter can afford to pay – and pay huge sums in compensation (or even heavy criminal law fines) – then there is really little impetus for such polluters to internalise the costs of harm to the environment and therefore to change their environmentally unsound ways. Stark examples of this reality are provided foremost by the oil and gas industry, with Shell's pollution of the Niger Delta over decades of exploitation, and Chevron's pollution of the Ecuadorian Amazon basin. States, too, are often complicit in such environmental destruction, as shown by the Nigerian example of Shell, and by Canada's approval of the exploitation of tar sands.

ENERGY VERSUS CLIMATE CHANGE

Part of the rhetoric, of course, is the peak oil debate and the ever-increasing urgency for states to ensure their own energy security. But this debate, incredibly, often ignores or at least sidelines the major debate of the 21st century, which is the mitigation of climate change and the consequent reduction of fossil fuel emissions. Here too economic instruments and principles were used by the main user states to protect their own industries and largely to carry on with business as usual. The adoption of the carbon market mechanism in the climate change regime was heralded as 'polluter pays' compliant in that the main polluters would be incentivised to reduce their greenhouse gas emissions. Yet, it is highly questionable whether the carbon market is actually reducing the level of global emissions[16].

Ultimately then, while the notion of ecocide appears to embody the 'polluter pays' principle in aspiring to require polluters to be criminally prosecuted, possibly before a national or international court, would such actions even impact the energy industry, which we have globally come to be so dependent upon? Sharife and Bond, writing on the notion of 'green' economy, doubt that heavy fines or even the imprisonment of CEOs is going to achieve real environmental protection without also requiring proper environmental management[17].

What is instead pivotal to protection of the environment is proper governance, namely robust environmental planning and the prior investigation of potential

▲ An OPTI oil sands refinery in Alberta, Canada. (©David Dodge, CPAWS via www.pembina.org)

environmental harm, notably a rigorous, and independent, environmental impact assessment process. It was this aspect, namely the prospect of the EU imposing the requirement of a full environmental impact assessment on shale gas fracking, that caused vociferous opposition from EU member states, such as the UK[18]. Arguably, the lack of value of economic mechanisms, such as the 'polluter pays' principle, have been shown over the past 40 years, and therefore maybe a new approach such as acceptance of a criminal law of ecocide should perhaps be encouraged. At present, it is unclear, however, if fracking would qualify as ecocide, and that is often one problem with environmental damage, and particularly criminal law approaches to environmental damage: it is often only after the damage has occurred, or when such damage is clearly a foreseeable consequence, that the threshold of harm will be sufficiently evidenced. ES

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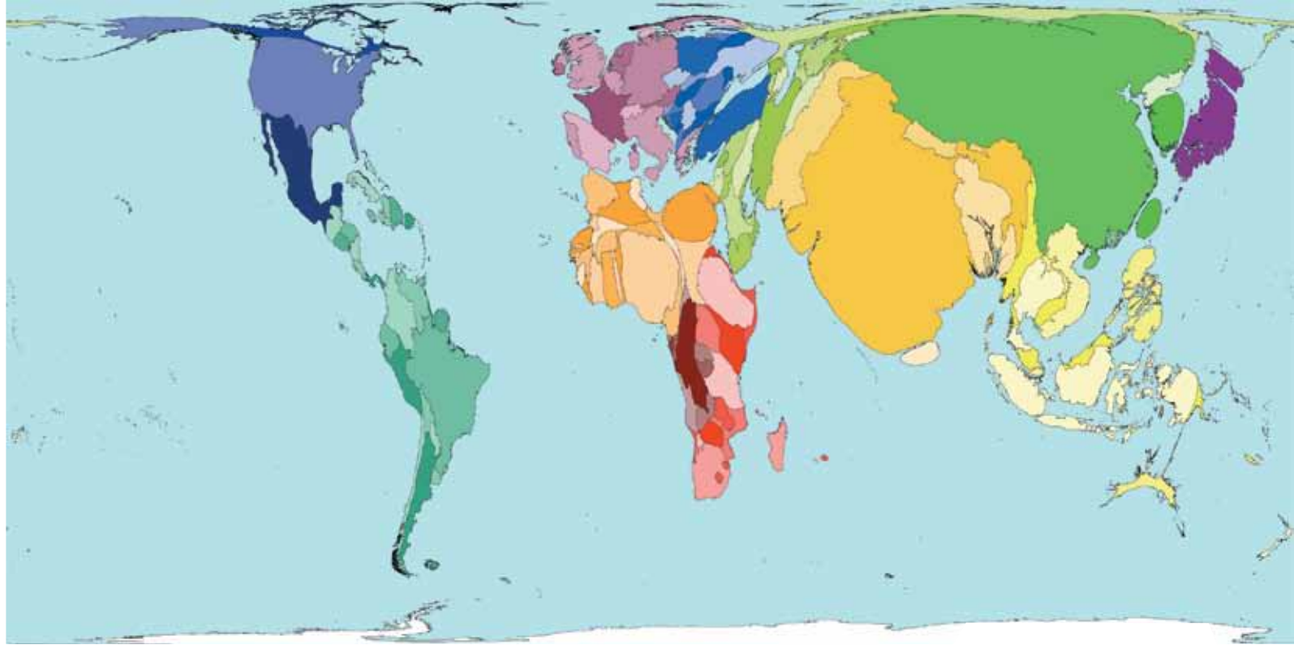


▲ **The size of each territory shows the relative proportion of the world's population living there. (©Benjamin D Hennig, Worldmapper.org)**

Are there too many of us?

Fred Pearce examines the fears about the largest human population in the planet's history.

We hear a lot about how the world's population is soaring. The human total has now exceeded seven billion people, more than four times the figure of a 100 years ago. Many people, especially environmental scientists, fear that overpopulation is driving the destruction of the world's resources and will one day make the planet uninhabitable.

But there is another story. A good news story about how the doomsters may have got it wrong. How the world is solving what has seemed about the most difficult problem for the future of humanity. What's more, it is being solved by the world's poorest people, especially women. The people often seen as villains in the population story are turning into heroes.

THE POPULATION BOMB

The world was alerted most forcibly to the population problem in the 1960s by the US biologist Paul Ehrlich, in his million-selling book *The Population Bomb*. There was reason to be scared. Back then, women were having five or six children, and most of those children were growing up and having their own children.

As a result, the human population was doubling every generation. Doubling food production seemed impossible. "The battle to feed humanity is over," Ehrlich wrote. "Sometime between 1970 and 1985, the world will undergo vast famines. Hundreds of millions of people are going to starve to death."

Since then, the world's population has gone from 3.5 to over seven billion. We have had some famines, but nothing on the scale that Ehrlich predicted. One reason is that global food production doubled ahead of time thanks to the 'green revolution' of high-yield crop varieties.

THE BOMB DEFUSED

That bought time. Time that has been used. Because the other thing that did not feature in Ehrlich's doomsday

prediction is that the population bomb is being defused. Today's women have just half as many children as their mothers back in Ehrlich's day.

The global average is now just under 2.5 each, which is very close to the replacement level. Allowing for girls who do not make it to adulthood, women globally need to have around 2.3 children to keep up numbers in the long run.

There is a reproductive revolution going on round the world. Half the world now lives in countries with fertility rates that are at or below the national replacement level. That includes Europe, North America and the Caribbean, most of the Far East from Japan to Vietnam and Thailand, and much of the Middle East, where Iran has seen one of the most dramatic changes. In the past 25 years, the number of children born to Iranian women has crashed from eight to fewer than two. Women in Teheran today have fewer children than women in London or New York.

The mullahs and some politicians did not like it. In 2006, the then-president Mahmoud Ahmadinejad called for women to return to their "main mission" of having babies. But women were not listening, and even his own government ran a condom factory.

Some of this worldwide reproductive revolution has been happening because of coercive governments running the kinds of birth-control programmes that people like Ehrlich often called for back in the 60s and 70s. Most of this has been in China, where the government decides how many children couples can have. They call it the one-child policy, though there are a growing number of exceptions.

But the odd thing is that such government diktats may not make much difference any more. Ethnic Chinese women elsewhere in Asia have adopted what amounts to a one-child policy of their own. When Britain handed Hong Kong back to China in 1997, it had the lowest fertility in the world — below one child per woman.

A FALLING TREND

Family planning experts often say that women only start having fewer children when they are educated or escape poverty. Pessimists have feared that if the rising population stops people getting rich, they will get caught in a vicious cycle of poverty and large families. But in most places, even the poorest and least educated are deciding they want fewer children.

Take Bangladesh, one of the world's poorest nations. Its girls are among the least educated in the world, and mostly marry in their mid-teens. You might expect big families. Yet they have on average fewer than three children. India is even lower at 2.8, half the figure in 1980. In Brazil, a hotbed of Catholicism, most women have two children. Nothing the priests say can stop millions of women getting sterilised.

I think something very simple is going on. Women are having smaller families because, for the first time in history, they can. In the 20th century, the world largely eradicated the diseases that used to mean most children died before growing up. Mothers no longer need to have five or six children to ensure the next generation. The population bomb went off in the years before reproductive habits caught up with medical advances. But it now looks like a very temporary phenomenon.

This reproductive revolution has also changed women and their place in society everywhere. Women are able to have two or three children and get on with a life outside the home. It is probably no coincidence that the reproductive and feminist revolutions have both spread round the world at the same time. Those revolutions are both very incomplete, but they are real and global.

There are holdouts, of course. In parts of the Middle East, traditional patriarchs still hold sway. In Yemen, where in remote villages girls as young as 11 are forced into marriage, they still have six babies. In parts of rural Africa, women still have five or more. But even here they are being rational. On a poor African peasant farm, children are useful from a very young age to mind the animals and work in the fields.

URBANISATION

However, more than half the world now lives in cities, where children are usually an economic burden. There are no jobs in the fields. You have to get them educated before they can get a job. And by then they are ready to leave home. Urbanisation is everywhere helping to reduce fertility. We are used to seeing poor-world megacities as symbols of overpopulation. Maybe, but they are also part of the solution.

And the big story is that rich or poor, socialist or capitalist, urban or rural, Muslim or Catholic, secular or devout, with tough government birth control policies or none, most countries tell the same story. Small families are the new norm. That does not mean women do not still need help to achieve their ambitions of small families. But this is now about rights for women, not population control.

Population growth has not ceased yet. We may end up with another two billion or so before the population bomb is fully defused. This continued increase is mainly because the huge numbers of young women born during the baby boom years of the 20th century remain fertile.

But the world recently reached a new demographic milestone: peak child. The number of children in the world has stopped increasing. So, even though people are living longer, we can look forward with some optimism to the day when the world's population as a whole peaks. After that, the world's population may even begin shrinking.

THE CONSUMPTION BOMB

What does that mean for the environment? Well, it is good news, of course. But, just as the population bomb was never really the problem, stable population is only part of the solution. Rising per-capita consumption today is a far bigger threat to the environment than a rising head-count. And most of that consumption is still happening in rich countries that have long since given up growing their populations.

Take today's contributors to climate change. The world's richest half billion people – that's about seven per cent of the global population – are responsible for half the world's carbon dioxide emissions. Meanwhile the poor 50 per cent are responsible for just seven per cent of emissions.

Or look at it another way. Economists predict the world's economy will grow by 400 per cent by 2050. If so, only a 10th of that growth will be due to rising human numbers. It is the world's consumption patterns – and how we produce what we consume – that we need to fix. We have not even begun to defuse the consumption bomb.

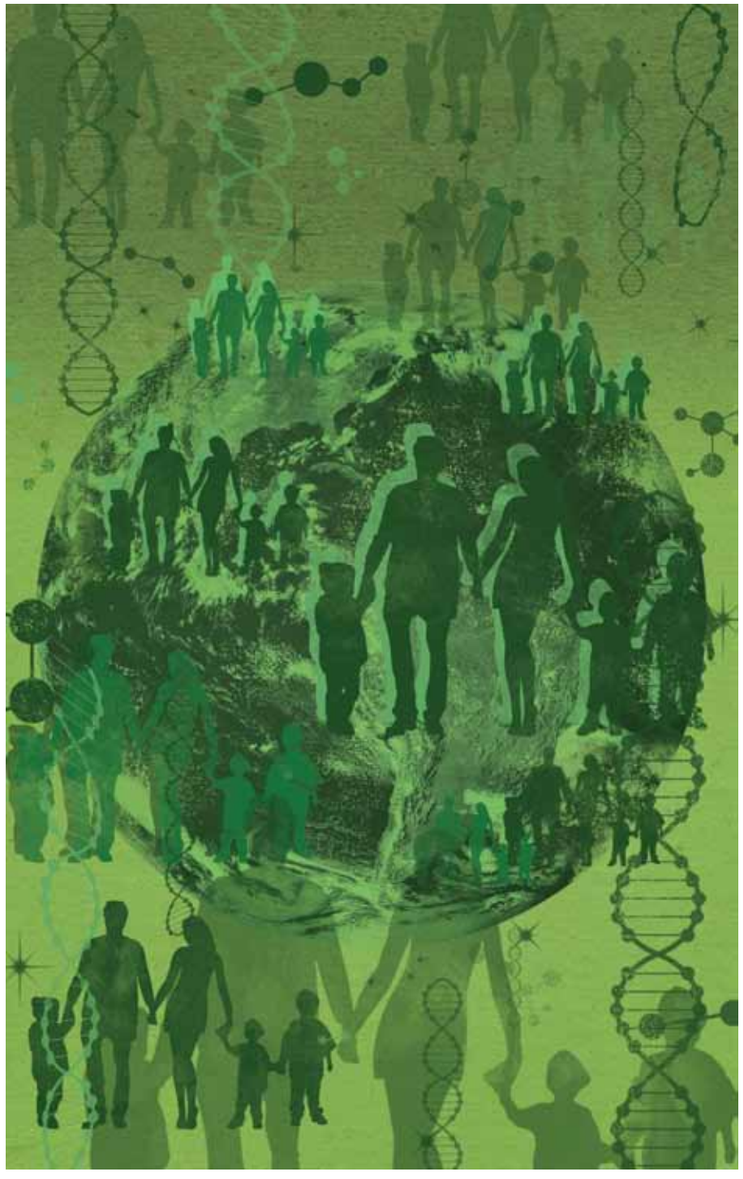
WHAT IS OUR DEMOGRAPHIC FUTURE?

Demographers used to believe that as countries develop and their birth rates fall, they will settle down at roughly replacement level. But the evidence of the great majority of countries that have got down to the replacement level is that they do not stop there. They carry on down, often to ultra-low fertility – below 1.5.

Often the lowest fertility rates happen in countries where the feminist revolution has made least progress. If forced to make a choice between working and children, young women will now mostly choose working. The results could be literally nation-destroying. If Italy gets stuck with present fertility levels, and fails to top up with foreign migrants, it will lose 86 per cent of its population by the end of the century.

By contrast, where men take a greater role in bringing up children, where the state intervenes to help working mothers, or where the labour market is sufficiently flexible, then fertility rates stay quite close to replacement. You can see that in Scandinavia, France and Britain, for instance.

The other major demographic trend is ageing. As we live longer, and as fertility rates fall, ageing is becoming a global phenomenon. This is *terra incognita*. Our species has never lived in societies where there were more people above the age of 40 than below. But soon we will. Japan is already there. Before long, China will have a declining population and more old people than anywhere else.



Some say this is the new population bomb, and that we will never be able to afford to look after all those old people. It is hard to predict how an older world will turn out. But we will certainly have to think of the old not as a burden, but as human capital, a source of wisdom and experience. And we may change in more subtle ways.

At the height of the worldwide population explosion, the 20th century was almost literally taken over by teenagers. They were rampant consumers. But those days are passing. As the population bomb is finally defused, the world will settle down a bit. It might be more survivable, and plain nicer.

The youth century had two massive world wars and nearly destroyed itself with nuclear weapons. But it is an almost-universal rule that only countries with young populations have wars. So the chances are that we will not do that again.

Pessimists could be right that in the 21st century, ageing societies might lose the ability to innovate and solve the huge problems still facing us. But my guess – my hope – is that the 21st century will be more mature, less frenetic, less consumerist, and a more frugal and greener society. Older, wiser, greener. That is my optimistic hope for the future. ES

Fred Pearce is a London-based freelance author and journalist. He is the environmental consultant of *New Scientist* magazine. His books include *Peoplequake* (Eden Project Books).

IES: new members and re-grades

Members	Occupation (M)
Christopher Braban	Environmental Physicists
Wai Yiu Kan	Assistant Consultant
James Bellinger	Consultant
Uzoma Okoroafor	Environmental Coordinator
Helen Dacre	Lecturer
James McNally	Technical Director
Hardip Mann	Senior Sustainabilty Advisor
Jamie Wood	Environmental Consultant
Alexander Warhurst	Senior Campaigner
Sarah Toms	Senior Geoenvironmental Engineer
Peter Sanderson	Technical Officer
Daniel Marsh	Senior Air Quality Analyst
Christopher Wadsworth	European Sustainability & ESH manager
John Ridpath	Acoustic Consultant
Abigail Plaza	Air Quality Expert
James Humphries	Process Scientist
Andrew Morrow	Scientific Officer
Matthew Ellison	Higher Research Scientist
Lynne Anderson	Senior Planning Officer

Fellow	Occupation (F)
Gary Kass	Deputy Chief Scientist
Oliver Grievson	Senior Process Engineer
Simon Watts	Research Manager

Associates	Occupation (A)
Katherine Martin	Process Scientist
William Hartas	Graduate Environmental Scientist
Zoe Webb	Ecologist
Jenna Brown	PhD Researcher
Samuel Gold	Assistant Environmental Scientist
Nicolas Souquet-Basiege	Graduate
Laura Didymus	Graduate
George Teesdale	Environmental Scientist
Zoe Morrall	Graduate
Lucy Gilbert	Environmental Consultant
Angela Jones	Graduate
Ian Davison	Principal Consultant
Michael Reynolds	Graduate
Austin Cogan	Consultant
Annabel Foskett	Environment Centre Manager
Jonathan Hall	Graduate Sustainability Consultant

Affiliates	Occupation (Af)
Chang Ge	Student
Laura Blair	Resource Effciency Consultant

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Associate is for individuals beginning their environmental career or those working on the periphery of environmental science.

Affiliate is for individuals with an interest in environmental issues but don't work in the field, or for students on non-accredited programs.

▲ **Figure 1. Rewilding underway. Planted Scots pines and naturally regenerating heather and bog myrtle create a 'natural garden' inside a deer-fenced exclosure at Athnamulloch in Glen Affric, in contrast to outside fence, where peat hags dominate in the uniform grassland held at a low level by excessive numbers of deer.**

Rewilding in the Scottish Highlands

Alan Watson Featherstone explains the advantages of and barriers to large-scale landscape restoration.

'Rewilding' is a term that was originated by the conservation biologist Michael Soule in the mid-1990s to describe "the scientific argument for restoring big wilderness based on the regulatory roles of large predators", as part of a radical, large-scale vision for the future of nature in North America. Since then, it has been developed and adapted by ecologists and conservationists, and is now used more widely to refer to the return of ecosystems to a state of ecological health and dynamic balance, which are self-sustaining into the future, without the need for ongoing human management or intervention.

Rewilding is based on the recognition that we live in an increasingly ecologically depleted world, where the pressures of ever-growing human numbers and our associated economic activities have substantially degraded many natural ecosystems, through the loss of significant constituent species and interference with, or elimination of, key ecological processes.

In the 20th century, and continuing to this day, most conservation campaigns have been defensive in character, and have concentrated on what can be viewed as 'damage limitation' – attempting to save species or habitats from destruction due to human impacts.

In the last decades of the 20th century, a more proactive dimension to conservation began to emerge, which attempted to reverse the damage that had already taken place through the development of practices such as ecological restoration. Rewilding can be viewed as an important element of this larger movement, and it is radical in that it runs counter to the prevailing

▲ **Figure 2. Wild boar disturbing the soil as it roots for bracken rhizomes, at Trees for Life's Dundreggan Conservation Estate in Glen Moriston.**

trend of our global culture today, which is based on the principle of ever-increasing management of nature to achieve human goals and benefits. In practical terms, rewilding consists of the restoration of healthy vegetation communities; reinstatement of key ecological processes, such as succession, predator–prey relationships and natural disturbance; a reduction and/or cessation of human management of ecosystems; the removal of human infrastructure (e.g. roads, dams, fences); and the reintroduction of key species (e.g. top predators) that have been extirpated.

In the UK, there has been increasing interest in the concept and practice of rewilding, and much of this has been directed towards areas such as the Scottish Highlands. However, there are also rewilding projects under way in other parts of the country, including Wales, the Lake District and the fens of East Anglia. The reasons for the focus on the Scottish Highlands include the low human population; the relatively large areas of land with limited, if any, economic activities; and the increasing recognition of the highly degraded condition of the land and ecosystems in much of the region.

TREELESS HIGHLANDS

In a Highland context, the starting point for rewilding in most situations is the restoration of healthy vegetation communities. There is a paucity of these at present, due to the historical legacy of overexploitation, including deforestation (and consequent waterlogging of the soil), nutrient depletion and overgrazing. These have affected formerly forested land and naturally open areas such as bogs and mires, so that today most of the Highlands are treeless and many areas are scarred by peat hags – sections of land where erosion has exposed the underlying peat. Vegetation is unable to recolonise deforested areas and peat hags because of overgrazing by excessive numbers of deer and sheep. They have prevented the establishment of any new trees in most

▲ **Figure 3. Windthrow, such as that of this Scots pine blown down by a storm in Glen Affric, is a natural disturbance factor in the forest. It adds structural heterogeneity to the ecosystem and provides opportunities for new life to flourish. However, at present no trees will grow to replace this fallen pine, because of the pressure of overgrazing by deer, and rewilding is unable to occur. (© Alan Watson Featherstone/Trees for Life)**

▲ **Figure 4. Windfarms, such as this one at Gordonbush in Sutherland, present one of the main obstacles to rewilding in the Highlands today. (© Alan Watson Featherstone/Trees for Life)**

places for 150–200 years, leaving the surviving forest remnants as 'geriatric woodlands' consisting only of old trees that are dying off without being replaced.

Even the woodlands that do survive in many cases consist only of birch trees. Birch is a pioneer species that is short-lived and, in a healthy ecosystem, is gradually replaced through the process of succession by slower-growing or longer-lived species such as Scots pine and oak, depending on the soil conditions and site aspect, etc. The fact that so many Highland birchwoods have become derelict, with the old trees dying off without either being succeeded by other species or at least replaced by younger birches, is an indication of the absence of the key process of succession.

EXCLUDING GRAZERS

In the last two or three decades, considerable efforts have been made to restore and expand native forests, through the use of either fenced exclosures, where deer and sheep are completely absent, or by reducing deer numbers to a very low density by greatly increased cull targets. The results of such initiatives are readily apparent in many sites from Beinn Eighe and Creag Meagaidh to Glen Affric and Abernethy, with a new generation of trees becoming established through natural regeneration, along with a healthy and vigorous growth of understorey plants, including blaeberry, heather and bryophytes.

Fences create problems though, and are not an ideal solution in themselves. Rather, they are an emergency measure, used for a relatively short time (in terms of the lifespan of a tree) to kick-start the recovery of the vegetation. The total exclusion of large herbivores is not a natural condition (although no grazing is better, for a few years at least, than overgrazing), and the fences pose a hazard to low-flying woodland birds such as capercaillies and black grouses. They also run counter in some regards to the principle of rewilding, in that they are a tangible expression of human management, albeit one that seeks to correct the gross imbalances created by past human exploitation. The irony is that, in kick-starting the process of rewilding, more human intrusion into the ecosystem is necessary, at least on a temporary basis.

Rewilding is also underway in parts of the Highlands for internationally important peat bog areas, where the plantations of non-native conifers that were established under tax-break schemes in the 1980s are now being

▲ **Figure 5. Birch trees felled by a European beaver (*Castor fiber*) at the Aigas Field Centre near Beauly in the Highlands. Beavers are 'ecosystem engineers' and create a range of habitats for other organisms through their felling of trees and creation of pools of still water. Their reintroduction is an essential part of the rewilding of aquatic and riparian ecosystems in Scotland. (© Alan Watson Featherstone/Trees for Life)**

felled, and the sites restored to natural bog and mire conditions, with drainage ditches being blocked etc. to encourage a return to the former hydrological conditions.

Once healthy vegetation communities become re-established, further elements of ecosystem recovery take place spontaneously. The vigorous growth of plants attracts flying insects, whose larvae feed on the leaves and other plant parts. They in turn draw in insectivorous birds, which may also transport seeds in their gut and deposit them in their droppings, providing new plants to add to the recovery and diversity of the vegetation. Increased populations of birds and small mammals will support raptors and terrestrial predators such as pine martens, foxes and wildcats.

REINTRODUCING SPECIES

At this stage, the rewilding process could be said to be well underway, but further steps are still required for ecosystems to return to full health and ongoing sustainability without the need for further human management. Such steps include the reintroduction of missing species, ranging from wood ants (which have a short dispersal distance and therefore are missing from many isolated woodlands, both old remnants and newly established ones), to top predators such as Eurasian lynxes, wolves and brown bears. A growing body of evidence from restoration and rewilding projects in other countries is showing that apex predators (those at the top of food webs) play a crucial top-down role in the regulation of ecosystems. In Yellowstone in the USA, a whole series of unexpected ecological benefits have now been documented due to the return of wolves, and there is no doubt that the reintroduction of wolves in Scotland would produce similar ecological benefits here.

The re-establishment of healthy population of raptors such as sea eagles, ospreys and red kites are one of the success stories of re-wilding in the Highlands. The trial reintroduction programme for European beavers at Knapdale in Argyll was an important step forward for rewilding as well. It was the first official attempt to reinstate one of the country's large mammal species that was extirpated through past human activities. As a keystone species in freshwater aquatic and riparian ecosystems, the return of beavers has already shown tangible benefits for other species. At the same time, the spread of an 'unofficial' beaver population in the Tay River catchment is providing a valuable opportunity to study the impact of the species in a larger freshwater ecosystem, complete with migratory salmonid fish.

The wild boar is another species considered for inclusion in rewilding projects. While no officially sanctioned reintroductions have been proposed, escapes from wild boar farms have resulted in *de facto* wild populations becoming established in several areas within the Highlands. By disturbing the soil, wild boars create ideal conditions for the germination of the seeds of trees such as Scots pines, and they can also limit the spread of bracken, an opportunistic native species that is now out of control in much of the country.

The more significant step of reintroducing a large terrestrial predator has not yet been attempted. Wolves are often discussed in this respect, but Eurasian lynxes are a more realistic prospect in the near future, and many advocates of rewilding are now calling for serious consideration of a lynx reintroduction. If this gains traction in official circles, it will be an indication that the value and importance of rewilding is being given credence at the highest level.

While the reintroduction of apex predators such as wolves or lynxes is often proposed as a means of reducing the excessive numbers of red deer and roe deer respectively in the Highlands, the main impact of the return of those carnivores is likely to be felt in a different way, through their role in disturbing herbivore populations, and causing the animals to move more frequently to escape being killed.

THE IMPORTANCE OF DISTURBANCE

This forms one relatively small-scale example of the missing ecological process of natural disturbance. Larger and more dramatic examples include infrequent events such as wildfires, windthrow of trees due to stormy weather, and flooding. Attempts to control flooding and prevent wildfires illustrate the ongoing efforts of people to manage nature, and for rewilding to be fully implemented it will be necessary to allow those occasional disturbance events to take place again. This can only be seriously considered, in the case of wildfire at least, when healthy vegetation communities have become much more widespread and abundant again – in current circumstances a wildfire could lead to catastrophic losses of the few relatively intact remnants of the native pinewoods of the Caledonian Forest that still survive.

OBSTACLES TO REWILDING

Rewilding faces some other serious obstacles though, before it can be said to be fully implemented in a Highland context. These include the imbalance between excessive numbers of large herbivores and the depleted and overgrazed vegetation communities today, together with the complete absence of apex predators and their associated ecological functions. While the culling of deer by people does play a role in limiting the population, it does not replicate the other functions of predators, such as the disturbance effect already described.

Sheep numbers are declining in the Highlands now, as a result of changes to the system of subsidies that has kept their numbers unsustainably high. However, there is no evidence that the deer population is being reduced. Deer numbers are kept artificially high by winter feeding to sustain the 'traditional' system of land management that has been in place since the latter part of the 18th century. The concentration of land ownership in the Highlands in the hands of a small number of owners, many of whom now live abroad and who still work to maximise their economic gain from the depleted landscape, is a large barrier to rewilding in many areas. However, some of the newer landowners are taking a lead in rewilding projects, with examples including the Alladale and Glenfeshie estates.

One of the most serious impediments to rewilding today is the proliferation of large-scale windfarms across much of the Highlands. Financed by massive subsidies, these are being installed at a rapid rate in areas that previously have been relatively unaffected by human infrastructure. Each windfarm creates not only an enormous visual intrusion in an otherwise relatively natural landscape, but also, through its network of turbines, access tracks and powerlines, a hazard for large raptors and bats, and an invasion route for non-native plants as well as disruption to local hydrological systems.

Beyond these physical constraints, other factors operate at a cultural level to limit or prevent the implementation of rewilding. Those include public attitudes to predators such as wolves, which have been deeply ingrained by a long history of demonisation of the species. This is an expression of a human fear of wild nature, which shows itself in many forms in our modern culture. That in turn is one of the main drivers for the overarching objective of contemporary human culture to be in control of the planet, and to manage nature in every way possible. Rewilding represents a counterpoint to that trend, and it will only become fully successful if we as a species are willing to step back from the current impetus to use every part of the Highlands, and indeed of the whole world, for human material gain, and let nature, and natural processes, prevail in some areas at least. ES

Alan Watson Featherstone is the founder and Executive Director of Trees for Life, an award-winning conservation charity that has been engaged in practical work to help restore the Caledonian Forest in the Highlands of Scotland since 1989.

Partnerships under the weather

Carolyn Roberts looks at the winter 2014 flooding in the UK and highlights the communications challenges facing would-be participants in the debate.

The last few months have provided abundant evidence of the UK's inability to approach hydrological challenges in a logical and measured way. The floods of winter 2013-14 prompted an unedifying spectacle of warring Ministers, blame-seeking media, and an Environment Agency caught on the defensive after several years of reductions in government funding. The professional bodies with interests in water management argued publically and acrimoniously about the relative merits of dredging versus sustainable drainage schemes as potential 'solutions', and the water companies largely denied any responsibility but complained to their shareholders about the likely impact of incoming legislation on dividends. Meanwhile the residents of the Somerset Levels, Oxford, and the lower Thames lifted hundreds of thousands of sandbags but nonetheless ended up wading through, or sculling over, up to three metres of sewage-contaminated floodwater. Uninsured small businesses are now facing bankruptcy, whilst some householders allegedly find themselves unable to secure insurance policies. We might well ask how much progress has been made since the last similar events, and whether anything has been learned in the interim.

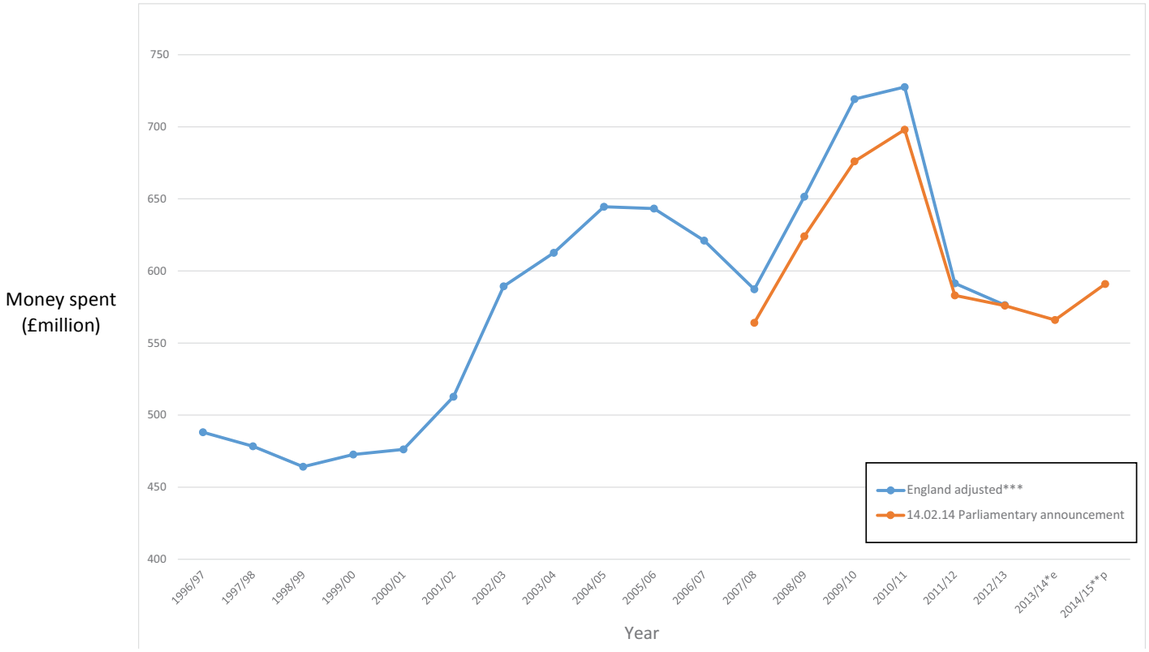
The exceptional meteorological circumstances behind the latest floods make thought-provoking reading, particularly in the context of climate change. The winter of 2013-14 was arguably the longest, most extreme wet period on record, certainly with the wettest January ever in southern England; many areas received the equivalent of five months' rainfall in December and January alone. This occurred in combination with remarkable winds, and high tides that caused a surge comparable with the 1952 event that drowned hundreds on the UK's East Coast. Groundwater levels reached unprecedentedly high levels in aquifers across England. The Environment Agency

HYDROLOGICAL MYTHS AND LEGENDS

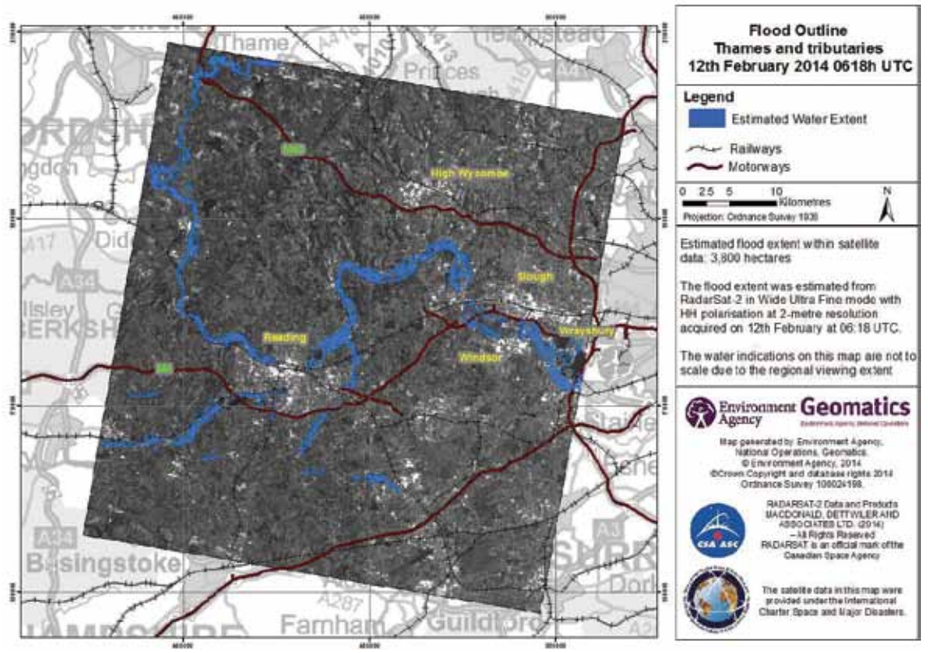
1. They opened the lock gates and flooded my village deliberately to save them over there
2. Dredging the river would solve the flooding problem once and for all
3. This line on the map defines the river's floodplain; outside that it's safe to build
4. Sand bags are an effective way to keep out the water
5. If planners thought about this, we could store all the floodwater in reservoirs or in the ground and solve our summer water supply problems
6. Floods in the UK are getting more and more frequent
7. It flooded last year, so it won't happen again for ages
8. If we had a better Met Office, we would be able to predict flood levels accurately
9. The scientists/Environment Agency got their forecasts completely wrong (again)

issued 155 severe flood warnings between December and February, compared with only seventeen in the equivalent period of 2012 when localised flooding was also experienced. The Thames tidal barrier, originally expected to be required only occasionally, needed to be shut some fifty times between December and March, accounting for 25 per cent of all the planned closures in its thirty year history. This not only prevented incoming water from the North Sea from surging up the Thames, but through management of water levels allowed some of the freshwater flow to escape downstream at low tide. Sadly, 7,000 properties in the middle Thames were nevertheless flooded, creating misery and economic damage, whilst the undermining of Brunel's iconic coastal railway line at Dawlish will feature in natural disaster images for some time.

Yet, the story is not all bad. In comparison with the extreme flood emergency of summer 2007 in central and southern England, a situation described by the Chief Constable of Gloucestershire, Dr Tim Brain, as the largest civil emergency since the Second World War, more property was protected. Sir Michael Pitt's subsequent national Review recorded that in 2007 a total of 55,000 homes were inundated from river and surface water flooding, some 30,000 of them in July alone. The Environment Agency are currently suggesting that in 2014, some 1.4 million properties would otherwise have succumbed if the flood defences of the last thirty years or so had not been built and maintained. The Agency also utilised new technologies to good effect- demountable barriers were deployed along the middle Severn.



▲ **Figure 1. Historical flood defence spending by the UK Government adjusted to 2012 values using the Bank of England Inflation calculator. (Figures reported to the the IES after a freedom of Information request.) *e = estimated **p = Predicted**

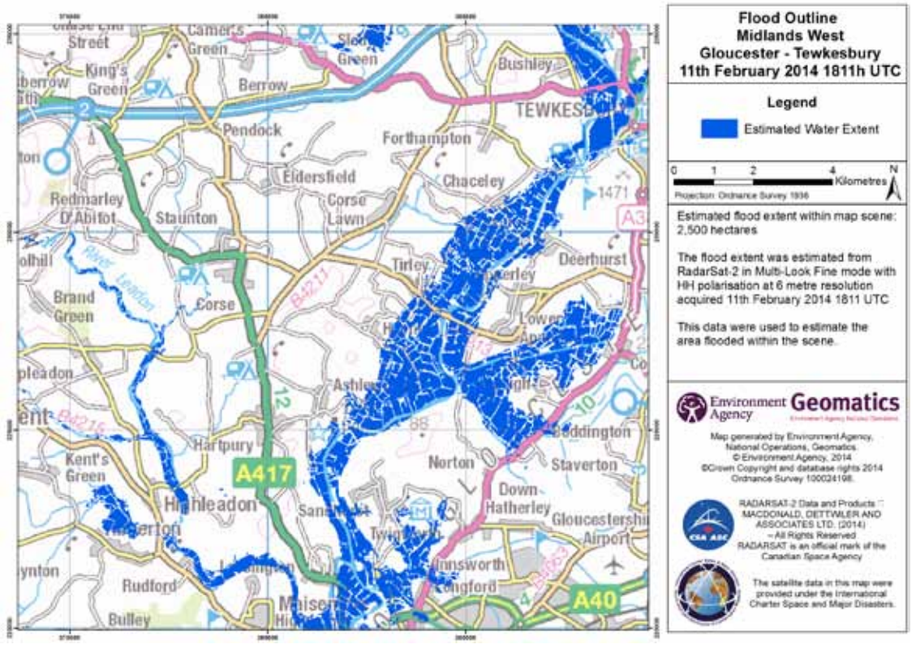


▲ **Figure 2. Estimated flooding extent for the Thames and its tributaries, February 2014. Image provided under the International Charter: Space and major disasters.**

Whilst substantial rural areas of the Somerset levels vanished under a seemingly inexorably rising lake, much of the Home Counties was saved from disaster. Even the younger members of the Royal family were spotted lending a hand in response to this genuine catastrophe. There were some innovative solutions, too. At Winchester, for example, massive bags of gravel were lowered from the M3 motorway to block the river, this single operation diverting water away from the historic areas of the town and from hundreds of vulnerable people. Social media platforms such as TwitterAlert were extensively used to provide advice to residents on actions to make their own houses more resilient. **Figure 1** shows how much money has historically been spent by government agencies in England.

The Environment Agency are currently suggesting that in 2014, some 1.4 million properties would otherwise have succumbed if the flood defences of the last thirty years had not been built and maintained.

The aftermath of the flooding prompted a culture of blame, with the causes of the inundation ascribed variously to the hand of God extracting retribution for the legalising of gay marriage (the UK Independence Party), the lack of dredging in the Tone and Parrett catchments in Somerset particularly under the last administration (Government Minister Eric Pickles), or the general failure of Local Authorities and planners to regulate floodplain development and the paving of front gardens. Environment Agency Chairman Lord Chris Smith found himself under attack for not visiting the Levels sufficiently speedily, and subsequently for not resigning his post. There were media debates about exactly what a 'flash flood' comprised, or whether a floodplain remained a floodplain if it had a degree of protection. And perhaps most worryingly, experts differed over whether this single event could be ascribed unambiguously to the impact of climate change, or perhaps provided a harbinger of worse things to come. Everyone had a view. **Figures 2 to 5** show the extent of the winter 2013/14 floods.



▲ **Figure 3. The estimatd extent of flooding near Tewkesbury in Gloucester, February 2014. Image provided under the International Charter: Space and major disasters**

Flooding of this sort illustrates all ten of the characteristics that the urban planners Rittel and Webber captured as 'wicked problems' in their seminal paper of 1973. Summarising, wicked problems are those that are poorly formulated and complex, with interconnected physical or scientific and human or sociological dimensions, where what happens in one place and time affects what happens somewhere else, at a different time. They involve many different stakeholders who do not agree about what is important, who use terminology in different ways and who cannot agree if and when the problem has been solved. Indeed in many ways, wicked problems, just like flooding, have no definable 'solutions', although some approaches (for example an intention to minimise the damage, or to increase community resilience) may be more desirable than others (for example, to do nothing in the face of increasing risk). In the last few years there has been an addition to the wicked problems family –'super-wicked problems' that display such additional characteristics as requiring urgent solutions, lacking

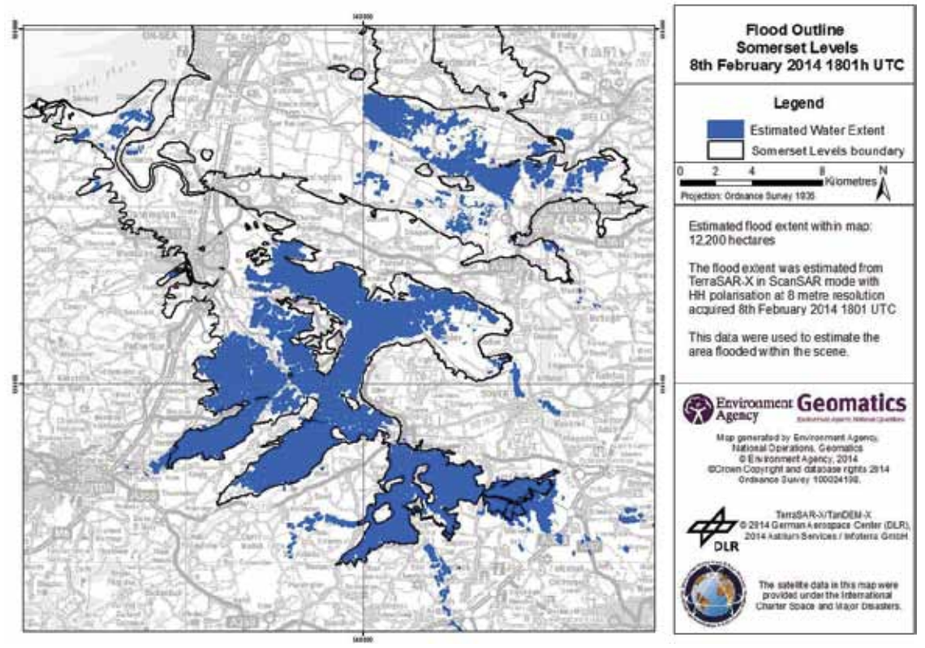
▲ **Figure 4. High floodwater at Tewkesbury Abbey. (© Chrispo)**

centralised authorities who can act unilaterally, where potential solution providers may also be creating the problem, and where the future implications of actions taken now are not considered rationally[1].

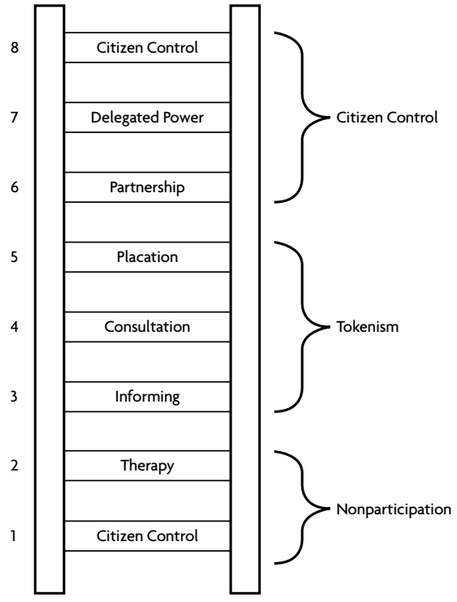
Rittel and Webber suggested that wicked problems were unlikely to be tamed by recourse to recognised authorities taking simple sequential steps, but rather than they need to be approached through dialogue and collaboration amongst the various stakeholders. For flooding in the UK, the set of people potentially involved is enormous, and growing in response to changes introduced since 2007 – from local authorities, central government, emergency rescue services, the Environment Agency (or Natural Resources Wales and other devolved administration agencies), the Highways Agency, power and water companies, engineering consultancies and the insurance sector, to local residents, business owners, farmers, community groups, lawyers, universities, social services, health authorities and charities. **Figure 1** shows how much money has historically been spent by government agencies in England.

European legislation mandates stakeholder engagement in matters such as flooding, and this is now represented in UK legislation as well. Communication between such groups, especially the process of 'consultation', is also challenging. Whereas previously 'consultation' might have been cursorily addressed through a meeting with local residents, in which an explanation of what was to happen would be given, today engagements have moved further up the 'ladder of citizen participation'[2] (See **Figure 6**), from being largely therapeutic or tokenistic, towards more genuine partnerships and citizen power. However, there remains the challenge of effective communication between collaborators with very different perspectives and experiences. On so many occasions, as witnessed by the mobs of angry residents, and the panicky exhortations of local politicians wearing too-new wellington boots, the lack of a common language is overwhelming.

Three examples of how these challenges are being investigated and addressed suggest how improvements might be made, and more open styles of innovation and collaboration fostered. The recently-concluded, EU-funded WaterDiss2.0 project examined and evaluated the modes of dissemination of findings used by researchers who had received European Framework 6 and 7 programme funding for water-related research. Hundreds of millions of Euros have been allocated to



▲ **Figure 5. Estimated flooding extent on the Somerset levels, February 2014. Image provided under the International Charter: Space and major disasters.**



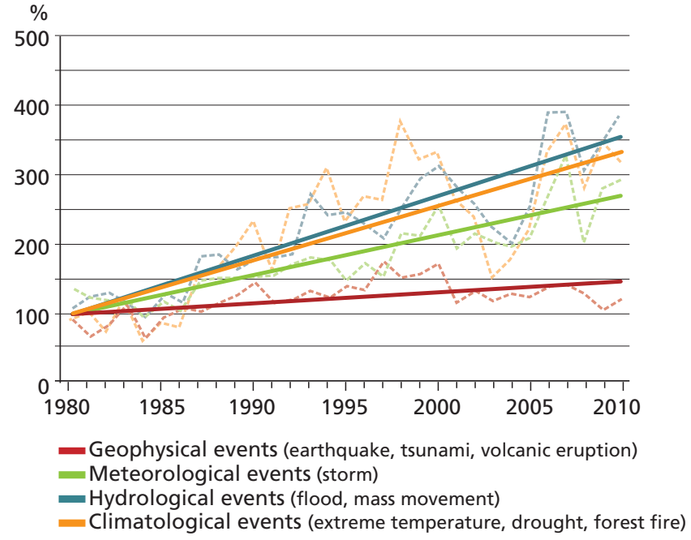
▲ **Figure 6. Arnstein's 'Ladder of citizen participation[2].**

multinational consortia of universities and research organisations, sometimes with input from the business community, over the last decade. After conducting interviews, questionnaires and wider explorations, it was apparent that particularly for FP6 projects, dissemination of results to policymakers and others was very much an afterthought. In the majority of cases, the first priority was publication in academic journals, and presentation at scientific conferences, both means of dissemination that are largely blocked to local, and even national, stakeholders. More recently, the plethora of websites associated with different projects, and the lack of a central repository of findings which might be consulted by policymakers and those in charge of allocating monies for further projects, have led to extreme inefficiency and some duplication of effort. Many findings remain locked in academic journals, and are not used to improve policy on flooding and other hydrological themes. This is clearly undesirable. The WaterDiss2.0 project established a website for research interactions, and concluded with a set of recommendations about knowledge exchange, specifically addressed to the EU Commission when they are considering applications for funding[3]. Beyond that, a lively debate about the relative merits of employing specialist scientific knowledge brokers was stimulated.

In the UK, the Natural Environment Research Council's Project FOSTER, established following the 2007 UK flooding, investigated dialogues between scientists and the local authorities. County Councils were in the process of acquiring greatly enhanced managerial roles under the provisions of the 'Flood and Water Management Act 2010', and it had become apparent in Gloucestershire's Scrutiny Inquiry following the catastrophe, that interchange of ideas was far from perfect. There were particular problems in conveying ideas around the probability of events, scientific uncertainty in modelling, and climate change. Local Councillors – whilst clearly being expert in community negotiations – frequently held strong beliefs about the mechanics of floods and the potential for their mitigation that were scientifically unfounded, whereas scientists had limited knowledge about the elements of their research that would be of most immediate benefit to society more widely. The project looked at the backgrounds and knowledge characteristics of scientists, elected Councillors and Council Officers, and evaluated a series of pilot training events in different formats, including lecture-type sessions and role play. The results showed that scientists could effect considerable improvements by communicating their research findings simply and effectively, in non-technical language, for example though video. Moreover, preconceptions about the likely abilities of (frequently) elderly Councillors to engage with innovative on-line material could easily be wrong. Their appetite for, and ability to learn from the use of virtual worlds such as SecondLife™ as platforms for collaboration amongst diverse and geographically-dispersed groups was particularly unexpected[4].

Finally, the UK Government, though its agency the Technology Strategy Board, has been addressing the challenges of engaging businesses with researchers, stimulating technological innovation by using the specialist services of Knowledge Transfer Networks. Until 2014, the Environmental Sustainability Knowledge Transfer Network (ESKTN) drew together businesses with technical challenges related to the water environment, and researchers with research capabilities or potential solutions, into focussed collaborations. Embryonic clusters were supported to identify, and apply for, sources of research and development funding. The recognition of the different roles of on-line services, and face-to-face engagements was arguably a particular source of strength; most of the participants argued that knowledge transfer is very much a 'contact sport'. A series of events and competitions for funding was held, for example, to develop new technical approaches to the design, deployment and retrofitting of Sustainable Drainage Systems (SuDS). From Spring 2014, ESKTN's 12,000 members were amalgamated with the other thirteen national Knowledge Transfer Networks, to engender greater cross-sectoral collaboration across disciplines such as nanotechnology, chemistry and built environment technologies, albeit with the same philosophy of promoting open innovation[5,6]. The greater critical mass is intended to stimulate greater innovation in what many observers have regarded as a traditionally conservative sector. **Figures 7** shows the global friends for loss - related ends including flooding. Given the projected trends, this will continue to be an issue for both the environment and economic considerations.

The context in which the management of flooding is taking place is constantly evolving, not least as a result of the window of opportunity afforded by recent disasters. The focus of the late twentieth century on flooding as a rather narrowly-defined 'environmental problem' has shifted towards regarding flood management as part of a drive towards sustainability, with its economic, social and cultural dimensions and an emphasis on community resilience and adaptation. The recognition of the impact of flooding on key infrastructure nodes for power, transport, ICT and water supplies, has also increased, and despite economic stringencies there are more effective collaborations. Partnership between stakeholders is hence now a more genuine aspiration, rather than the somewhat manipulative and instrumental approaches to dialogue of previous decades. The pressure to develop such collaborations has already manifest itself in Wales through the formation of the new agency Natural Resources Wales, with duties in relation to flooding sitting alongside far wider environmental responsibilities; it remains to be seen whether this approach to collaboration amongst some of the key agencies will spread across the UK. The need to reduce the increasing cost of flooding, and the numbers of people whose lives are disrupted and livelihoods destroyed, remains crucial. **ES**



▲ **Figure 7. Relative trends of loss-relevant world-wide natural extreme events by peril group 1980–2010. Figure adapted from EASAC 2012** *Extreme weather* **report.**

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Dammed if you do, damned if you don't

Mark Everard explores the complexities of using dams and related heavy engineering solutions to control and supply water.

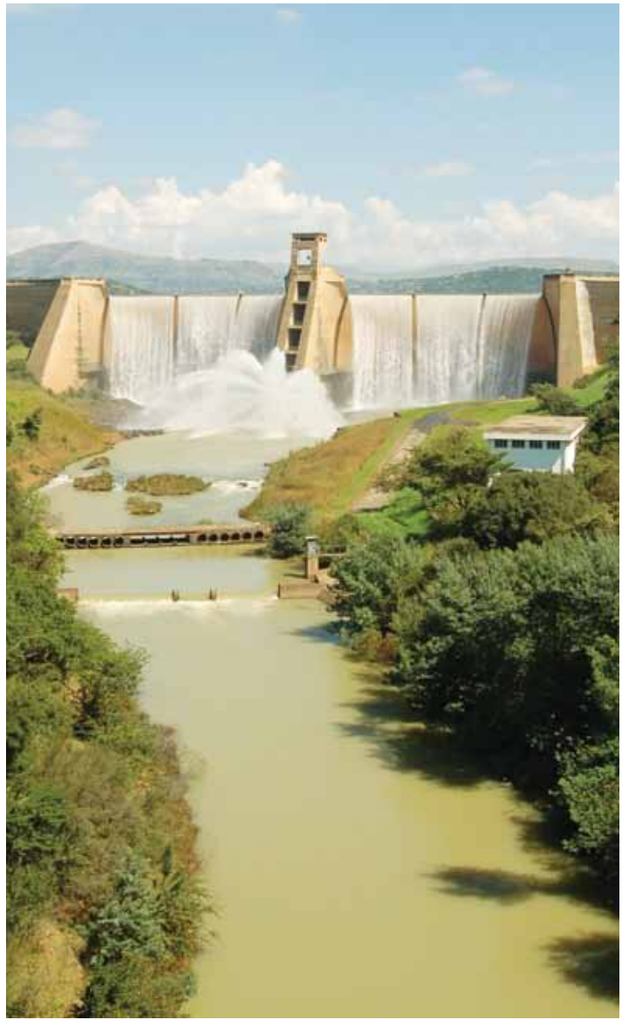
Humanity is ultimately buoyed by the water-yielding ecosystems with which we co-evolved. Control of water flows was central to the first recorded Mesopotamian civilisation 8,000 years ago, and has substantially shaped our cultural and economic evolution. Finite, yet inherently renewable, though under increasing competition, water and its management will also define much of our future.

Dams and related infrastructure are today amongst the planet's largest engineering schemes. Every day since 1900, the world has completed roughly one large dam (i.e. at least 15 m high or retaining a reservoir volume of at least 3 million m^3). The 1930s saw a new era of large dams, the first of these was the Hoover Dam in the USA, completed in 1935 and, at 221.4 m tall, still the second-highest dam in the USA. Global dam-building peaked in the 1970s, during which 7,511 large dams were completed, averaging two or three each day. Construction of large dams in China, Egypt, India, the USA and elsewhere became, in the eyes of many, synonymous with modernisation and economic progress.

Dam design varies with geography and geology, climate, population density and the decision-making process, offering a range of solutions for water supply, hydropower and sometimes flood attenuation and navigation. Today, schemes such as the Three Gorges Dam and other dams, forming part of massive infrastructure in China to redirect water northwards across almost the entire country, are re-plumbing whole sub-continents. These massive structures modify river ecosystems, including the interests of people dependent upon them, to a staggering extent.

DAMMED IF YOU DO...

Negative outcomes are still often overlooked in dam planning, and may not be audited following commissioning. Consequences include wholesale ecosystem disruption with impacts on wildlife such as migratory terrestrial and aquatic fauna and native fish stocks. Geomorphological disruption is substantial through the almost-complete trapping of sediment, with important implications for the structure and fertility of downstream habitats, grazing and cropland, whilst siltation shortens dam life and utility. Methane generation in deep tropical impoundments may outweigh much of the reported offsetting of climate-active emissions from hydropower production. Salinisation of cropland irrigated with water retained in dams is an increasing problem globally. Earthquakes can also be triggered during dam filling due to the dam's massive weight, and impounded water and the smoothing of downstream river flows enable the spread of diseases including schistosomiasis (bilharzia), malaria, Japanese encephalitis and Rift Valley fever.



▲ **Wagendrift Dam on Bushman's River in South Africa.**

Displacement of people from construction areas, flooded valleys and areas designated for compensatory wildlife habitat is another major impact. The marginalisation of people by development decisions advantageous to a politically and economically powerful minority is not new. Historic dam-induced displacement of people across the world accounts for 40–80 million people, who are mostly already marginalised. Life for displaced people remains harsh, with few compensated, particularly landless or tenant populations. Disruption is more than physical, as livelihoods and traditions are lost, and displaced people may come into conflict with inhabitants of relocation areas. These factors commonly contribute to a cycle of poverty and ill health.

One example of where the relatively few, and overstated, planned benefits of a dam were substantially offset by a wide range overlooked negative outcomes is the Pancheshwar Dam, planned on the Mahakali River on the India–Nepal border. A study of likely ecosystem service outcomes found major disparities in the distribution of benefits and negative consequences[2]. Many of these overlooked costs were likely to arise through impacts on the structure and functioning of the catchment ecosystem, and would be borne by a sizeable majority of less economically and politically advantaged people who were neither considered nor included in planning. Consideration of environmental and social consequences seemingly occurred in a cursory way, too late in the cycle to influence scheme design and decisions with their associated sunk costs, and no other options were contemplated or appraised. This calls into question the net value of the proposed Pancheshwar Dam to India, Nepal and beyond, the democratic legitimacy of decision-making, and therefore assurances to potential project funders.

Not all dams are designed without wider consideration. However, it would be disingenuous to suggest that engineering and flow interception on such a massive scale is anything short of a wholesale change in regime to catchment structure, function and socio-economic potential. Large-scale water management, with dams as just one option, therefore has to be assessed on this basis.

There is growing global awarness of the need for the need for a 'blue revolution'

BENEFITS WITH COSTS

The universal benefits once ascribed to dams are coming under increasing scrutiny. In 1997, the World Bank and the IUCN established the World Commission on Dams (WCD) to resolve contention around large dams, reassessing their potential future role. Following exhaustive studies, the WCD found that: (1) dams have contributed to human development; but (2) too frequently with unacceptable and unnecessary social, environmental and economic costs, (3) particularly due to inequities in distribution of benefits, so (4) there is a need for dialogue amongst affected parties, and (5) unfavourable projects could be eliminated at an early stage by considering alternatives[1]. 'Business as usual' is neither feasible nor desirable. The WCD proposed an approach to decision-making integrating social, environmental and economic dimensions with greater transparency.

THE SOFT PATH

Ecosystem-based management may be better suited to providing the kinds of distributed water services that people actually need across landscapes, from domestic consumption to watering cropped and grazing land.

Catchment production and storage can also add value to 'hard engineered' solutions, reducing maintenance inputs and extending asset life. Indeed, there is a renaissance in catchment management to improve the many, formerly undervalued, benefits of the natural processes that intercept, store and clean water. Pioneering initiatives such as SCaMP (Sustainable Catchment Management Programme) in north-west England and Upstream Thinking in south-west England use catchment management as a means of delivering water services to customers more cheaply, simultaneously producing a range of beneficial ecosystem services such as smoothing seasonal flow variations, improving flood risk, stabilising farm incomes through more favourable land management, and protecting biodiversity and fisheries. Recognition of the value of catchment services is beginning to reshape management across the world, augmented by methods such as rainwater harvesting,

▲ Temple on the sangam (meeting of rivers) at Pancheshwar.

interception of water from mist, and the protection or reinstatement of trees to provide these services as they often did before clear felling.

CO-BENEFITS

Water demand is also an important element of systemic management. Virtual water – water not consumed directly but is used to produce food, fibre and mined goods and for the production, processing, packaging and transport of products – is a substantially unrecognised facet of water demand. It takes a net 140 litres of water to produce a cup of coffee and a pair of blue jeans could account for 11,000 litres, whilst producing a steak in Texas may consume 15,000 litres of water. Virtual water in supply chains is economically advantageous to richer, often moister countries importing water-intense commodities from poorer, often drier nations. Trade may raise foreign revenue, yet unwittingly may export huge amounts of virtual water that could more valuably provide for domestic needs. This represents a form of 'hydro-colonialism', entrenching asymmetric exploitation of the resources of poorer nations.

Natural processes, particularly those of wetland systems, can also be harnessed to treat wastewater as well as attenuate peaks of floodwater, with a range of co-benefits including carbon sequestration, nutrient cycling, restoration of formerly lost landscapes and enhancement of wildlife, including stocks of fish of commercial and recreational importance.

Rather than seeing ecosystems only as requiring altruistic preservation through conservation measures, often perceived by economic interests as constraints on legitimate development, the shifting emphasis of the Ecosystem Approach recognises the multiple value that 'natural infrastructure' provides to people. This brings ecosystems into an economic context, with all interventions improving or undermining a range of benefits. From a systems perspective, a simple maximisation of a narrow subset of benefits, such as water storage for piped supply and hydropower generation, may impose net costs on society for services that are disregarded and often consequently degraded or lost.

There is growing global awareness of the need for a 'blue revolution', maximising societal value per drop of water, succeeding the post-Second World War 'green revolution' that increased food production per unit land area through substantially increased inputs, including of water. Consequently, there is a need to reframe rewards for land use and to view it not merely for the production of food and fibre, with often only token concerns for wildlife and ecosystem services, and instead reward a far wider range of the ecosystem services provided by landscapes, explicitly including 'farming for water'. Payments for ecosystem services (PES) is emerging rapidly across the world as a means to develop markets for formerly undervalued ecosystem services, including water, as in SCaMP and Upstream Thinking.

The logical extension is to recognise the full value of 'natural infrastructure', bringing the services provided by nature into the mainstream of decision-making and practice across policy areas. Progress is being made in developing hybrid 'hard' and 'soft' systems in urban areas under initiatives such as 'green infrastructure' and SuDS (sustainable drainage systems), multi-service integrated constructed wetlands (ICWs), and catchment management to add value to 'hard' water service, drainage and flood defence infrastructure. Indeed, there is a pressing need to make use of and to innovate more systemic solutions, defined as …low-input technologies using natural processes to optimise benefits across the spectrum of ecosystem services and their beneficiaries"[5], as a major step towards sustainability.

DAMNED IF YOU DON'T

It would be profoundly unhelpful to perpetuate an over-simplistic 'engineering bad, ecosystem good' contention. The inconvenient truth is that neither heavy engineering nor ecosystem-based management is a panacea in isolation. Imagine, for example, a city in which we had to depend on our back gardens for wells and disposal of liquid wastes, or how impossible it would be for 'heavy' water infrastructure to function without the benefits of nature's catchment infrastructure for intercepting, storing and cleaning water. If we want to maintain a high global human population, or indeed simply to survive it, we need to rise above an over-simplistic dichotomy.

FRAMEWORKS FOR DECISION-MAKING

Water governance may have been framed largely as a financial and technological challenge up to the 1980s. However, novel approaches, such as the Government's Catchment-based Approach[6], are turning to options for participatory decision-making about management options to achieve sustainable, multi-benefit outcomes addressing competing human demands. We are reaching tentatively for a new hydropolitics, integrating decentralised decision-making with the functions of local ecosystems and their services including the creative merger of 'hard' and 'soft' techniques.

The challenges facing us are as massive as they are pressing and unavoidable. Plenty of generic principles have been advanced to promote more sustainable and integrated management of land and water systems including the WCD's strategic priorities, the Dublin Principles of integrated water resources management, the ecosystem approach, and principles promoted by TEEB (the economics of ecosystems and biodiversity). Whilst a limited set of key principles is helpful for communication, an extended set is more helpful as a workable route map through water management decisions. I presented an extended decision-making flow in a discussion paper for the 6th World Water Forum in Marseille in March 2013, refined in my book *The Hydropolitics of Dams: Engineering or Ecosystems?*[7].

The simple fact remains that we have to learn to share water within the natural carrying capacity of catchment ecosystems, to value the services of 'natural infrastructure', and to both protect and emulate it in a creative merger of 'hard' and 'soft' techniques that can meet our needs on the most sustainable basis. There is no room for contention about that in an ever-more populated, water-stressed and climate-challenged world.

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Who's afraid of waste incineration?

Roger Barrowcliffe explores fears around the health effects of emissions and the mistrust of those responsible for regulating these emissions.

The burning of waste as means of disposal is a very old activity – people have probably been burning waste in an uncontrolled fashion for thousands of years. In the UK, the systematic introduction of incineration as a means of municipal waste disposal occurred in the latter part of the 19th century, prompted by the Public Health Act of 1875 and the need to find an alternative to the traditional rubbish tip on the edge of towns, in the face of pressures from strong population growth and urbanisation.

In the 1870s, the first operational incinerators began to appear. One of the more successful first attempts was a 'destructor' engineered by Manlove, Alliott and Fryer of Nottingham and operated by the Manchester Corporation from 1877. By 1912, there were 338 such refuse incinerators in Britain, 80 of which also generated electricity for local use. In comparison with the local rubbish tip, with its flies and rats, this probably seemed like a clean and tidy alternative. In reality, these 'destructors' were very primitive and responsible for causing local air pollution and nuisance to residents.

The incinerator at Torquay was the subject of an extensive investigation, as recorded in several issues of *The Lancet* in 1902. This incinerator began operation in 1898, but provoked numerous complaints that its very visible emission was causing health effects in the form of irritation of the throat, nausea, headaches and other symptoms. The intermittent operation of the incinerator and its poor location in a valley probably contributed to the problems reported. At many other locations, these 'destructors' may not have stood out as particular offenders in this period, in comparison with the multiple

forms of air pollution of that time, not least coal burning. Through the 20th century, municipal waste incineration declined as a means of disposal, as landfill became the dominant route. In 1993, there were 30 municipal waste incinerators operating in the UK, treating 20 Mt annually (seven per cent of the national total). At the same time, there were four private-sector hazardous waste incinerators in operation and approximately 200 other incineration facilities regulated by Her Majesty's Inspectorate of Pollution (HMIP). In addition, there were 700 to 800 small clinical waste incinerators operating in hospitals.

This was an important period in the development of waste incineration. Until this point, the use of incineration for waste disposal in the UK had not been the subject of regulation and pollution control, other than through the general dark smoke provisions for combustion processes. This changed sharply with specific legislation on limits to atmospheric emission introduced by European Commission directives on existing (89/369/EEC) and new plant (89/429/EEC). A directive was also introduced for hazardous waste incineration plant (94/67/EC).

EMISSION CONTROLS

In a parallel development, incineration was brought under the regulatory control of HMIP in 1989, requiring emissions to be minimised and best available techniques not entailing excessive cost (BATNEEC) to be applied as part of integrated pollution control under Part 1 of the 1990 Environment Act. A century or so after incineration was first used to dispose of municipal waste, some measure of environmental control began to be exerted. Many plants operational in the early 1990s had to be shut down as they could not meet the requirements of the new EU legislation. In their place, however, and in response to the growing disincentives for landfill, many waste planning authorities were contemplating waste incineration with energy recovery (energy from waste, EfW) as a means of treatment and disposal for municipal waste and the technology was on the rise once more, a century after it first appeared.


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INCENDIARY SITUATION

Outrage at latest bid to place an incinerator next to nature reserve

by LEANNE FENDER

Up in smoke: A wood incinerator is proposed for the site next to Beddington Farmlands

The increasing numbers of proposals for new waste incinerators were not universally welcomed. The established environmental pressure groups, such as Friends of the Earth and Greenpeace, were opposed to waste incineration and the prior history of waste incineration did not help the image of the industry in the eyes of some members of the public. This antipathy to waste incineration has not diminished with either the increased number of new facilities or the vastly improved regulatory requirements. In the last 20 years, the legislative and regulatory pressure has increased to the point where waste incineration is arguably the most strictly controlled of all industrial activities for emissions to atmosphere. The current Directive (first introduced as 2000/76/EC) imposes very strict limit values on the pollutants of greatest concern. The Environment Agency in England has a thorough process for assessing applications for an Environmental Permit and always

ensures such applications are diligently scrutinised. None of this structure appears to satisfy many objectors in local host communities, or national campaign groups such as UK Without Incineration Network (UKWIN).

This article examines why it is that some of the public harbour reservations about the safety of incineration with respect to human health, and considers the evidence for this scepticism. There are many other points of debate about waste incineration (with energy recovery), such as its effect on recycling rates, but these implications are not addressed here.

PUBLIC CONCERNS

Perhaps we should not be surprised that burning waste arouses fear and anxiety amongst some people. It is, after all, a matter of common experience that setting fire to waste products tends to produce noxious fumes. Municipal waste may originate from our own homes, but once we leave it at the edge of our properties for collection it becomes something very undesirable when mingled with waste from elsewhere. It is easy to imagine that, when burnt, the emissions are toxic.

Experts in risk communication know that waste incineration fulfils many of the criteria that are described as 'fright factors' or tend to provoke 'outrage'. A recent World Health Organization report[1] describes these as being triggered if risks are perceived to be:

- involuntary rather than voluntary (such as from personal smoking);
- inequitably distributed;
- inescapable;
- from unfamiliar sources;
- a cause of hidden and irreversible damage;
- a cause of particular danger to small or unborn children;
- a cause of death or illness;
- poorly understood by science; or
- subject to contradictory statements from reputable sources.

These can also be summarised very simply as the 12 principal components of outrage[2].

▼ **Table 1. The principal components of outrage.**

Safe	Risky
Voluntary	Coerced
Natural	Industrial
Familiar	Exotic
Not memorable	Memorable
Not dreaded	Dreaded
Chronic	Catastrophic
Knowable	Unknowable
Individually controlled	Controlled by others
Fair	Unfair
Morally irrelevant	Morally relevant
Trustworthy sources	Untrustworthy sources
Responsive process	Unresponsive process

Another important factor is the mistrust and suspicion felt by people in host communities, not helped by the erosion of trust in regulatory agencies to monitor and control facilities in line with the legislation. Neither are private companies trusted to manage operations effectively. In most development proposals I have worked on, many members of the community have expressed reservations about the Environment Agency's abilities, either because of a belief in its alliance with industry or because of a lack of resources.

The apparent exclusion of the public from decisions about the siting of waste treatment facilities in the locality or in shaping the policies relating to waste management is also a contributory factor that antagonises sections of the community affected. Waste planning authorities publish and consult on their plans and mostly go to great lengths to inform the public about these plans, but it is typically the case that many people do not pay attention to the plan and its implications until a development proposal for an incinerator is made on their doorstep. Until this happens, significant engagement is not generally feasible because of the lack of interest.

Given these ingredients, therefore, it is understandable that there will be people who are afraid of waste incineration because of its perceived effects on health. The question is, are these fears justified?

THE EVIDENCE FOR HEALTH EFFECTS

Most of the literature readily available to the public on the health effects or risks associated with waste incineration tends to be from the perspective of people opposed to the practice. A search of the worldwide web is likely to feature publications by Friends of the Earth and the British Society for Ecological Medicine (BSEM) at the top of the list. The Wikipedia page on incineration appears to have been edited by opponents of incineration more strongly than by proponents. For example, the Scottish Environmental Protection Agency's rather sober statement on the subject of waste incineration and health effects is cited as an argument against it and the (former) Health Protection Agency's statement is said to be a "lesser summary" and criticised by "many toxicologists".

The presence of this literature by organisations with an active interest in opposing waste incineration tends to obscure the very large body of scientific literature on the subject of health effects. There are probably over 700 such scientific publications, encompassing a wide spectrum of conclusions. It is no surprise, therefore, that this array of evidence can be selectively presented to support one point of view. It is in the nature of science that it does not bring certainty, only evidence that may be supported by evidence from other studies to form a consensus view. One thing this subject does not lack is a large body of evidence. Unfortunately, the evidence is open to interpretation and is often the subject of wilful misinterpretation.

A prime offender in this regard is the aforementioned BSEM report[3]. Superficially, and probably to many members of the public reading the report, it appears to be written in a scientific tone and it appears to be authoritative. In fact, it is very non-scientific and highly selective in its interpretation of the scientific literature. It would never survive a proper peer review process for publication in a reputable journal. Most of all, it confuses 'hazard' and 'risk', a common feature of the work of opponents of incineration. A critical response to this document was published by the Health Protection Agency (now part of Public Health England), and Health Protection Scotland was not persuaded either of its objectivity or the basis for its conclusions[4]. The BSEM is an organisation whose membership is open to medical practitioners who support the Society's aims of promoting "the study and good practice of allergy, environmental and nutritional medicine". Perhaps the most telling fact about the BSEM is that it has been, and still is, a strong supporter of Dr Andrew Wakefield, the author of the now infamous 1998 paper in *The Lancet* purporting to show a link between autism and the MMR vaccine for young children. This work is now widely discredited and thought to be a major factor in parents opting out of the vaccination programme, with subsequent outbreaks of measles.

Despite the weak credentials of the BSEM in this subject, its lack of rigour and peer review, I know from personal experience that some people in host communities for proposed waste incinerators are more persuaded of the merits of this report than they are of the Environment Agency or Public Health England's position. This relates to the point made earlier that there is a profound distrust of authorities and government. This distrust has grown over recent years and is now quite embedded. This debate currently lacks an honest broker – a person or organisation that cannot be depicted as supporting one side or the other.

CURRENT EVIDENCE

It is doubtful whether I could assume such a mantle, but I can offer a perspective on the scientific evidence as I see it. A great many research papers have appeared in scientific literature over several decades that attempt to examine the link between the presence of one or more waste incinerators and health effects in the local population. Epidemiology can be a powerful investigative tool and has greatly advanced our knowledge of the effects of

general and traffic-related air pollution on human health. To expect it to be able to identify health effects in a population from a single source is perhaps asking too much, however. Many authors have attempted to find associations with diseases that might be related to long-term exposure, since the many of the pollutants associated with health effects are persistent in the environment.

Polychlorinated dibenzo-*p*-dioxins, commonly called dioxins, have long been cited in this regard. Certain dioxin congeners of are highly toxic: they are known to cause serious health effects at high doses and are suspected of causing more subtle effects on the immune and reproductive systems at low doses over a long period of time, as well as being a suspected carcinogen. Cancers of almost any kind are a difficult health outcome to associate with emissions from a point source. Unfortunately, cancers are common and it is rarely possible to obtain information with the spatial resolution required to match with the dispersion pattern typically observed with a point source emission.


Welwyn Hatfield TIMES

www.whtimes24.co.uk Wednesday, January 30, 2013 70p

WIN a balloon flight for two p26

Joy at last in battle to stop incinerator

Government acts and now a public inquiry will decide

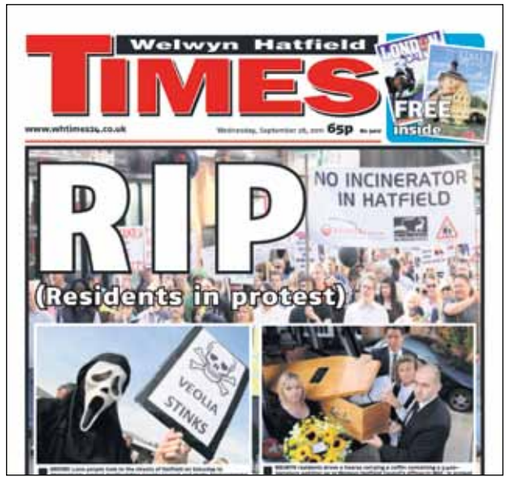
Daylight ramraid on bank page 9

WIN a Valentine's bouquet

Many authors have used residential proximity to the incinerator as a simple measure to relate its emissions to the incidence of certain diseases in the local population. As air quality scientists know, this is a poor proxy for the actual dispersion pattern of an emission from a chimney, which is influenced by the local wind climate and its predominant wind direction. In addition, the maximum impact is at some point downwind and not adjacent to the chimney. Some researchers have recognised this effect and have tried to use dispersion model estimates of the impact to be more sophisticated in seeking associations with the spatial incidence of diseases. The bigger problem, however, lies in the fact that the incidence of any disease or medical condition is not spatially uniform and is subject to a multitude of influences, not least socio-economic indicators. Epidemiologists make great efforts to remove confounding factors, but it is very hard to disentangle all the influences on health for a population.

A recent example of this relatively simple approach to linking industrial emissions to health effects can be found in the work of Garcia-Perez *et al*[5]. The authors conclude that:

"Our results support the hypothesis of a statistically significant higher risk, among men and women alike, of dying from all cancers in towns situated near incinerators and hazardous waste treatment plants and, specifically, a higher excess risk of in respect of tumours of the stomach, liver, pleura, kidney and ovary." (Garcia-Perez *et al*, 2012)[5]


Welwyn Hatfield TIMES

www.whtimes24.co.uk Wednesday, September 26, 2012 65p

FREE inside

RIP (Residents in protest)

NO INCINERATOR IN HATFIELD

VEOLIA STINKS

This sounds like a very straightforward and clear-cut conclusion. To a local group campaigning against an incinerator proposal, this is unequivocal material. To a scientist looking at the paper more closely, several doubts about the solidity of this conclusion arise. The study considered the possible effect of over 100 different types of industrial installation across Spain in the period 1995–2007. Fourteen of these installations were incinerators of an unspecified size, type and age. Closer inspection of the results shows that only three of these 14 incinerators were associated with any statistically significant risk for cancers. There are major differences between the associations observed for men and women: increased incidence of bone cancer is reported for men, and increased incidence of liver, brain and thyroid cancers were significant in women. Other potential deficiencies are apparent in this study that I will not describe in detail here, not least the difficulty with identifying a genuine control population for comparison.

Instead, it is perhaps more instructive to point to another very similar study by Reeve *et al*[6]. This epidemiological


▲ Viridor Lakeside incineration plant.

study examined the relative risk of the incidence of various specific cancers, all-cause mortality and infant mortality in five areas of England where incinerators processing 150,000 tonnes per annum or more were operational in the period 1998–2008. Five matched control areas were identified and socio-economic confounding accounted for by using the indices of Multiple Deprivation. The authors conclude that "there is no evidence of elevated risk of cancer or mortality in the vicinity of large industrial incinerators in England". (Reeve *et al*, 2013)[6].

A definitive and opposite conclusion to that reached by Garcia-Perez *et al*. Personally, I find the Reeve *et al* study to be the better designed of the two, but I can also see that there is scope for scientific debate on this point, as some of the on-line comments on the Reeve *et al* paper on *BMJ Open* illustrate.

A much better approach to investigating the effect of an incinerator on the local environment and its implications for human health is through the use of biomonitoring. In these studies, samples of blood serum in an at-risk population and a control population are analysed for a marker substance and compared. Typically, certain dioxin congeners and polychlorinated biphenyls (PCBs) are used for this purpose, as they are identified as being products of incineration. They are also persistent in the environment and bioaccumulative in human body fat over a lifetime from long term exposure to a wide variety of sources. Their presence in elevated concentrations denotes long-term releases over many years. An example of this type of study was reported by De Felip *et al*[7], which found no difference in the presence of indicator dioxin congeners in two populations in Italy.

The majority of similar studies, as carried out in France, Portugal and Spain for example, have reached similar conclusions. These findings are not so surprising, in that one would expect any accumulation of dioxins to arise from eating contaminated food, rather than through inhalation. Diet is a much more significant source of dioxins and most people do not eat locally sourced food. When the complete literature is examined, it is possible to conclude that there is some evidence of the very old incinerators being responsible for contaminating the local environment with certain metals and persistent organic pollutants, such as dioxins.

Prior to the introduction of legislation limiting emissions, a typical waste incinerator was emitting quantities of dioxins and furans several orders of magnitude greater than is permitted today. A typical EfW plant currently emits less than 10 mg of dioxins annually. Nationally, the total dioxin and furan emissions (excluding accidental fires) is estimated to be 178 g expressed as a toxic equivalent. In 1990, the national total was 1038 g[8], approximately half of which was attributed to waste incineration of various kinds. The contribution from this sector has plummeted as a consequence of regulation and

better control technology. Amounts of metals released have also been sharply reduced.

PARTICULATE MATTER

Campaign groups opposed to incineration recognise that the emission of dioxins is no longer as strong an issue as it once was and generally choose not to lead with it as an argument when opposing individual development proposals. The attention has now turned to particulate matter. In the wider world of air quality, the association between exposure to $PM_{2.5}$ or smaller size fractions and premature mortality is well known and there is a realistic basis for believing that there is causation for the observed association. It seems logical to many people therefore to assume that waste incineration will be a significant source of particles and a cause of further mortality.

In fact, a modern EfW plant with fabric filters emits relatively little particulate matter and especially so in the ultrafine fraction, which is sometimes thought to be the most damaging to health. This seems counter-intuitive to most people: how can a filter prevent particles of less than 100 nm in diameter escaping to the atmosphere? The answer lies in the mechanisms that filtration exerts on particles passing through the filter medium. Three of these (impaction, interception and gravitation) are highly effective for particles of 1 µm and greater in diameter. For particles of 100 nm and smaller in diameter, the diffusion process is almost 100 per cent effective. It also helps to be reminded that the filter medium is not a thin membrane full of holes (analogous to chicken wire mesh with marbles flying through it), but instead a deep tangled mass of fibres that are individually much thicker than the ultrafine particles. On a human scale, it would be equivalent to attempting to run blindfold for a kilometre through dense forest without colliding with a tree. That is the theory, but measurement also confirms this is true. A series of papers by Buonanno *et al* on EfW plant in Italy shows conclusively that the particle number concentration at the point of emission is not substantially greater than that found indoors or in rural atmospheres. The concentrations are far below those observed next to heavily trafficked roads, for example. The conclusion from this work is that a fabric filter is 99.99 per cent efficient at removing ultrafine particles[9].

Unfortunately, this clear evidence from the scientific literature seems to be ignored by many opponents of incineration and much needless anxiety is communicated to host communities about the potential health effects. Clearly, there is some impact on local air quality and therefore some non-zero health effects from exposure to particles. From what we know of the relationship between long-term exposure to $PM_{2.5}$ and mortality, a reasonable estimate for the loss of life years on a per person basis for the exposed local population of some tens of thousands (or hundreds of thousands in a large city such as London) is measured in minutes, possibly up to an hour, depending on the size and location of an individual EfW plant. To health professionals, this is an insignificant effect. It is also far below the effects claimed by some campaigners. Of course, on a national basis, these small effects are additive and the aggregate value for the whole population appears to be a large number – 199 years for England through exposure to the particulate matter emitted, according to Forastiere *et al*[10]. This total must, however, be compared with the alternative means of waste disposal and also the very much larger effect of many other sources of particulate matter, not least road transport.

▲ **Proposed Veolia incineration plant at New Barnfield in Hertfordshire.**

DISCUSSION

Just how contentious should the practice of waste incineration be with regard to human health effects? The scientific evidence, it seems to me, is quite clear on this point. Whilst the very old, pre-1990 incinerators may have been responsible for some long-term contamination of the surrounding area, with possible consequent long-term health effects, any *credible* evidence for current EfW plants being responsible for *significant* or *detectable* health effects is non-existent. Their contribution to local air quality impacts is very minor and they are not major sources of any particular pollutant, be it dioxins or fine particles. As a combustion source, they contribute to NOx concentrations, but not in a substantial manner compared to many industries that operate with less stringent standards, or indeed the many small-scale combustion sources that are unregulated and unabated.

No proposed development of this kind has been refused planning consent on the grounds of its chimney emissions and effects on human health and nor has any application for an environmental permit been refused by the Environment Agency on these grounds. Many planning applications are decided at public inquiries, but the points of contention that planning inspectors take seriously are usually related to issues such as waste planning policy, site selection and visual impact. This does not prevent people objecting on grounds of air quality and health for the reasons outlined above; the abundance of literature purporting to demonstrate a serious effect and the mistrust of authorities responsible for regulating the plant effectively will always ensure this reaction.

I know from the personal experience of speaking with residents at community liaison group meetings, public meetings, public exhibitions and other engagement fora that many people are unpersuaded by the science or do not understand it. Over the last two years, I have witnessed the reaction to a proposal for an EfW plant in my own local community and it has been fascinating to observe how a vocal minority of residents is convinced that the air pollution will be severe and how adverse health effects are certain. From their point of view it is a simple proposition: a great deal of waste is being burnt, the facility will have large chimney and toxic pollution will be inflicted on the locality from which there will be no escape. Many of the 'outrage' factors referred to earlier are triggered. Oddly, such objectors never have the same response to the existing air pollution they face daily (and are partly responsible for if they are vehicle drivers) or the pollutants they are exposed to in mundane situations, such as their own kitchens. These are seen as benign environments in comparison. In their minds, the EfW plant is a huge, new source of pollution and an unwanted imposition.

LOOKING AHEAD

There is no obvious solution to this particular problem. So long as there are some individuals who believe passionately that incineration is a risk to human health there will be a wealth of material available via the internet to influence those who may be undecided and provide a source of doubt. Ultimately, this makes little difference to the number of operating EfW plants in the UK, although it does cause anxiety in host communities that could be avoided. Perhaps it is an issue that will fade because the number of new, large-scale proposals is set to decline. Fewer opportunities exist in relation to new long-term municipal waste contracts as more authorities have implemented waste management solutions that switch treatment from landfill.

There is little evidence that host communities are so afraid of EfW plant once it is built and has been operating – it seems that only new proposals are contentious. More could be made of this and the waste management industry might usefully sponsor some well-designed sociological research into the pre- and post-development attitudes amongst members of the host community. The experience of real people living with EfW plant is likely to more compelling than the science relating to emissions and health. The highly respected Small Area Health Statistics Unit of Imperial College has been contracted by Public Health England to investigate the incidence of infant mortality around operational incinerators and will report in 2015. Should this report conclude that there is no statistically significant risk, it will doubtless still not satisfy or convince the opponents of incineration. With this contentious issue, as with some others, it is hard to prove *conclusively* that there is *no* effect. ES

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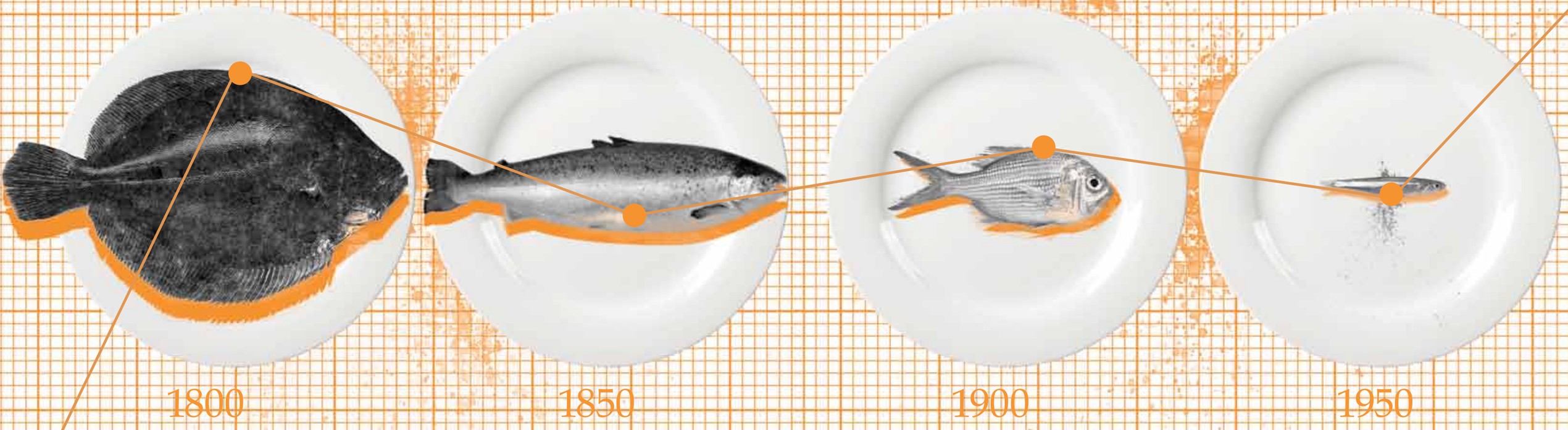

Explaining controversial issues to the media and the public

Bob Ward investigates how scientists can communicate results without creating undue controversy.

Scientists often have to explain issues that are controversial, usually because of disagreement over the methods, results or implications of research. Controversy can often arise when there are implications for human health or the environment, and the consequences can be significant if they change people's behaviour suddenly, for example in response to a new risk.

THE PITFALLS OF CONTROVERSY

Several pitfalls can prevent the public or journalists from gaining a clear understanding of a controversial issue. They may receive conflicting accounts of the interpretation or significance of research findings, and find it difficult to weigh up the evidence. Or they may find that a scholarly disagreement has become a polarised debate, preventing them from assessing what is controversial.

In many cases, scientists can make it more difficult for the public or journalists to understand an issue clearly. They may speculate casually about the implications of preliminary findings that have not been fully examined. They may use jargon that proves impenetrable to the layperson. Or they may convey information about risks and safety in a way that is open to misunderstanding.

But with proper preparation and practice, scientists can avoid the pitfalls and help the public and media to properly understand controversial issues.

The first and most important step is to recognise in advance what will interest the public or journalists. This can be done best by placing yourself in their shoes and considering what questions they may have.

For instance, if the research involves animal or human subjects, will they ask about the methods used? If so, can you explain in lay terms why such methods were necessary? Will they ask about previous work that came up with different findings? Can you explain why the results are different?

Very often your audience will be more interested in the implications of your research than the research itself. As these may not always be obvious, you can seek advice from other specialists, such as regulators, who have experience in considering, interpreting and communicating the significance of the work.

Although the implications may not be purely scientific, it is better to show an awareness of them rather than to plead ignorance, even if you do not feel qualified to offer a definitive view. Few people are reassured by scientists who do not seem to appreciate the wider significance of their work, particularly if ethics are involved. If you have not previously thought about the implications, it is better to admit it than to speculate on the spot.

A CLEAR UNDERSTANDING

Once you have recognised that an issue may be controversial, you need to practice how to talk about it to journalists and the public. This means describing the issue in clear, non-technical language. Never overestimate journalists' knowledge, but be careful not to underestimate their intelligence. Do not patronise them.

Ultimately, you are seeking to leave your audience with a clear understanding, neither exaggerating nor underplaying the controversy that surrounds the issue. You should be willing to acknowledge conflicts and to explain clearly why they exist, even if your own views put you firmly on one side of an argument. A journalist who senses that a scientist is not being completely honest about a controversy will usually be encouraged to dig further, and may go to others who might have vested interests in provoking a dispute.

Scientists can sometimes be caught out by potential conflicts of interest, which cause additional controversy if they are not openly declared. Think about whether the source of research funding may imply a competing interest, for instance if there is sponsorship by a company that manufactures the compound whose safety is the subject of the research. If so, it is better to be upfront and acknowledge its existence and explain whether it is likely to have had an influence on the outcome of the work.

▼ **Table 1. Example of a risk assessment framework.**

Likelihood	**Consequences**				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Certain >90% chance	High	High	Extreme	Extreme	Extreme
Likely 50 90% chance	Moderate	High	High	Extreme	Extreme
Moderate 10 50% chance	Low	Moderate	High	Extreme	Extreme
Unlikely 3 10% chance	Low	Low	Moderate	High	Extreme
Rare <3% chance	Low	Low	Moderate	High	High

You may also be asked to comment on the motivations of individuals who are involved in a controversial issue, because these can add 'colour' to a story. Be careful not to cause offence, and do not speculate.

In many cases, opposing views in a controversy are honestly held, and the protagonists and their supporters will hardly welcome comments that cast doubt on their integrity, for instance by suggesting they have an ulterior motive for their views.

DEALING WITH RISK AND UNCERTAINTY

Sometimes scientists unwilling to commit themselves on questions about safety and risk unintentionally generate a controversy. If you are asked whether something is safe, and you are in a position to assess the risks, you could try to quantify them rather than give a straight yes or no (see **Table 1**). You could also say that you are not in a position to assess risks, but you should then suggest somebody else who might be able to offer guidance.

Controversy can also arise if a scientist's work shows that the risks have changed. Be careful to distinguish between a relative change in risk and absolute risks. For instance, if you have found that a disease's risk has increased from one in 10 million to one in five million, you could say it has doubled, which might catch the attention of the media and the public. But you could provoke undue concern if you do not also give the absolute risk. Try to anticipate how a layperson might react to how the risk is expressed.

Risks and other findings can be even more challenging to explain if they are uncertain. It helps to distinguish between uncertainty that is inherent, for instance because it involves a forecast about a complicated phenomenon such as the weather, and that which may be temporary, for instance because current knowledge is incomplete.

Remember that some degree of uncertainty exists in almost every area of science. Be prepared to explain how significant the evidence is and make sure you recognise when other scientists might credibly offer different interpretations of it.

Make a clear distinction between evidence and the conclusions drawn from it. Even when the evidence is inconclusive, you should indicate where the weight of evidence and opinion lies, although there is a chance that a minority view may ultimately be proved correct.

Above all, be open and honest about controversial issues. It is important to recognise your audience's interests and motivations, and why they may be drawn to a particular controversy. Remember also that journalists aim not just to inform and educate, but also to entertain readers.

PRACTICE MAKES PERFECT

The task of communicating with the public and journalists can be made easier through practice and training. You can seek the advice of a press officer or other communications professional. But if you rely on them to explain an issue on your behalf, perhaps in a press release, check they are expressing it in a way that is not inaccurate or misleading.

Most universities and funding bodies also offer courses on how to speak to journalists and the public. As with any other skill, your success will increase the more you do it, particularly if you seek constructive criticism from others about your style and approach. ES

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www.scidev.net/global/communication/practical-guide/explaining-controversial-issues-to-the-media-and-t.html

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Beyond contention

Mark Everard makes the case for extending our horizons with systems thinking, as a way to understand and deal with contentious issues.

I have lost count of the radio interviews I have heard making the positive case for fracking (hydraulic fracturing), and the smaller proportion making the negative case. I still wait to hear a truly balanced case.

TWO SIDES TO THE ARGUMENT

The case for fracking is as compelling as it is passionately argued. Liberating all this shale gas will reduce energy costs, as is the case in the USA (allowing them to export cheap coal to Europe and Asia so that we can emit the carbon instead). It will increase energy self-sufficiency, freeing us from the vagaries of foreign markets and troubled regimes. It raises prospects of employment. Environmental credentials claimed for fracking circulate primarily around gas having a lower carbon footprint than coal-fired energy production. (Bizarrely, I have also heard the fundamentally wrong claim that shale gas is not a fossil fuel!)

The case against fracking is equally diverse and passionately argued. The water demand for hydraulic fracturing is substantial, often injected into strata underlying areas already subject to water stress. Chemical additives to that water are significant in terms of volume and environmental concern, and their fate, once injected, is substantially unknown and certainly uncontained. And of course shale gas is a fossil fuel, liberating into the atmosphere stores of carbon and co-pollutants until then locked away by physical, chemical and biological processes throughout billions of years by processes that have progressively 'cleansed' the biosphere.

As we unlock this sequestered carbon, we simultaneously lock investment into the perpetuation of fossil fuel dependence, inhibiting progress towards renewable energy generation. The ecological impacts of fracking remain substantially unknown. Implications for geological stability, including triggering earthquakes and disrupting aquifers, give further cause for concern. Add to this 'planning blight' near sites earmarked for fracking. The only certainty seems to be perpetuation of dependence on fossil fuels despite international commitments to phase them out, with a raft of uncertainties not about the likelihood but about the magnitude of consequences.

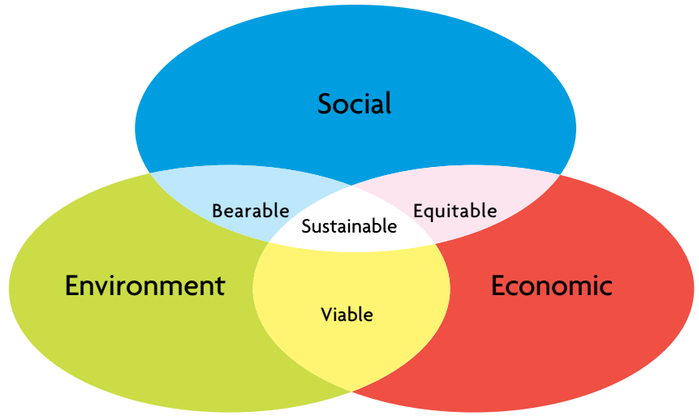
Both the pro and the anti cases have merit but which, if either, is right?

FRACTURING THE BIGGER PICTURE

Current UK decisions relating to hydraulic fracturing appear regrettably as fractured as the rock strata they perturb. Like many decisions made on the basis of a largely unreconstructed 'growth agenda', legitimised as an austerity measure, the tax breaks for operators and financial inducements to consenting local authorities favour only a narrow fragment of the wider picture.

And it is not just fracking. The world is full of divisive issues – from badger culling to the surrender of the Green Belt, HS2, road widening and new road schemes, additional runway capacity, the attempted sell-off of the UK's forest resource, major dam schemes around the world, and so on – in which the short-term business case drowns out all dissenting voices. The paradigm of the Industrial Revolution, converting resources to products for economic gain with scant or no regard for externalities, remains not only deeply rooted but also seemingly resurgent in economic and governance systems and the many vested interests deriving short-term gain from them.

And this notwithstanding international commitments (the Brundtland Commission, the Convention on Biological Diversity, Biodiversity 2020, etc.) and national intention (the 2011 Natural Environment White Paper *The Natural Choice*) to take a systems view when making decisions. Our commitments to sustainable development explicitly commit us to integrating economic, social and environmental development into a sustainable whole. Yet all too often, trade-offs still rule as we rather depressingly keep hearing about 'sustainable' decisions that permit ecological loss as it is offset by gains to economic activity and (narrowly defined financial) social wellbeing. Let us be absolutely clear about the fact that this is *not* sustainable development: it is a non-systemic trade-off of important, often irreplaceable, natural capacity for narrow gain.



▲ **Figure 1. The triple bottom line of sustainable development.**

TIME TO STOP PICKING CHERRIES

So the good news is that we have developed and committed to a range of systemic frameworks, if the harsh reality is that most are not used in a systemic way.

The ecosystem services framework categorises the multiple, interconnected benefits that the natural world provides to humanity. However, many commercial applications, implementations of regulations and interpretations in the literature focus on just one or a few focal services, omitting to consider the ramifications for the wider system of intimately interlinked services and their beneficiaries. For example, farming systems, locally and globally, still continue to be rewarded for maximising outputs of food and fibre with only token regard and subsidies for wider consequences such as soil erosion, habitat loss, carbon mobilisation, eutrophication, and hydrological and landscape change. The economic reward system is fundamentally flawed as it does not remunerate or penalise all of the linked consequences of land management. The regulatory system is as weakly enforced as it is inadequately targeted, since political preoccupation favours cheap food regardless of the long-term costs.

I am not finger-pointing just at farming here. The same analysis of narrow rewards for exploitation of one service, or a small subset of services, could be applied to quarrying, marine fisheries, aquaculture systems, primary resource supply chains and many other societal activities. This highlights fragmented governance that fails to recognise the systemic context, illustrated by fracking, in which benefits for energy costs, employment and energy security trump all other concerns.

It is not that we are lacking insightful systems tools to guide us. We have the ecosystem approach, which established 12 "complementary and interlinked"

principles for implementing the ecosystem services framework in geographical and socio-economic contexts. The Five Capitals Model is another systems model, for example used by Wessex Water to structure its 25-year plan to become a sustainable water and sewerage business. The STEEP (social, technological, environmental, economic and political) framework has effectively been used as a systemic framework for integrated management. The Natural Step (TNS) Framework has proven of substantial strategic value to various business sectors as a systemic basis for planning progress towards sustainability. Methods such as integrated water resources management (IWRM) also embody systemic principles, as do the principles of the Ramsar Convention.

The problem is rather that we tend to treat systems tools unsystemically, 'cherry picking' a few favoured bits and pieces, imagining that using systems language is sufficient to do a systemic job. A catchment management strategy that omits to take account of the diversity of forms of knowledge and value systems of all who share the resource may prejudice the interests of key stakeholders. This is often writ large in analyses of large dam and water transfer developments, and can also inhibit acceptance of catchment plans perceived as imposing unacceptable requirements on some sectors of society. If we forget the economic context, for example in making plans to implement the Water Framework Directive, our plans are likely to fail, or be subject to legal appeals from those who believe their economic interests are compromised. If top-down decisions are made on the basis purely of so-called experts, the interests of all who share a resource may be overlooked and the strategy may fail in implementation.

OVERCOMING THE CONTENTION

Issues do not necessarily become contentious through bad intent on either side of a debate. Often, as in any 'religious war' or other sectarian conflict, the strength of the contest is in fact amplified by each faction feeling that they are 'on the side of the angels', whether literally or metaphorically. And part of the difficulty is that they possibly are!

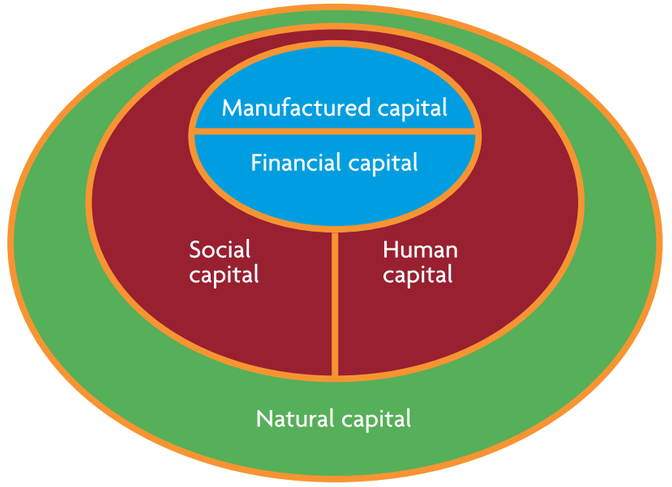
Far be it from me to ascribe saintly qualities to government ministers sidelining the perceived constraints of 'green tape' on economic growth, but a narrow focus on the single financial bottom line appears rational if that is the sole preoccupation. Slavery used to be perceived as an 'honourable trade', cutting down substantially on labour costs, as do modern equivalents such as indentured or inadequately remunerated labour in dangerous conditions along supply chains reaching out to provide the benefits of globalisation to nations conveniently 'unencumbered' by social and environmental niceties. Converting urban airspaces into toxic smogs used to be seen as an unfortunate but largely aesthetic consequence of industrial advancement, until health implications became clear enough to precipitate statutory responses.

All sides of a debate can be framed as rational if one is ignorant of, or else disregards, the systemic connections to which all of us are, at least in theory, committed. Hence, one can gain some sort of insight into the perverse accusation by the Prime Minster, David Cameron, that opponents of fracking are "irrational" and "religious" in their opposition, (who exactly is on the side of the angels?) and also his ideological opposition to a 2030 decarbonisation target for the power industry "unless and until it is known whether carbon capture and storage is a technology that works" (in comments to the House of Commons liaison committee about shale gas, environment and women's issues on 14 January 2014). A narrow economic focus can almost rationalise this myopia, were it not for the fact that we know from the 2006 *Stern Review on the Economics of Climate Change* that climate change reflects one of the greatest market failures and that tackling climate change proactively would have significant economic advantages compared to continuing to ignore it. And that is before we turn to the apparent disregard for the Precautionary Principle. ('Let's just keep heading for that iceberg until we have ultimate proof that hitting it will be bad for us!')

TRAGEDY OF THE COMMONS

In this and so many other contentious situations, Garrett Hardin's 'tragedy of the commons' is evident. There is a literature discrediting aspects of the 'tragedy of the commons as, in the absence of formal governance, many commons are well managed by informal protocols. But in any serious analysis of the great environmental commons – such as the atmosphere and the ways we overload it with pollutants such as climate-active gases, the oceans and the asset-stripping nature of modern intensive capture fisheries, and our short-term intensification of land management eroding topsoil vital for future human wellbeing – the parable holds true as advantages accrue to an acquisitive minority whilst a wide spectrum of ecosystem service beneficiaries, critically including future generations, bear the costs.

The implications of all issues are in reality complex, in the systems theory sense of phenomena that emerge from the interaction of different objects. Every issue, at least every environmental issue, has ramifications for people and the economy, and thus for businesses, communities, employment and biospheric integrity, as all issues are part of the complex socio-ecological system in which we co-evolved. So we had better get used to the fact that contention is a symptom not of an insuperable factional argument winning out over other world views, but is a symptom of unresolved thinking about the net societal worth of decision-making. Respectful listening to all forms of knowledge and subsequent innovation to resolve them, or at least to



▲ **Figure 2. The five capitals model.**

make any trade-offs transparent and consensual, is the pathway to resolution, rather than allowing the loudest or wealthiest or otherwise more powerful voices to win, as still sadly seems the norm.

We have the tools for systemic assessment, taking account of all aspects of complex issues. For example, the 2020 Vision programme established by The Natural Step in 1999, applying the TNS Framework as a means to recognise all views and to seek sustainable innovation rather than allowing one argument to overpower another, proved an effective means to defuse tensions and redirect energies to sustainable innovation with respect to GMOs, bulk printing, sustainable drainage systems (SuDS), reuse of biosolids from sewage processing, PVC, the thermal treatment of waste, and sustainable material use cycles.

The ecosystem approach is, as outlined above, defined by a sophisticated set of principles setting implementation of the (internal system) of ecosystem services in wider geographical and socio-economic contexts. And this helps us put into practice other systemic frameworks such as the 'triple bottom line' (**Figure 1**) of sustainable development, STEEP and the Five Capitals Model (**Figure 2**).

THE HUMILITY TO SEE OUR PLACE IN A BIGGER PICTURE

The big issue then is to admit that we are fallible human beings, not all-knowing entities. Hence, only by having the humility to seek solutions in a big picture informed by the ways that the world actually works, and accounting for the views of all stakeholder groups on behalf of whom we purport to be making decisions, can we hope to innovate solutions that are genuinely sustainable.

That has to be good for the economy as we ensure that growth is sustainable, not undermining resources vital for tomorrow and instead directing investment into that which has a longer future in which to be repaid. It also has to be good socially as we derive more equitable solutions and hence greater net benefits across society and across generations, understanding and safeguarding what is of value to people. And it has to be good environmentally as ecosystems are not only of altruistic concern to disparate 'bunny-huggers', but are also the most fundamental resource underwriting human wellbeing.

When we have grown up enough to recognise the real benefits of sustainable, systemic thinking, suppressing short-term profit-taking by narrow world views and vested interests, we will recognise that what we refer to as 'contentious issues' are no more than indicators of important topics about which we have yet to think and act systemically. ES

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