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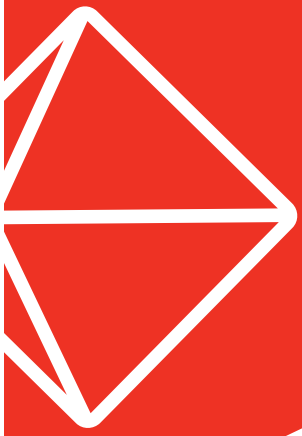
NESTA Making Innovation Flourish

Breaking the boundaries

Transformative innovation for the global good

By Fred Steward

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The greatest challenge of our time

Over the past decade, awareness of climate change has brought diffuse concerns over our planet's environmental limits into sharp reality. Environmental sustainability is everyone's fault and nobody's problem. As such, addressing it represents a public good 'par excellence'. But because of its scale and complexity, it defies conventional solutions. It treats even national borders as artificial administrative boundaries, and makes a mockery of governmental structures.

Unfortunately, the innovations that power modern society have led to systems of energy, transport, food and housing that are unsustainable. The solution is a commitment to innovation for environmental sustainability as an overarching goal of national policy.

Sustainability is not just another issue on a political shopping list – to merely treat it like other goals does not qualify as planning for what Gordon Brown has described as the 'great project of our generation'.[1] Yet, our political leaders remain equivocal – in deeds if not in words. In March 2008, the UK Cabinet split 50:50 on the minor but symbolic choice as to whether the selection of ministerial cars should signify the strategic importance of carbon emissions (the Toyota Prius) or of national competitiveness (the Jaguar).

This new sustainability-oriented innovation policy must draw on the lessons of other national mobilisations in pursuit of big societal goals. The appropriate analogies are not the Manhattan Project or the Apollo Program. These were quite specific 'big science' projects pursued for national strategic advantage. They led to radical technical innovations but did not transform everyday life or our systems of production and consumption. A model of selective, top-down technology solutions, based on these high profile, mission-oriented projects, is an oversimplification of the innovation challenge ahead.

Far more apposite are the public health reforms of the 19th century and the emergence of the welfare state in the 20th century. These policy revolutions began as a variety of bottom-up innovations promoted severally by knowledge professionals, social reform movements and business entrepreneurs. Initially giving rise to piecemeal fragmented policy measures, they ultimately led to wider policy transformation through top level synthesis by policy reformers such as Chadwick and Bevan and the implementation of substantive new measures of legislation and government expenditure. In each case, specific crises such as the Thames 'Big Stink' of the 1850s or the 1930s dole queues drove the formation of a pervasive policy agenda.

These epoch-making policy changes represent 'transformative innovation'[2] – they express a process of pervasive, system-wide change bringing forth a host of specific innovations ranging from new social institutions such as local government and the public clinic through to the new technologies of sewage plants and mass vaccination. They fundamentally reconfigured the normal way of doing things. Notably, they were the result of purposive policy change.

Transformative innovations need not be aimed at social benefit, or indeed be 'aimed' at all. The spread of mechanisation in the 'industrial revolution' or the ubiquitous data processing of the 'information society' led to pervasive change in the global economy. Although often explained in simplistic technological terms, these innovations embraced a wide range of specific innovations in business models, organisational forms and human behaviour.

Policy and research attention has traditionally been limited to profit-oriented science-based innovation with a consequent emphasis on generic technologies such as machine tools or microelectronics pushing change upon society. Sustainability policy has been divided into two camps: one promising a breakthrough technical solution that will allow us to continue to live as ever before; and another that suggests we all change our behaviour, boiling only half a kettle and cutting down on flights.

However a new model of 'sociotechnical' transition[3] has emerged, giving greater weight to the interaction between many actors in achieving such large-scale changes. In this, technical developments and social change combine to displace the incumbent companies, principles and priorities with a new arrangement. Achieving this is often associated with the role of 'system builder' or 'network translator' in articulating a new shared vision and enrolling support. Government may on occasion assume such a role, or more frequently seek to identify and influence other actors in a facilitating and catalytic role.

The relevance of this to the emergence of policy interest in environmental sustainability is striking. A profusion of bottom-up initiatives and policy measures are evident, yet broad transformation toward sustainability-oriented innovation remains unrealised. Celebration of the diversity of innovation for sustainability led by business and civil society needs to be accompanied by a new level of engagement by government. Despite these widespread initiatives, responsibility for meeting this global challenge continues to rest most heavily with national governments and the exercise of their legal, fiscal and budgetary powers. It is difficult to envisage the achievement of urgent and radical change without embracing a strikingly different role for government policy.

The rise and rise of environmental sustainability

Environmental sustainability continues to push its way into the mainstream policy agenda. Although often treated as marginal to the traditional political concerns of public services and economic competitiveness, it refuses to go away.

From the fringes to the mainstream

Modern environmentalism has its roots in the 1960s and 70s with the emergence of international organisations like Greenpeace and Friends of the Earth. It combined new activism with awareness of the global character of environmental sustainability. Triggered initially by crises such as the toxic pesticides condemned in Rachel Carson's *Silent Spring* or the oil pollution catastrophe of the wrecked supertanker, the Torrey Canyon, it moved increasingly into new political territory characterised by two features. One was the focus on global issues such as the effects of CFCs on the ozone layer of the Earth's atmosphere or the transnational impact of radiation following the Chernobyl disaster. The other was a new mix of political and personal responsibility expressed through, for example, recycling initiatives.

This new consciousness was expressed in the rise of a movement that combined civil society activism with critical scientific expertise. It found a more formal global voice through the United Nations with its Earth Summit of 1972 and the establishment of the UN Environment Programme. Over time this has led to a quite new context where national (or in the case of Europe, transnational) governments have increasingly become committed to taking a share of responsibility in the resolution of global environmental problems. The striking success of an international treaty, the Montreal Protocol, in phasing out ozone-depleting substances marked a turning point in this process.

From being an issue promoted 'outside' of government, the environment has become a set of commitments 'inside' the formal domain of policy. The contemporary challenge is to secure the translation of these new obligations into effective practice.

What is sustainability?

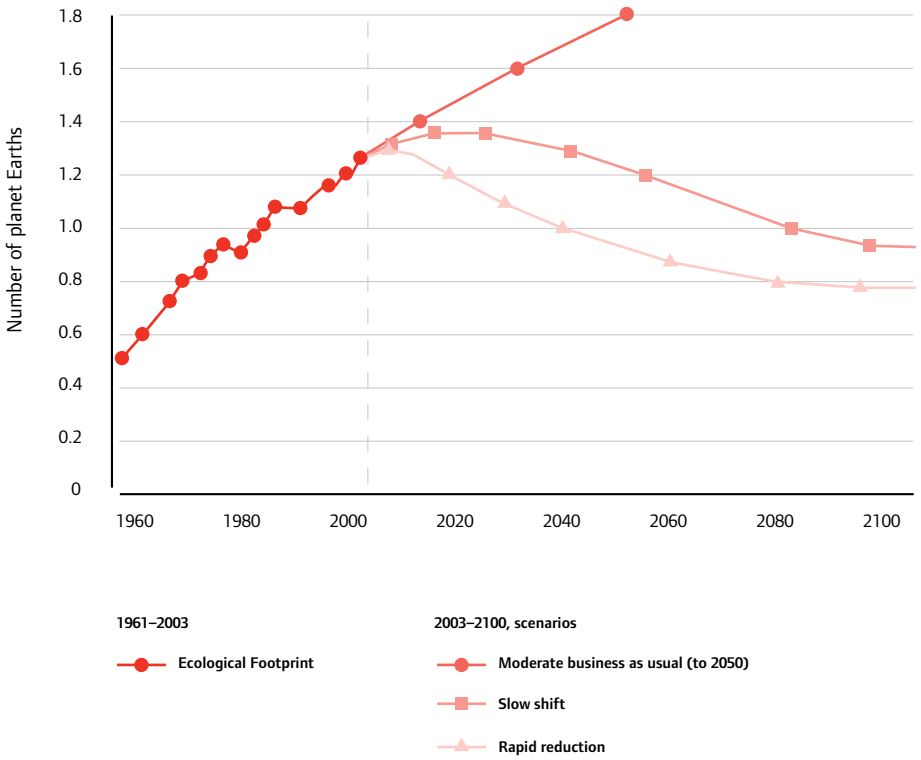
Sustainability is about 'living within environmental limits', defined in the current UK Sustainable Development Strategy[4] as 'respecting the limits of the planet's environment, resources and biodiversity'. The UK strategy of a 'One Planet Economy' recognises that 'current developed country patterns of consumption and production could not be replicated worldwide'. Continuing on a 'business as usual' path is unsustainable and we need to 'decouple economic growth from environmental degradation'.[5] The world's composite 'ecological footprint' shows that we crossed the

'one planet' threshold in the early 1980s (WWF[6]) and decoupling will take decades to restore the balance (Figure 1).

Different parts of the world vary in their overall national environmental impact and in their intensity by person (Figure 2).

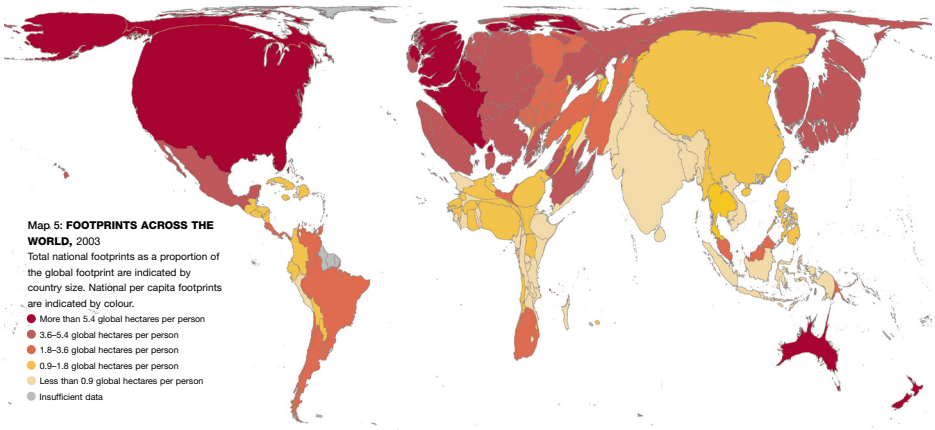
A transition to a 'one planet' economy requires 'innovation in both technologies and behaviours'. Sustainable decoupling needs transformative innovation. Without this, CO_2 emissions will continue to rise in spite of incremental lower carbon improvements (Figure 3).

Figure 1: The world's global ecological footprint. Contrasting paths: unsustainable 'business as usual' or sustainable 'decoupling'.



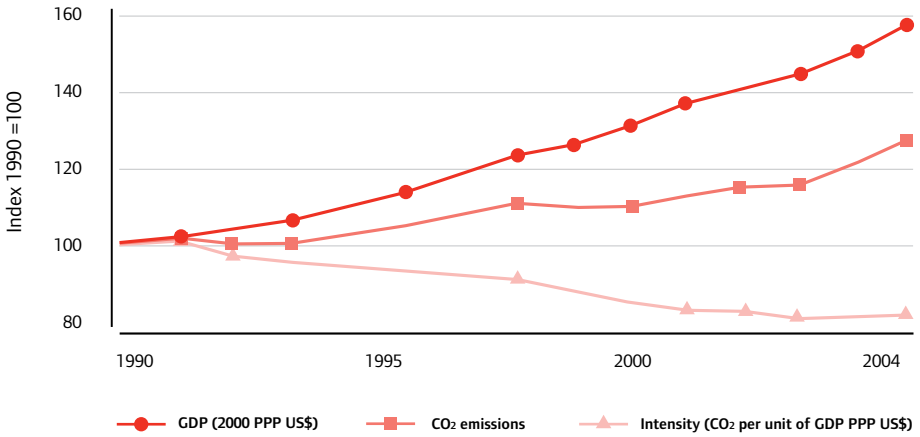
Source: WWF (2006) 'Living Planet Report.' Godalming: WWF

Figure 2: Environmental impacts across the world. Diversity in size of national impact and intensity by person.



Source: WWF (2006) 'Living Planet Report.' Godalming: WWF

Figure 3: Carbon emissions and lower carbon innovation.



Source: UNDP (2007) 'Human Development Report 2007/2008. Fighting Climate Change: Human Solidarity in a Divided World.' New York: Palgrave Macmillan

A new narrative

In the 1970s, the debate over environmental sustainability was dominated by discussion of the 'Limits to Growth' discourse, which suggested that the only possible solution was to accept slower and ultimately restricted economic growth. This (along with its polar opposite – simplistic advocacy of economic growth as the cure-all for the environmental ills) characterised much of the early public debate.

The past 20 years have seen the emergence of a new narrative. Initially, it was framed in the general terms of sustainable development, following the promotion of the concept in the Brundlandt report of 1987. It led to a focus on how economic growth could be 'decoupled' from its negative environmental impact on resources and pollution. This is the broad global framework that was established through the UN Environment Programme.

Growing recognition of the seriousness of a specific problem – the creation of dangerous climate change from rising carbon emissions – has led to a more specific focus on the mitigation of climate change. This arose from the treaty obligations of the 1992 UN Convention on Climate Change and its 1997 Kyoto Protocol to reduce greenhouse gas emissions. It has, of course, been the global threats associated with this which has propelled it up the political agenda, although it can reasonably be seen as a particular expression of the broader theme.

Two reports

Two recent authoritative reviews of the problem of climate change have reaffirmed the need for urgent and radical change in order to address this problem. The International Panel on Climate Change in its Fourth Assessment Report in 2007 argues that a strategy of 'mitigation' to reduce and reverse human impact on global warming is a viable possibility if pursued vigorously.[7]

The Stern Review commissioned by Gordon Brown makes the general economic argument that the costs of pursuing such a mitigation strategy are far less than the costs of coping with the consequences of global warming. Stern also argues that the successful mitigation of climate change requires a different path of technological and economic development. This is expressed as 'managing a transition to a low-carbon economy'.[8]

Stern's analysis has had a significant influence on the UK policy context by providing legitimacy for much more public intervention than would otherwise be allowed by a traditional and narrower definition of 'market failure'. It recognises that the low-carbon innovations which will underpin a longer-term transition toward sustainability will initially be uncompetitive compared with the carbon-based incumbents. If society wishes to pursue such a transition it needs to support them.

Into the political mainstream

There are signs that some mainstream politicians are making environmental sustainability central to their world view. David Cameron expressed this in his strategy for the leadership of the Conservative Party – 'we must make the green agenda central to everything we do'.[9] David Miliband sees the 21st century challenge of sustainability as pivotal as the social settlement of the 20th century welfare state.[10] This represents a shift from when these issues were the main preserve of the Liberal Democrats and the Green Party.

Such a stance is still not established in the mainstream of political action. Sometimes climate change is limited to a separate and specific security threat rather than an expression of a wider issue of environmental limits. Often environmental sustainability is still seen as a secondary concern to the traditional policy staples of economic performance and social welfare. A 'third way' may be credible in other policy arenas, but here there is a stark choice over priorities: the UK Government's stance on this fundamental choice will determine the pace and success of transformative innovation for environmental sustainability.

Innovation will save the world

At the core of most policy responses (although rarely expressed as such) is the belief that innovation can offer a route to the delivery of continued and growing prosperity combined with significantly reduced environmental impact. Simply put, innovation means that the public can have their cake and eat it – a convenient narrative for elected politicians.[11]

This is frequently expressed in the unusual emphasis by many government leaders on the need for 'revolutionary' change in technology to deliver environmental sustainability. Tony Blair and David Cameron competed not over the old 'white heat' but the new 'green cool' of technological revolution. Its political neutrality is asserted in its being championed by both US president George Bush and Chinese Prime Minister, Wen Jiabao. Yet such ambitious rhetoric is accompanied by disappointing performance.

Oversimplified metaphors of technological success tend to privilege scale over pervasiveness. Big projects, whether they be nuclear power, carbon capture, or ecocities have a tendency to dazzle the modernist gaze yet experience suggests that they often lead to sectoral silos rather than to widely diffused change.

A push for greener versions of familiar products is better-supported by the good track record of incremental innovation but promises less impact on overall sustainability and is distinctly less glamourous. A particular problem has been the 'rebound' effect: more ecofriendly individual innovations such as fuel efficient vehicles and energy efficient appliances are being introduced, but the aggregate picture in the transport sector or household is one of rising consumption leading to growing environmental burdens.

The potential of generic 'info', 'bio' and 'nano' technologies to enable a new sustainable industrial revolution is frequently given too comfortable a gloss. The promotion of innovation *per se* cannot be assumed to be synonymous with the pursuit of sustainability. In fact, it may be in conflict. Even for innovations with great sustainability potential – such as the use of information technologies to enable the 'weightless' substitution of material products, MP3s for CDs, email for letters – the impact may be detrimental. Despite the visions of a paperless society, the growth of desktop computers and the internet has been associated with increased paper use. Despite the aspirations for a weightless economy, an avatar in the virtual world of Second Life has been estimated to have a larger carbon footprint than a citizen of Brazil. The point is not that new generic technologies do not have sustainability potential but that these will not necessarily be realised spontaneously. Most technologies embody multiple and

contradictory possibilities. The point is that there needs to be societal promotion of sustainability as a deliberate goal.

These partial and sometimes misleading narratives of innovation reveal that the implications of an underlying reliance on innovation in the pursuit of sustainability have not been seriously addressed. A consequence is a rather schizophrenic policy mentality that continually shifts between grand technological solutions and the need for individual behaviour change by consumers. There is a need to think in a fundamentally different way and recognize the pervasiveness and plurality of the transformative innovation needed for environmental sustainability.

Unsurprisingly, the new prominence of climate change as a common threat requiring disruptive solutions has been accompanied by the emergence of a set of narratives drawing upon historical parallels.

Historical analogies which evoke sharp alternatives of technological or social determinism are unlikely to be very helpful. The Manhattan Project is evoked by the former as an exemplar of successful massive state support for radical new technology. The Abolition of Slavery is evoked as the viability of a moral crusade to change behaviour. Neither resonates appropriately with the present challenge.

More interesting analogies might be found in the internet where a publicly initiated infrastructure innovation unleashed an accompanying torrent of private sector innovation, or in the New Deal where local investments were oriented to job creation for civic purpose. As modes of innovation they appear to offer more prospects of pervasive change, though their relevance to a mission of sustainability remains unexplored.

Fundamentally, there remains a failure both to embrace sustainability as the new core mission of national innovation policy and to bring new thinking about innovation into the domain of sustainability policy. An effective response will challenge many of the boundaries which shape this policy domain.

Through a glass darkly – the contemporary policy window

Interpreting the UK's current policy landscape on innovation and sustainability is a daunting task. There exists a host of institutional initiatives including a new Office of Climate Change and a new Committee on Climate Change, an Environmental Technologies Institute and an Environmental Transformation Fund, a Sustainable Consumption Round Table, and a Business Taskforce on Sustainable Consumption and Production. Compounding this profusion are policy legacies that remain an uneasy backdrop for this host of individual initiatives.

Innovation policy – turning the problem into the solution

The current market-oriented model of innovation policy remains reluctant to directly engage with commercial deployment of innovation. It superseded the mission-oriented UK innovation policy of the 1950s and 60s, abandoned as a misguided attempt to 'pick winners'. Consequently, the aspiration is to provide a 'technologically neutral' market context in which innovation activity is left to the private sector. Other approaches such as regulation are often disparaged as 'command and control' statism. What was initiated as a healthy bout of policy reform has tended to congeal into a new policy dogma in favour of market-based instruments and against regulation, even in cases where they appear to be an obvious instrument. Low energy compact fluorescent lightbulbs, standby controls on electronic appliances, and standards for house extensions are striking cases. Such inertia and inaction feeds idiosyncracies such as the belated plastic bag campaign, which – though welcome – hardly addresses the core challenges of sustainability.

This policy heritage seems at odds with the urgency and radicalness of innovation demanded by the analyses of the IPCC and Stern Reviews. These imply the reintroduction of societal mission into the heart of innovation policy, along with a recognition that innovations for sustainability need to be helped to overcome lock-in and the power of incumbents.

More fundamentally, if the strategic goal of transformative innovation is to be taken seriously, then a far deeper and wider definition of innovation is required than that of a technology fix. It needs to embrace a complex mixture of organisational and cultural change and social innovation as well as new technologies. It needs to build upon new thinking which gives greater weight to user, consumer and citizen involvement and open innovation. There is some evidence that mainstream innovation

policy is beginning to respond to this agenda but it remains disconnected from the overarching goal of environmental sustainability (although the Commission on Environmental Markets and Performance has begun to try and broaden out the innovation agenda to embrace demand-oriented policies[12]).

Sustainability policy – the dog needs to wag the tail

In spite of the sweeping aspirations of sustainability policy to reshape the path of economic development, it is still tied to its traditional roots in the reactive area of pollution control and environmental protection. Its location in government remains an extension of environment and countryside affairs rather than becoming a new strategic high-level policy domain. It is more comfortable with the language of science and ecology than that of business and innovation.

In spite of the ceaseless invention of new institutions in this area, there is little sign of a growing cohesion and centrality for sustainability policy in government. Instead there is a proliferation of specialised domains scattered between sustainable consumption and production, climate change, waste management, and biodiversity. The separateness of new policy apparatus, such as the Committee on Climate Change, may confound rather than consolidate the centrality of sustainability policy in general.

One consequence is that innovation promoted by one part may be at the expense of another. The negative consequences of biofuels for biodiversity is a recent and conspicuous example. Another consequence is that sustainability policy remains separate from broad arenas of policy such as transport, housing, energy, and business where much of the innovation needs to take place. The current controversy over airport expansion policy indicates that there is a need for conscious measures to promote sustainability priorities in relation to specific problem areas. This represents an area of specific choice, not a false dichotomy: are increased mobility (perhaps increased pleasure) and increased revenue more important than the ensuing environmental damage?

These limitations leave sustainability policy vulnerable. The weak engagement with innovation not only fails to reorient critical sectors but also risks losing the public support which is essential to such a process. Successful innovation requires more than a supportive market framework. It needs an appropriate culture with people and organisations having the necessary capabilities to make innovation happen. The promotion of this must also be a serious objective for innovation policy. Even for competitiveness-oriented innovation there is enormous variation between societies and organisations in their capabilities. This applies even more so to sustainability-oriented innovation.

Towards transformative innovation

The backdrop for national sustainability policy is more favourable than at any time before. This signifies an awareness

of a global problem, the acceptance of national responsibility for contributing to its resolution and a recognition that urgent action is required. This capital should be aggregated and used to promote a new paradigm: environmental sustainability as the core of transformative innovation.

Transformative innovation is broad in scope and radical in character. The term 'radical innovation' implies a high degree of novelty in either technology or functionality compared with incremental innovation. However, it refers to a specific product, process or practice. Transformative innovation is about radical change of a more generic kind. It is about the implementation of paradigm-breaking, system-wide novelty. One type is pervasive disruptive technology like mechanisation or information technology which can explain revolutionary changes in economic systems. Another type is epochal change in the public sphere such as the provision of public health or the welfare state which require fundamental shifts in policy paradigms. In both types, it is characterised by a core of originality which crosses traditional sectoral boundaries and redraws existing social and economic arrangements. It involves a wide diversity of actors, and often takes decades to move from margins to mainstream. Transformative innovation involves substantive risky investments by its champions, conflicts between emergent and incumbent actors, and reconfiguring of traditional sectoral and policy boundaries.

At present, neither innovation policy nor sustainability policy are configured to allow a serious pursuit of transformative innovation.

Five principles for reconfiguring innovation policy for sustainability

The current distribution of government responsibilities for environmental sustainability, climate change and innovation is expressed in several separate public service agreements. This is unsuited to the strategic focus needed.[13] **A new synthesis between them is required.**

A sustainability-oriented innovation policy needs to break many conventional policy boundaries. It is a global, long-term issue which requires local, near-term action. It requires innovation which embraces technological and social change. It will engage old and new, the public and private sectors, corporate and entrepreneurial actors.

1. Long-term visions – short-term action

One of the consequences of the recent work on sustainability and climate change has been to direct attention to change over long time periods. This concerns both the long time taken for global environmental impacts to occur as well as the long time for major innovations to emerge and spread.

The evidence on man-made climate change relies on long time series data. Analysis of the major sociotechnical transitions that accompanied the rise of a carbon-intensive economy – windpower to steampower, horse drawn transport to internal combustion engine – shows that periods of several decades were involved. Traditional policy is often criticised for its short-termism and there is no doubt that sustainability-oriented innovation requires long-term targets for carbon reduction and objectives for low-carbon innovations. Yet long-term policy goals need effective translation into the present if they are to be effective. UK carbon emissions, after a decline in the 1990s, have stabilised over recent years and need as much attention as arguments over targets for 2050. The Climate Change Bill offers a legal framework for setting 5-year carbon budgets which could provide a mechanism for bridging this long-term/short-term gap. Innovation goals will be as important as emission targets if this pioneering legislation is to live up to its promise. The nature of the innovation journey will be as critical as the destination.

The challenge within this new policy regime is to frame effective short-, medium- and long-term innovation targets in the pursuit of a transition to a low-carbon economy. Greater urgency is a pressing need. Overspeculative, remote possibilities, in generic fields such as nanotechnology, need caution. On the other hand, too narrow a focus on alleviation through end-of-pipe emission control such as carbon capture could

further lock us in to fossil fuel-based electricity production.

This implies an ability to discriminate between contemporary innovative steps, which could contribute significantly to transformative innovation, and those that are less likely to. The policy goal should be radical incrementalism – short-term action with real prospects of translation into radical long-term change. New policy approaches are needed for the management of expectations which bridge the far and near futures. They need to seek to avoid the negative dynamics of ill-informed hype/disappointment cycles. These could be expressed through 'green foresight' policy instruments which deliberately engage a variety of stakeholders – producers, users, experts, environmentalists – in the construction of future scenarios. Such participative approaches offer greater prospects of reciprocity between government, business and the public than reliance on traditional expert-led technocratic programmes.

2. A sociotechnical approach – bridging the arenas of new technology and behavioural change

Policy interventions tend to treat technological innovation and behavioural change as distinct alternatives. Different government departments like BERR, DIUS and Defra may put more emphasis on one or the other. But successful innovation embraces a complex mixture of technical and social elements. Radical change is unlikely to be achieved through just one or the other.

In the past, new technologies such as the automobile or the refrigerator were accompanied by the death and birth of major businesses, transformations in consumer culture, changes in residential and recreation patterns, creation of new supply chains and expertise. They required innovation in both production and consumption.

Innovation is seen far more accurately as the creation of a new interactive sociotechnical network than separately as new technology or changed behaviour. The pursuit of innovation for sustainability must face this explicitly. Neither the zero carbon airplane nor the zero carbon citizen appear plausible stand-alone solutions. Yet policies to promote new technology and behaviour change continue to operate in isolation.

A sustainability-oriented innovation policy needs to catalyse the creation of new sociotechnical networks. These can be seen as niches or emergent alternatives to the prevailing unsustainable carbon-intensive regimes. They need to be nurtured and enabled to grow in order to contribute to society's sustainability goals.

Innovation policy needs to be oriented much more toward domains of consumption and social practice rather than to specific technologies in order to achieve this. Otherwise we risk sticking too closely to the old or being too narrow in our future vision. Enthusiasts for particular technological solutions need to engage with users and competitors in a creative conversation. It will require a reorientation from technology or product-

focused approaches to broader functional provision in terms of mobility, shelter, food and communication. The sustainable transition policies of the Netherlands promote arenas which deliberately engage entrepreneurs, incumbents, consumers and environmentalists in a process of dialogue and network building.[14]

Such stakeholder innovation arenas offer a quite different model from the current UK prevalence of science- and business-based technology projects. The Innovation Platform model of the new Technology Strategy Board could be reoriented toward this, but only with a wider concept of stakeholders and of innovation itself. It would need to tap into existing informal networks of green entrepreneurs and environmental advocates. These are emergent arenas but need greater visibility, focus and connection to resources to thrive.

If national government continues to struggle to create appropriate arenas, there is a powerful case for focusing attention at a more local level such as cities where stakeholder innovation arenas could address radical solutions for mobility, shelter and food. The London Congestion Charge and the low-carbon Transition Town initiative both indicate strong local interest. National carbon budgets could be cascaded to the local level and linked with substantial focused resources for innovative community-wide ventures. This implies a quite different steer to local and regional innovation strategy.

3. The global and local – reconfiguring national innovation policy

In spite of the emergence of international agreements on sustainable development and climate change, the focus for most policymakers remains resolutely national in scope. Yet we are all embedded in a global system. Superficial comparisons about the global impact of the USA and China tend to undermine the international significance of UK policy. But the answer is not that the UK can do nothing, nor that it, alone, can ensure an environmentally sustainable future for the planet. The answer is to engage differently on the international stage.

There are two particular challenges for the UK. One is the relationship with Europe. The other is that with the rapidly emerging economies such as China.

Arguments about the limited global impact of sustainability measures adopted by the UK have far less resonance when the focus is the European Union. This transnational entity has the third largest global carbon footprint – close behind the US and China. Action in Europe will count significantly on a world scale. The European Union has a shared legal framework and is an independent signatory to the Kyoto Treaty on greenhouse gas reductions. If the UK aspires to global leadership on climate change, then one of its most effective routes will be through Europe. Achieving this would mean a quite different approach to European innovation policy. After a period of ambivalence over the primacy of competitiveness or sustainability (expressed through the

debate around the competitiveness-oriented Lisbon agenda versus the sustainability-oriented Gothenburg agenda), the EU has relapsed to the former.

The relationship with rapidly growing economies such as China means recognising that UK and European consumption has a responsibility for part of the growth of emissions in other parts of the world. Much of the recent discussion on China's coal-fired power station programme has neglected this. Two recent studies have shown that perhaps 25 per cent of China's carbon emissions arise from activities due to Western consumption.[15] If the UK's carbon emissions are calculated by the global impact of UK consumption on overseas production and transport, then results show them to be much bigger and on a rising trend than the normal official figures suggest.[16] There needs to be a much stronger international dimension to innovation policy to address this. The new Environmental Transformation Fund partly addresses this but we need much more transparency on the UK's global environmental impacts and its implications. This implies a stronger and more positive engagement with countries like China.

Interestingly, a recent public opinion survey[17] showed that 65 per cent of Chinese citizens regarded climate change as the most important global issue and felt that China should act on it despite its lower level of economic development. This challenges the widespread assumption that sustainability has quite different meanings in the developed and developing world. In fact, it suggests shared global aspirations as well as the common problem of lock-in to unsustainability – whether through the embeddedness of unsustainable sociotechnical regimes in the developed world, or rising expectations in the developing world. It implies much greater significance for civil society engagement with policy at the global level. Indeed, the successful internationalisation of innovation policy requires a renewed relevance to the individual citizen.

4. Invention and imitation – being realistic about novelty

The science push narrative emphasises 'complex' radical technological novelty. The behavioural pull discourse counterposes this to 'simple' social changes. A new policy approach needs to recognise both that radical change can be accomplished without extreme technical novelty, but that it is also the case that any purposive change is a complex challenge.

There is growing evidence that the pursuit of sustainability-oriented innovation releases new potential for existing technical know-how. The global success of ICI's water-based paints, Vestas' wind turbines and Rothamsted's biodegradable pesticides all drew on established know-how applied to new environmental purposes. It is a mistake to overemphasise pure technical novelty. Reinnovation can also deliver radical results. It is therefore essential that the innovation policy domain is not overdetermined

by the priorities of the basic science community.[18]

Reinnovation is different from incremental innovation. It is not simply about small stepwise changes in prevailing technologies, such as the Market Transformation Programme's focus on improving the energy efficiency of household appliances. Instead it embraces innovations which can contribute to a deeper sustainable transition yet which draw on established technologies.

It is often the case that a new innovative business model releases enormous potential from established technology. The explosion of internet businesses was a classic illustration of the need for new business models to release a technology's latent potential. The innovation of the low-cost airline is another example of a new business model having a dramatic effect. Easyjet was an innovation in pricing and logistics and unleashed a new era of mass air travel with serious implications for sustainability. It was not about the airplane as an innovation but as an easily available, reliable, established technology. It would seem a reasonable proposition that innovative business models embracing sustainability could unleash a wave of innovations exploiting existing technology.

This requires an acceptance that UK leadership does not have to necessarily involve the creation of new technology as such. At present this sits awkwardly within the conventional innovation policy wisdom that global social and economic leadership arises principally from technological originality. What this stance consistently underestimates is the competitive advantage that can be derived from the capabilities to exploit old technologies for new purposes.

5. Incumbent and emergent – recognising the contradictions within the business world

Transformative innovation will involve significant changes in the business landscape. Policy needs to recognise the difference between unsustainable (but successful) incumbents and sustainable (but marginal) entrants as a basis to engage constructively with both. Current policy tends to involve government in close relationship with a small number of leading national corporate businesses, well illustrated by the membership of the Business Council for Britain and the driving forces behind the Energy Technologies Institute, and a distant relationship with a mass of small and medium-sized firms. A sustainability-oriented innovation policy needs to be much more discriminating and supportive of entrepreneurial firms whose mission is complementary to public environmental objectives.

This is partly explained by the ease of engaging with large businesses. Emergent ones are often less obvious to eyes of Westminster and Whitehall and frequently come and go. However, making this a policy priority, and ensuring that this sector becomes as familiar to politicians as the corporate world, would go a considerable way towards redressing this balance. The green entrepreneurs

need as effective a showcase as the Financial Times gives to the big players. Innovation policy should help fill this space. Environmental entrepreneur support schemes, like those of the Carbon Trust, need to make these businesses more visible to a wider audience as well as casting the net more broadly to embrace social as well as technological entrepreneurs.

We need more resources going to entrepreneurs who can contribute to the realisation of sustainability-oriented transformative innovation. Broad small-firm support measures are quite unsuitable as they don't discriminate as to their role in the pursuit of an overarching societal goal. Instead, targeted policy initiatives are required which deliberately favour some firms over others. This means reintroducing a level of selectivity which might be dismissed by some as a reversion to 'picking winners'. But policy can be designed to avoid choosing the wrong innovation and bankrolling it in perpetuity from the public purse. Learning from any intelligent fund manager in the private sector, government must adopt a portfolio investment strategy that would recognise the need for a variety of prospects with an acceptance that some will fail. Misguided dogmas based on the catastrophic failure of a few monolithic government bets in the 1970s and 1980s now hinders creative policies to support entrepreneurs who share public goals. Unless we become more selective, government will remain a mere spectator, applauding entrepreneurs but doing nothing to influence whether they sink or swim.

New policy domains for sustainability-oriented innovation

There are many voices at present, across the political spectrum, who agree that government is failing to meet popular aspirations for actions on sustainability. The risk is a policy hype/ disappointment cycle. Expectations stoked through grand aspirational commitments are disappointingly let down by overcautious practice.

Part of the solution requires more effective integration in government of the lead responsibilities for innovation, sustainability, climate change and energy. The locus for sustainability policy in government must have the resources and authority to be a demanding user of innovation policy. This means a public agency with both a focused sustainability mission and the capacity to articulate broad innovation requirements across the full sphere of policy. While the Sustainable Development Commission has an important scrutiny and advisory role, there needs to be an executive department with the exclusive but broad remit of innovation as its mission and environmental sustainability as its target.

Such a refreshed focus in government needs to be accompanied by new policy measures which resonate with the diversity and drive of bottom-up innovation initiatives in the business world and the community. These measures need to be pitched at a zone which lies between the broad macro level of emission targets, green tax and carbon trading and the specialised micro level of product standards or new technology projects. They need to catalyse transformations that cross the consumption/production divide and address sustainability in the broad arenas of societal purpose such as shelter, mobility, food or communication. This implies a higher level of citizen and consumer involvement in the practice of innovation than is traditionally recognised in innovation policy.

The recognition that change in the behaviour of individuals is itself part of a multifaceted innovation process is fundamental and is often overlooked. Commonly, behaviour change is viewed as an outcome of information provision (the 'deficit' model) or as shaped by constraint (the 'regulation' model). Such assumptions underlie policy proposals ranging from green labels to the personal carbon allowance. Valuable as they may be, they give little attention to the role of social interaction as a potent route to individual change and the promotion of innovation. As Leadbeater argues, interaction between users is a much underestimated source of innovation.[19]

Recent work on persuasion by Cialdini[20] highlights the central importance of 'reciprocity' (that action by the individual is reciprocated by government or business) and 'normativeness' (that experience of others changing their behaviour is vital to individuals also

making that choice). Public support for taxes on high carbon travel is affected by whether government reciprocates with investment in sustainable transport innovation. Use of household energy saving innovations is strongly influenced by individual knowledge of neighbour behaviour. The conditions for such interaction are much more likely to be met through policy initiatives that directly engage the public in practice than through indirect framework measures, or specialised technical policies.

Transformative innovation requires risky investments by its champions. If the UK wishes to be a leader in a sustainability-oriented innovation policy, it requires commitment of resources, but also imagination. Innovation ultimately relies on the culture and capacity of a society and its institutions to act within that framework to create novelty in practice. We need a series of imaginative sustainable innovation programmes which engage the public and are interactive in style. Learning from successful transformative innovations of the past, they need to be open and responsive yet pursue a societal goal with seriousness of purpose. There are a number of new domains of sustainability-oriented innovation policy which deserve exploration.

Demanding futures

Markets can be shaped by governments to influence innovation by using a judicious mix of policy measures. They should be guided by a philosophy of pragmatic pluralism – regulations, financial measures, procurement can all play a role in appropriate circumstances. Forward Commitment procurement has been promoted by the Environmental Innovation Advisory Board as a successful method: setting high sustainability performance targets for innovation with a guaranteed market.

Regulatory forcing can also be used to favour innovations achieving high standards. It has recently been argued by the former Chairman of Shell, Sir Mark Moody-Stuart, that new cars below a minimum level of fuel efficiency (35mpg) should simply be prohibited.[21] Japan's Top Runner programme has promoted improvements in sustainability performance, not by the imposition of minimum standards, but by identifying the leading performer (the top runner) and agreeing with stakeholders a time period after which it will become the standard. It has had striking successes through making the performance of different producers publicly visible, rather than using detailed laws.[22] Elsewhere, financial measures have been employed to make the market attractive for the deployment of new sustainable technologies – such as the 'feed-in tariff' for renewable energy in Germany.[23]

The UK's current approach to innovation for sustainability is piecemeal, fails to recognise the role of demand and is too influenced by ideological presuppositions regarding the desirability of types of policy instrument. It should be replaced by a demand-led innovation programme that combines precise targets with a plurality of policy instruments.

Sustainable innovation commons

Lawrence Lessig has described the internet as an innovation commons. A publicly funded infrastructure free of proprietary constraints was made available to entrepreneurs and social actors to exploit in a creative fashion for their particular purposes. The condition for proprietary innovation was that they shared the infrastructure and conformed to its rules. It has unleashed a profusion of commercial and non-commercial innovation. Is there anything that can be learned from this model of innovation that could be used in the pursuit of sustainability?

Advocates of the introduction of a 'smart' electricity grid see it as an analogy. The current electricity network was designed with one-way transmission from supplier to customer in mind. It is more suited to large power stations than to microgeneration by an individual household. The innovation commons model would redesign the grid explicitly as an interactive network to make it much easier for consumers and communities to also play the role of innovative energy suppliers. As with the internet, its role as a 'commons' relies on a mix of technical and legal attributes and would be a major public infrastructural investment, but in this case designed to enable bottom-up innovation in energy supply.

More generally there has been growing interest in the sharing of knowledge in the innovation process arising from the successful development of Open Source software. This has challenged the traditional corporate appropriability paradigm for intellectual property and suggests that a more open sharing model for knowledge may be more beneficial for innovation than is usually recognised. Given the challenge ahead, could a more open approach to intellectual property be justified and strongly encouraged in the area of innovation for sustainability?

Radical reinnovation

There deserves to be a lot more effort directed to exploit the sustainability opportunities of existing and established technologies. In its nature a focus on this 'reinnovation' makes an appeal to a much wider constituency than hitherto, bringing together technical experts with lay innovators and business entrepreneurs. The pursuit of radical reinnovation will require an interesting mix of technological and social innovation.

The reemergence of windpower as a renewable energy source is a classic case of radical reinnovation. Denmark did not invent the windmill, but it successfully grew a new windpower sector around this old technology and the rewards have been considerable. Its lead company, Vestas, holds a major share of the global market for wind turbines. There are many traditional technologies with potential for low-carbon sustainability which could offer similar opportunities.

Green New Deal

Cities and other localities are likely to be the most important setting for transformative innovations in mobility and household provision. Already there is

evidence of bottom-up initiatives around low-carbon villages and transition towns. Regionally oriented innovation policy should focus on this potential and support major initiatives to innovate around local solutions.

Current regional innovation policy often suffers from an unrealistic focus and distance from the concerns of the local populace. Harnessing resources around sustainability would make them more relevant and meet sustainability's demand for localised knowledge. There could be much more effective synergy between policies to promote public infrastructural investment in particular places on the grounds of unequal economic development/social exclusion and the overarching societal goal of sustainability.

Indeed, there may be a convergence between economic and environmental goals in the near future which could legitimise a new level of public local infrastructural investment equivalent to the US New Deal in the early 1930s.[24] Certainly, it is straightforward to see the prospects for a virtuous relationship between employment creation and the pursuit of environmental sustainability through local innovation in mobility and household systems.

Sustainable transition arenas

Some sustainability issues, like air travel and waste recycling, receive attention through adversarial conflict without any facilitation by public policy. Valuable though this is, it constantly runs the risk of responding only to particular campaigns (plastic bags, for example). There is also a need for wider coverage of sustainable futures on themes with less public visibility and lower attention by particular advocacy groups.

Drawing upon Foresight-type programmes and the transition arenas pioneered in the Netherlands, the UK should aim to develop a richer national discourse on sustainable visions and options for the future. Such events also contribute to the emergence of new networks for sustainability and help develop social expectations – which play an important role in popular visions of innovation opportunities and may thereby strengthen the UK's innovation climate and culture.

They further provide an important visible forum for entrepreneurs to interact with each other and with incumbent businesses. They would certainly help policymakers change from being observers of sustainable enterprise to providers of serious partnership and support.

There has been an explosion of entrepreneurial activity in this area in a variety of technical and non-technical fields (see, for instance, NESTA's research report, 'The Disrupters'[25]). Often only visible to small groups of enthusiasts or experts, this activity needs to be brought out of the ghetto into the public realm. If entrepreneurs are pursuing a goal that is congruent with government-endorsed societal purpose then their activities merit celebration and endorsement.

Meeting the challenge

Taking environmental sustainability seriously requires not just pushing it up the rhetorical political agenda, but actually breaking the boundaries of what government does and how it does it. It is not enough to tell scientists to produce new technologies, nor tell the public to consume less. Meeting this challenge will require both of those things, but something more: a purposive approach by government, focused on its role as a champion, facilitator and catalyst.

Doing this will not be straightforward. It means developing new methods to support new forms of innovation, and overcoming the non-interventionist policy dogma of the past two decades. The challenge of transformative innovation needs some radical new policy ventures. At least in the area of policy innovations it is time that we picked some winners.

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