Chapter 2.8

From Enlightenment to Enablement: Opening up Choices for Innovation

Andrew Stirling, University of Sussex

Introduction

Since the Enlightenment, we have tended to think of scientific and technological progress as linear and cumulative. In the high-level debate over "the knowledge society," this is still the way these crucial issues are treated in worldwide governance. Technology policy is routinely described as indiscriminately "pro-innovation" and its critics labelled generally "anti-technology." Scope may be conceded for debates over risk, or the distribution of costs and benefits. But the main challenge is seen as a competitive race along a pre-ordained track. As a key feature of the "knowledge society" and a founding theme of the Enlightenment, it is a remarkable fact that this linear understanding is just plain wrong. This paper will explore some implications.

The truth is that, in any given area, science and innovation may actually advance in many alternative directions. As in biological evolution, while many pathways for progress are possible, not every path that is feasible and viable will actually be realized. At each stage of development, societies pursue only a restricted subset of the diverse potentialities. As processes of evolution unfold, certain pathways encountered earlier are "closed down," while other possibilities are "opened up." Whether deliberately, blindly, or unconsciously, societies choose certain possible orientations rather than others for change in science and technology.

These choices are driven by multiple factors in complex decision making processes. Directions of change are particularly susceptible to the exercise of power. Many questions arise. To what extent are choices deliberate and democratic? Is public policy open, inclusive and accountable in dealing with links between technological risk, scientific uncertainty, social values, political priorities and economic interests? What are the relationships between social and technological progress, on the one hand, and public participation and responsible precaution, on the other? What are the most appropriate and practical ways, under different conditions, to get the best out of specialist expertise, while engaging stakeholders, learning from different experiences, and empowering the least privileged groups in society?

In beginning to pose such questions, worldwide "knowledge societies" are facing a new transition—potentially comparable in significance to the Enlightenment itself. Beyond simply recognising the possibility of progress in knowledge and innovation, we are beginning to engage with the realities of the multiple, contending directions for advance. This paper argues that by becoming more clear-eyed and empowered about the possibilities for a more deliberate steering of progress, we face the opportunity to move from Enlightenment to what we might call "Enablement." As with other such transitory opportunities, it remains unclear whether we will make this choice or pass it by.

Two faces of technological vulnerability

This dynamic of continuously branching choices is characterized by two important kinds of vulnerability. The first is society's vulnerability to technology; that is, people, their environments, and fellow creatures are perpetually vulnerable to the unforeseen, unintended or contested consequences of our evolving technological commitments. Some examples might include offensive weaponry, nuclear materials, toxic chemicals, urban congestion, alienating architecture, commodity crops, intensive husbandry, zoonotic diseases, processed foodstuffs, and fossil fuels. In each case, it is the possibilities of alternatives that make these exposures "vulnerabilities" rather than immutable conditions of existence.

The second vulnerability is the converse of the first: that of technology to society. Entirely feasible and viable technological pathways are themselves vulnerable to being foreclosed, especially at their incipient stages, by circumstance or contrary societal forces. Examples include renewable energy, sustainable agriculture, preventive health care, green chemistry, public media, socialized transport, open source software, community architecture, etc. No matter how much more favorable a particular path may seem, it can rapidly become impossible to shift course once certain formative moments have passed.

Complex historic forces determine how societies selectively commit to certain technological pathways as opposed to others. Some systematic mechanisms result in channelling a restricted subset of possible directions. For instance, though they may originate in essentially random patterns, the simple positive feedback dynamics of market "lock-in" may direct the course of change, as with the ubiquitous, but dysfunctional QWERTY keyboard—the result of 19th century mechanical typewriter design requirements—which persists in today's highly competitive computer products. Similar mechanisms of path-dependency and lock-in characterize such artefacts as bicycles, automobiles, road systems, prisons, nuclear power, computer software, chemical production, civil engineering, and weapons systems, all of which reflect the needs, preferences, values, and interests of rather restricted social groups. This is also true of the routines, practices, and thought paradigms of even the most successful and influential innovating organizations, which become imprinted in resulting technologies and the trajectories which they promote.

Cultural expectations may also assert the sensibilities of relatively privileged social actors, such as entrepreneurs, investors, regulators and opinion makers. Once established, these socio-technical interests can become institutionalized and acquire their own momentum at the expense of less-privileged alternatives, and may, in turn, become virtually autonomous, "capturing" ostensibly neutral (or even supposedly contending) social actors. This phenomenon is often observed in such areas as nuclear infrastructure, the fossil fuel and automotive industries, industrial chemicals, genetic modification, cigarette manufacture, food additives, pharmaceuticals, and military systems. In this way, early assertive expectations over which pathway will be followed can be self-fulfilling. Investors, suppliers, regulators, and customers will often pick winners on the grounds of perceived inevitability, rather than judgements of superiority. Expectations can thus be self-reinforcing, foreclosing even what all agree to offer preferable long-run options.

In recent times, this foreclosing of contemporary technological choice is in many ways intensified by increasingly transnational capital flows, regulatory standardization, trade harmonization, market concentration and globalising governance, all of which may all exert a homogenizing effect on what might otherwise be more varied selection environments. Such developments may reduce global diversity in areas of technology choice, such as food production, energy services, public health, materials management, urban mobility, information, and communication. Although real world complexities do allow for some degree of persistent technological diversity, it remains impossible to realize fully all physically feasible—or even functionally viable—technological configurations, with no guarantee that even the most favorable long term pathways will be utilized.

Who pays the highest price for this foreclosure of choice? One pervasive consequence of the indeterminacy of technological vulnerability is that, despite the diversity and complexity of these branching choices, adverse repercussions tend to fall most heavily on those people with the least resources, privilege, or power. This is true for three main reasons: first, because technological evolution implies change and uncertainty. As shown with tragic frequency in earthquakes, floods, droughts, hurricanes and epidemics, even where there exists general parity of exposure across rich and poor, the impact tends to fall most damagingly on the least affluent and most excluded of people. Poverty impairs adaptive capacity and resilience; subsistence farmers are unable to follow recommended practices; the lowest paid workers operate outside health and safety law; product usage regulations fail to account for the way children play; toxic waste management excludes export to poorer countries. And, as with natural disasters, pre-existing social conditions of marginality exacerbate vulnerability to even the most general of the unforeseen, unintended and contested consequences of technological commitments.

Second, technological vulnerabilities, as distinct from natural ones, bear even more disproportionately on the least powerful because of the systematic tendency for preference to be given to those technological pathways which favored existing privileged interests. The adverse effects associated with modern processed food, for example, fall disproportionately on those who are most marginalized, even within affluent populations. The third reason follows distinctly from this. Not only are the poor vulnerable to the technological choices of the rich, but the technological choices that might most favor the interests of the poor are also disproportionately liable to being foreclosed.

Governance of technological risk

In recognising that vulnerability to the consequences of technological choices fall most heavily on the least powerful, it is interesting to note the desire on the part of contemporary institutions of technology governance to express socially progressive aspirations. "Sustainability," "equity," and "poverty-reduction" feature prominently as the declared motivations behind international policy making.[1] Taken at face value, these suggest serious commitments to reducing the adverse effects of technological choices. In order to deliver on such socially progressive claims, one might expect that technology policies and strategies would address the underlying challenges of technology choice. Of course, even given that such lofty ambitions to remedy all the deeply-entrenched uncertainties are unlikely to be successful, it seems reasonable to judge the general efficacy of technology governance by how seriously leaders actually engage with these fundamental realities.

It is, therefore, quite striking that much high-level discourse in technology governance does not reflect these issues. Rather than highlighting the pros and cons of alternative pathways, the reality of choice itself is denied, exacerbating the associated vulnerabilities. This was eloquently illustrated by the President of the UK Royal Academy of Engineering in the globally-broadcast BBC Reith Lectures, who portrayed history quite explicitly as a one-track "*race to advance technology*," with the challenge being simply "*to strive to stay in the race.*" He asserted that technology "*will determine the future of the human race*," rather than the other way around. Existing patterns of technology are seen as self-evidently good, with the role of the public being simply to "*recognise … and give* [technology] *the profile and status it deserves*."[2]

According to these elite representations of technology change, Prime Ministers and European Commissioners, for instance, routinely defer to the supposedly determining role in decision making of unspecified notions of "sound science," while public misgivings over particular technologies are either misrepresented or stigmatized as being "anti-science" or "anti-technology." Senior politicians treat dissent over specific aspects of unfolding directions of technological change not as legitimate evaluative positions, but as prejudiced and unreasonable. Indeed, to a former deputy director of the United Nations, criticisms of particular technologies were interpreted as indiscriminate anti-technology fears, reflecting a "flat earth society, opposed to modern economics, modern technology, modern science, modern life itself."

Political rhetoric will typically advocate the "way forward," without specifying a direction. Yet it seems only in the field of technological progress that this polemic has been elevated to metaphysical status. There is no doubt that the political implications are expedient. But they may also reflect more emergent forms of dissonance. The multiple possible vectors for progress are reduced to a single scale. Technology is invested with its own agency. Attention is fixated on actuality rather

[1] See, for example, UNEP, 1997; Millennium Development Declaration, 2000; and Obama, 2009.

[2] Broers, 2005.

than potentiality. Value is held to be self-evident. Progress is teleologically defined by whatever unfolds. In all these ways, conventional elite discourses on technological progress appear reminiscent of "pre-operational" thought in child development. In other words, they are akin to "baby talk."

Whether intentional or not, the effect of this language renders it more than just rhetoric. In effect, it denies even a vocabulary for dissenting interests in technology choice. It undermines the very discussion of the adverse effects of technological choice and risks alienating those dedicated political resources, practices, and institutions which have been so hard-won in other areas and which have facilitated healthy, critical, democratic politics of social choice. The least powerful are further disempowered.

One possible exception to this picture serves to underscore the general pattern: in the area of climate change, problems of vulnerability to ill-advised technology choice are undeniable. Emerging climate change policies are unprecedented in the scale of deliberate societal aims to remedy the obvious adverse effects of existing technologies. Even here, though, there is scepticism over the mismatch between targets and established market trends. And, despite the explicit values proclaimed, specific technologies continue to be seen in remarkably unitary terms. The transition to a low-carbon economy is often treated simply as a matter of "management," with associated choices and values implicitly self-evident and devoid of political content. Despite the many low-carbon possibilities, it is routinely claimed on behalf of options favored by incumbent interests (such as nuclear power), that there exists "no alternative." When such misleading assertions are challenged, the back-up arguments are that we should do everything. Each position, like the mainstream discourse described above, excludes the real challenges of prioritization and commitment in technology choice.

To recognize that in this area, as in others, societies face real technological choices in no way trivializes the monumental scale and urgency of dealing with the effects of climate change. With options including carbon capture and storage, various forms of geo-engineering, a multitude of frameworks for demand efficiency and energy service innovations, alternative varieties of nuclear power, centralized continent-scale renewable energy infrastructures or shifts towards a diversity of new distributed small-scale sustainable energy resources, there is a plethora of feasible low-carbon pathways. With contrasting pros and cons and enormous potential for scale economies and learning-by-doing in every case, each of these could plausibly be considered as a potentially central element in dedicated climate technology policies. Granted, any strategy must inevitably involve some diversity and not all of these options can be fully realized together. However, climate change policy remains a critical arena within which technology governance *amplifies*, rather than reduces, the risk of "closing down" technology choice.

This alarming dearth of attention to choice should not be taken to imply that all aspects of technological vulnerability are entirely neglected in mainstream governance. For example, the prominent field of risk regulation involves a worldwide framework of institutions and practices of formidable scale and complexity. In areas such as occupational health, consumer safety and environmental pollution—if not yet in the field of climate change—there is no doubt that this infrastructure has been responsible for significant reductions in the adverse effects that might otherwise have been presented by unfettered market-based processes. The point is, however, that existing provisions for risk regulation address only a limited subset of the complex issues raised by multiple technological potentialities. Far from highlighting choices between radically contrasting orientations for technology, mainstream risk management tends to focus on modifying the details of existing paths. The resulting effects of regulation can thus serve to further enhance "lock-in" to those already existing pathways and the erection of barriers to more radical change. In other words, by concentrating political attention on circumscribed notions of risk, conventional regulation—despite its incidental benefits—serves at times to reinforce vulnerabilities to narrow or restrictive technological pathways.

In order to substantiate this serious claim, it is important to consider more carefully how conventional risk regulation routinely *excludes* scrutiny of alternative options or claimed benefits, as tends to be the case across almost every sector and virtually every jurisdiction. In such areas as food safety, chemical pollution, or genetically modified organisms, risk assessment typically focuses in a narrow fashion on highly codified notions of "evidence" concerning the probabilities of restricted kinds of hazard in particular favored technologies. In addition to the evidence presented in the voluminous analytic literature, the author can also testify from personal experience on a number of regulatory advisory bodies that the criteria for regulatory intervention are typically very demanding. Rarely is any consideration given to complex or additive effects or cumulative trajectories. Even where a focus of concern lies in the functioning of relevant laws, it is typically assumed that social actors comply with the applicable regulations. Only if a given adverse property of a new product can be found to be absent from any other technology on the market, is this considered as grounds for regulatory action. Thus, the baseline for acceptable risk is effectively taken as the performance associated with the *most harmful existing product*, no matter how negative this is acknowledged to be. The unfolding of associated technological pathways is thereby addressed as a succession of single incremental cases, each taken in isolation, and subject only to testing at the level of the lowest common denominator in contemporary practice.

In order to be credible in this highly restricted, asymmetrical discourse, those who advocate for the values or social benefits of alternative technologies must articulate their position in more covert ways. They must substitute legitimate social evaluation with what will be accepted as "science-based" grounds for concern over the physical harms to human health or environment which are threatened by the mainstream technology. These critics must demonstrate these harms rigorously in advance, often requiring expensive forms of audit and analysis and according to highly demanding standards of proof. Even in the field of medicine and human health, where risk-regulatory intervention tends to be most stringent, the demands are systematically stacked against those who are sceptical of existing directions of technology change. Here, as elsewhere, it is asserted as a principle of "sound science" that concerns must be evidence-based in highly circumscribed ways, even if the salient features in question are—as is by definition the case with much innovation—substantively novel in their details. Yet, in a highly unscientific corollary of this, absence of evidence of harm is routinely treated in risk regulation as if it constituted *evidence of absence* of harm. These are some of the ways in which risk regulation routinely helps to promote mainstream industrial interests over potentially viable alternatives in such areas as chemical production, nanotechnologies, pharmaceuticals, genetically modified organisms, civil engineering, transport infrastructures, information, communication and military systems. Clearly, this invocation of science in risk regulation prompts further consideration of the roles of knowledge in technology choice.

Power and knowledge in the social appraisal of risk

Political, economic and institutional forms of power are not just *implicated* in the tangible business of technology choice. They are also routinely entangled in the substance, limits and interactions of the contending knowledges that help to inform and condition these choices. Indeed, deeply engrained conceptions of the nature of knowledge can serve to compound technological vulnerabilities in a number of ways.

The first unfounded assumption is that the mere marketability of a particular innovation is sufficient authority for presuming that it is socially acceptable. In other words, if, in the view of market actors, a particular next step in an innovation can be shown to work, then this is *prima facie* evidence that it signifies "progress" and that it is somehow inevitable. As we have seen, established regulatory structures qualify this picture only in cases where exceptional risks are identified. Attention to wider political interests, ethical issues or cultural values is typically given only where an innovation may offend the strongest sensibilities of established religions: for example, in the ethical preoccupations with reproduction or control over one's body, rather than equity in pharmaceutical priorities, infringements of commons in release of genetic modifications, or the risk of organized violence from military weapons. But even for those risks that are subject to such explicit ethical considerations, the effect (as in risk regulation) is more often to modulate—and even reinforce—established practice than to open up alternatives. Little room is left for scrutiny of the purposes or motivations that drive the favoured directions for science and technology. In this way, technical *feasibility* is effectively treated as a proxy for social *acceptability*. In this way, technology governance systematically excludes crucial issues explored by such thinkers as Aristotle, Kant, and Habermas, who have shown that knowledge is an insufficient moral basis for action.[3] Just because we know *how* to do some possible thing, does not mean that we *should* do it.

A second false assumption is that if knowledge is adequate to enable an innovation, then it will give us a complete understanding of the consequences. Clearly, our knowledge of

[3] Habermas, 1984.

the consequences of technology choice—both positive and negative—is, in any given area, seriously incomplete. Humanity's experience with unexpected carcinogenic, mutagenic, neuro- and repro-toxic and endocrine-disrupting effects of synthetic chemicals show repeatedly that we are as vulnerable to the harmful risks from entirely novel mechanisms of otherwise well-functioning innovations, as from known hazards. Therefore, even when we have the best available information, it is difficult to determine unequivocally which of a range of alternatives may prove most favorable. Yet the absence of *documented* risk continues to be asserted as sound scientific grounds for presuming that existing strategies in such new areas as nano-materials are acceptable. Since contemplating the unknown necessarily requires imagining beyond the available evidence, it is treated as "unscientific" in conventional risk regulation. What might truly be thought unscientific, however, is this effective denial of the unknown, which obscures the fact that knowledge of the familiar and of the novel are not necessarily one and the same, and further privileges favored pathways of innovation over existing alternatives. Once again, to assume completeness of knowledge and address seriously only those potential risks for which there is already evidence excludes the ancient wisdom of Lao Tzu and Socrates, as well as of modern economists such as Knight, Keynes, and Loasby, that what we don't know is as important as what we do know.

A third wrong, but less acknowledged, assumption about the nature of knowledge compounds this dilemma. Even the most apparently complete knowledge may nonetheless be indeterminate in its implications. In other words, no matter how much we think we know, we will always be subject to surprise. This may be because pertinent knowledge is unevenly distributed in society: different aspects of the consequences of contrasting choices will be known to varying degrees in different communities. We are especially vulnerable to this where—as with Rumsfeld's famous "known knowns"—we are complacent about what is supposedly "known," without paying due attention either to the meta-criteria by which this itself can be known—by what means and to whom—or to the crucial social origin and context of the knowledge in question. For example, approval for the halo-hydrocarbon refrigerants and aerosols which later caused stratospheric ozone decline was initially driven by complacent acceptance that these substances were benign. Yet the knowledge of specialists concerning the vulnerability of the atmosphere to these compounds was effectively-ignored for many years until later awarded a Nobel Prize.[4] Even in the rigorously codified and exhaustively explored field of mathematics, Gödel showed axiomatically that apparently complete domains of knowledge may always conceal indeterminacies.

A fourth problem area arises because the relationship between knowledge and ignorance is the inverse of what is conventionally presumed. Even if the fallacious assumptions cited above are avoided, it might still seem reasonable to expect that *increasing* knowledge will at least *decrease* our ignorance. This is why risk assessment frequently suspends judgement pending further research, presuming that the resulting increased knowledge will dispel our ignorance. Unfortunately, hard-won but oft-forgotten experience shows this also to be a precarious assumption. For example, advances in knowledge resulting from complex systems research and enhanced computing capabilities reveal chaotic nonlinear dynamics—and thus imminent surprises—in even the most determinate of systems. Knowledge of specific outcomes in such fields as climatology, oceanography, and ecology may thus come to be recognized as less well-founded after such advances than before. Increased knowledge has actually led to increased ignorance.

A fifth incorrect assumption holds that knowledge is additive. If it is conceded that knowledge is distributed across different groups and that pooling this may increase ignorance, as discussed above, surely we may at least be confident that adding such knowledges together at least means increasing the total stock of knowledge. Unfortunately, this is also not necessarily true. In regulating GM crops, for example, the varying understandings of geneticists, virologists, cell biologists, soil scientists, ecologists, agronomists, economists, and sociologists are fundamentally in tension, and so inimical to simple aggregation. The same is true of the "knowledge" of biotechnology entrepreneurs, chemical producers, plant breeders, industrial agriculturalists, and subsistence farmers, since such knowledge is strongly conditioned by their diverse social contexts and disparate cultural values. Yet risk assessment proceeds as if it were possible simply to add together different knowledge "inputs" and arrive at a single more comprehensive—or even more "objective"—picture.

Sixth, risk regulation assumes that "facts" and "values" are

[4] Farman, 2001.

effectively independent. At heart, knowledge is assumed to be constituted by facts, irrespective of any conditioning values or interests. This is the essence underlying, rigid institutional distinctions between "risk assessment" and "risk management." Again, this is manifestly incorrect. Our understandings do not exist in innocent isolation, but are unconsciously intertwined with contingent experience and interests. In sectors such as nuclear power, genetically-modified crops, proprietary pharmaceuticals and nanotechnology, for instance, knowledge is actively shaped by our wider social, economic, and technological commitments. Vast infrastructures are constructed not only on the basis of what we think we know, but also of what we wish for—and act as if it were so. This does not simply increase exposure to associated ignorance. It also forms powerful pressures to exaggerate convenient knowledge and suppress inexpedient ignorance. The more we are committed to what we think we want and know, the greater is the pressure to exclude that we might be wrong.

This latter powerful political dynamic may help to shed light on the inexplicable persistence in risk regulation of these unsafe assumptions about the nature of knowledge. Whatever the reasons, each assumption tends to compound our technological vulnerabilities. Together, they exacerbate exposure to risk and detract from real understanding of the consequences of technological alternatives. They provide a screen behind which those powerful interests which determine how knowledge is represented can adopt the most expedient interpretations, thus compounding specific risks. Further, they provide a pretext for the active dismissal of inconvenient knowledge possessed by marginal groups. And such dismissal can apply as much to progressive social interventions intended to reduce or forestall unforeseen, unintended, or contested effects as they do to the technological pathways themselves.

Precaution in the regulation of technological risk

Recent years have seen the growth of an important institutional response to these neglected entanglements of power and knowledge in technology governance: the precautionary principle.[5] Associated controversies play out in academic literatures on risk, in environmental science, social science, international law, and feature prominently in mainstream political discourse. Nurtured in the earliest multilateral initiatives for environmental protection in the 1970s, precaution (*Vorsorge*) first came to legal maturity in German environmental policy in the 1980's. Since then, it has been championed by environmentalists and strongly resisted by some of the industries they challenge. Diverse formulations of the principle proliferate in international instruments, national jurisdictions, and policy areas. From a guiding theme in European Community (EC) environmental policy, it has become a general principle of EC law, and a repeated focus of attention in high-stakes trade disputes.

Applying especially to technological risks in areas such as food safety, chemicals, genetic modification, telecoms, nanotechnology, climate change, and public health, precaution has until recently been particularly controversial in the United States. Elsewhere, however, its influence has extended from environmental regulation, to wider policy making on issues of risk, science, innovation, and world trade. As it has expanded in scope, so precaution has grown in profile and authority and in its general implications for the governance of technology.

Sometimes generally characterized as an injunction that "*it is better to be safe than sorry*", precaution has been subject to a storm of strongly-asserted criticisms, specifically, that it is ill-defined, intrinsically 'irrational', inherently favors discriminatory measures and implies a blanket rejection of technology. It is striking, even in academic debate, how much of this criticism avoids engaging with the real form taken by precaution, let alone the wider implications. Although there exists a variety of variously permissive or stringent forms, this can be illustrated by focusing the canonical version of precaution, expressed in Principle 15 of the 1992 Rio Declaration:

> *"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."*

By considering even this relatively early and straightforward expression of the precautionary principle, we can see how misguided are many of the most prominent criticisms.

First, far from being ill-defined, the precautionary principle actually hinges on the presence in decision making of two particular properties: a potential for irreversible harm and a lack of scientific certainty. Thus, precaution is not a detailed

[5] Stirling, 2009.

decision rule in its own right, but, as its name conveys, a general principle. Just as principles like proportionality or cost effectiveness are partly defined by their methods—such as risk assessment and cost-benefit analysis—so, too, precaution is as much about methods and processes of appraisal, as about rules and instruments in risk management. It makes no more sense to say the principle on its own is "ill-defined" than to say this of any other such general principle.

Second, rather than being intrinsically "irrational," precaution simply involves being transparent over the evaluative presumptions under which rationality is to be applied. As we have seen, though they play an essential role in conventional risk regulation, values are often concealed by the language of "sound science." Precaution, on the other hand, explicitly articulates a position under which qualities of environmental integrity and human health are on balance favored over the more restricted sectoral or strategic institutional interests asserted by incumbent market actors. Real irrationality lies in the denial that risk science is devoid of values.

Third, there is the undifferentiated "anti-technology" rhetoric that we have already examined. Far from necessarily implying the blanket rejection of even single technological pathways, precaution actually refers to the *reasons for action*, not to the substance or stringency of the consequent actions themselves. It may, thus, as readily lead to strengthened standards, containment strategies, licensing arrangements, labelling requirements, liability provisions, compensation schemes, substitution measures, and research strategies as the much-feared bans or phase-outs. Precaution is about being more deliberate in our technology choices.

Fourth—and contrary to concerns that it inherently favors discriminatory measures—precaution applies in principle symmetrically to all technological or policy alternatives in any given context. There is no reason why it should be felt to favor one pathway over another. Precaution thus constitutes a general discipline in technology choice, under which environmental and human values are rendered more explicit and transparent and the intensity and orientations of commitments become a matter for deliberate political engagement.

In short, regulatory innovations prompted by the precautionary principle are responding to each of the flawed assumptions found in the last section to underlie conventional risk-based approaches to the governance of technological vulnerabilities. The explicit value of precaution addresses both the insufficiency of knowledge as a moral basis for action and the reflexive intertwining of knowledge and interests. The focus on scientific uncertainty addresses properties of incompleteness and uncertainty in knowledge that are otherwise neglected in risk regulation. Finally, and more indirectly, by prompting further reflection and more sophisticated practices in response to uncertainty, precaution helps focus greater attention on the sometimes inverse relationship between knowledge and ignorance and the lack of coherence between and among different knowledges.

The essential contribution made by the precautionary principle, is therefore to provide a framework under which to broaden out the processes through which societies come to understand the implications of our possible technological choices. By focusing policy attention on uncertainties of a kind that are otherwise neglected or denied, precaution acts to help extend and enrich the ranges of issues, the arrays of options, the varieties of scenarios, the palettes of methods, and the pluralities of perspectives that are engaged in the social appraisal of alternative technological pathways.

Risk, power and public engagement

It was shown earlier how various problematic assumptions and political processes serve to "close down" social commitments around technological pathways favored by existing interests. Part of this phenomenon is the way that power also operates in the institutions and practices of appraisal, to condition not only the concrete choices themselves, but even the form of our knowledges concerning possible alternatives. Liability law, for instance, often allows private decision makers effectively to ignore those possible forms of harm which may reasonably be claimed to be unknown. Even if damages actually transpire, circumscribed definitions of harm, time constraints, procedural rules, compensation limits, fault restrictions, and channelling of responsibility may all serve to protect the beneficiaries from the repercussions of their optimistic assumptions. Likewise, the practice of insurance—for those protected by the terms of contract—apparently translates intractable conditions of uncertainty into a more comfortable state of actuarial risk.

The effect of all these institutions and procedures is to close down not only technology choices, but also what counts as legitimate or plausible representations of knowledge on the associated implications and meanings. This, in turn, provides the vital political resource of justification, thus allowing "decisions" to be conceived, asserted and defended, and "trust" and "blame" to be effectively managed. As a result, powerful incumbent interests manage to further externalize the consequences of the uncertainty and inevitability of technology choice. The inconvenient limitations of knowledge do not disappear, of course, but are simply rendered invisible. It is then only a matter of time before they bite back with the tragic inevitability of Bhopal, Chernobyl, or the global "credit crunch." In this self-reinforcing dance of imperatives, restricted, risk-based methods for addressing technology choice are both produced by, and actively help reproduce, the wider political dynamics. This is the predicament neatly described by Beck as "organized irresponsibility."

It is against this background, that we may come to better understand the real significance of increasing moves towards public engagement on questions of technology choice. Across all parts of government, business and civil society, diverse forms of this discourse are now burgeoning. Champions arise well beyond practitioners and social scientists and emerge in places as diverse as the European Commission, Greenpeace, the House of Lords, the Royal Commission on Environmental Pollution, government departments such as the Department of Innovation, Universities and Skills (DIUS) and large corporations such as Unilever, as well as within established institutions of science, engineering and medicine from the Royal Society and the Wellcome Trust to the Research Councils. Yet attention typically focuses more on *how* engagement takes place rather than *why*. This is especially true with political choices over the directions taken by science, technology, and innovation.[6]

Public engagement here has many faces. Variously pursued as "citizen participation," "inclusive deliberation," or "stakeholder dialogue," it takes place both in and with contrasting publics. Specific approaches include citizen juries, focus groups, consensus conferences, interactive websites, strategic commissions, and stakeholder panels. Yet amidst the clamor, this basic question of "why?" has no single answer. It prompts a variety of equally reasonable but contending responses. Is public engagement about enriching and invigorating our democracy? Is it about fostering trust and acceptance? Or does it try to build better, more robust pathways for science and technology? Under different circumstances and from different perspectives, different points are emphasized. The question gets more complex—and more intrinsically political.

Central here are the neglected realities of scientific and technological progress discussed earlier. As we have seen, whether in agriculture, energy, ICT, materials or public health, technical and institutional innovations may unfold in a variety of directions. Low-carbon energy strategies may focus on efficient use, smart grids, carbon capture, nuclear fission, or centralized and distributed renewables. The path to sustainable agriculture is variously claimed by organic farming, advanced cultivation, GM crops, and non-GM biotechnologies. Responses to the shortage of human organs are promised by embryonic or adult stem cells, xenotransplantation, various medical technologies, or preventive public health. Innovation for public health might more generally prioritize proprietory pharmaceuticals for treating relatively innocuous diseases of the rich, or "open source" responses to some of the most devastating afflictions of the poor. It is against the background of the pressing realities of choice that we can consider the fundamental political dynamics underlying discussions of public engagement.

In short, the answer to the question "Why engage?" receives different, equally reasonable responses, depending on how public engagement is perceived, designed, implemented, and evaluated. First, a dominant view among many academics, commentators, and practitioners is that public engagement is about enhancing the *democracy* of scientific and technological choices. In this view, engagement is justified, even if the choices that arise are agreed to be less effective, efficient, or timely. As long as the *process* itself is more enriching, empowering, or fair, then democratic aims are satisfied. The design (and evaluation) of engagement is geared to counter undue influence from vested interests and ensure qualities like accessibility, transparency, equity, and legitimacy in the course of decision making.

In contrast, the linear, Enlightenment view of progress taken in the world of policy making focuses more on outcomes and less on process. Here, public engagement is a means to an end, fostering commodities like acceptance, credibility, and blame management (for the directions of change favored by incumbent interests) or trust and strategic intelligence (sup-

[6] Jasanoff, 2007.

porting associated institutions and policies). This more *instrumental* rationale hinges on relatively narrow institutional aims, concerning political *justification*, rather than on qualities of the engagement process or supporting vigorous political debate to enable more legitimate choice.

Of course, there is a spectrum of such instrumental positions. There may often be flexibility over which precise outcome is favored, as long as it is effectively justified. Like conventional consultation, expert committees or risk assessments, public engagement can help here in the vital political tasks of maintaining consent and managing conflict concerning whatever recommendations should arise. But in other cases, there will be a clear idea of the particular outcome to be justified. Even without overt manipulation, there are many ways in which engagement—like expert analysis—can be framed so as to favor the "right" answer. By subtle (possibly inadvertent) shifts in process design, particular sites can be selected, specific products approved, or individual policies legitimated. Again, this is not a partisan point. It applies as much to an environmental NGO looking for radical changes in energy or transport behaviors as it does to powerful industrial interests defending the *status quo* in present technologies and policies. Whether such an instrumental motivation is judged good or bad depends on the point of view. Either way, the design (and evaluation) of engagement is focused not on process, but on privately favored outcomes (such as trust, acceptance, or blame avoidance).

The third general motivation for public engagement in technology choice also hinges more on outcomes than process. Here, though, the merits are not judged in terms of narrow sectional interests. Instead, they appeal to widely-recognized substantive qualities, such as reducing impact, protecting health, enhancing precaution, or promoting social well-being. Though details differ, all agree as to the overall desirability. For instance, a corporation may be genuinely open-minded about which products to develop, but simply wish to understand the needs and values of potential customers and the wider society. Similarly, organizations such as government departments, regulatory agencies, scientific academies, and intergovernmental bodies all agree that broad public engagement at the earliest stages in the development of a technology can help gather relevant experience and knowledge, and so provide early warning of possible problems.

When it is realized that technological progress occurs as much by intrinsically political choices as by the inevitable unfolding of our knowledge of Nature, then this argument for public engagement is not romantic. Bearing in mind the complexities of knowledge discussed earlier, this simply recognises that public engagement can draw on the relevant knowledge of users, consumers, or local communities to help test more rigorously the assumptions underlying expert perspectives and so confer more robust and plural results. Specialist expertise is essential, but it is not sufficient in order to definitively compare, prioritize, or distribute different forms of benefit or harm. This is not just about validating subjective judgements over issues like the prioritization of avoiding injuries or disease, harm to workers or children, or the impact on biodiversity or jobs. Nor is it primarily about fairness or democratic legitimacy in political processes. A substantive rationale for public engagement aims rather at ensuring deeper, broader, and richer consideration of relevant options, issues, uncertainties, and values. It is in this way that we might hope to enable more socially robust choices; and so in this very real sense, "better" technologies.

Opening up directions for choice

It is for these reasons, that there can be no single final or definitive answer to the question "why engage the public on scientific and technology choices?" Responses will inevitably vary by circumstance, perspective, and timing. We may wish simultaneously to nurture democratic process and promote more specific and private instrumental ends on the lines outlined above. But these motives have different implications for the ways in which we view and carry out public engagement in science and technology.

There are particularly serious implications for the *evaluation* of engagement. Since they vary with motivation, evaluation criteria may display odd contradictions and circularities. In the British government's 2003 dialogue exercise about genetic modification (GM) of foods,[7] one of the evaluation criteria was the impact on decision making. Since the outcome was rather sceptical about GM, it failed to justify more positive government policy. As a result, it was not particularly influential. This contributed to under-performance in the official evaluation, which was cited, in turn, as a (circular) reason for government caution over the exercise in the first

[7] DEFRA, 2003.

place. To include "policy influence" as an evaluative criterion for well-conducted public engagement (rather than for wider governance) is a sure sign that there are unrelated underlying motivations.

Taking account of all these complexities—and the backdrop of branching technology choices discussed earlier—we can draw a distinction between initiatives that try to open up decisions on science and technology and those that close down.[8] Conventional approaches to public engagement tend to assume that the most desirable general outcome is the achievement of closure (a verdict in a citizen jury or consensus in a consensus conference). This appears simultaneously to fulfil the functions of democratic process, practical justification and the identification of substantively "best" options. Yet it is just this kind of closing down that presents some of the most acute problems. If closure takes place invisibly within a specific engagement process, then questions arise as to what the role of established democratic institutions should be. How representative, legitimate, or accountable are the included participants or procedures? Might a similar exercise have arrived at different conclusions if it were structured or informed in a different way? What was the opaque (possibly accidental) influence of power *within* the engagement process?

Instead, we may use a range of different approaches to achieve a complementary role for public engagement exercises on science and technology. Rather than aiming at closing down around a single recommendation to policy making, approaches such as open space, deliberative mapping, interactive modelling, multi-criteria mapping, scenario workshops, and dissensus groups instead transparently open up implications of different possible choices. They explore in detail—and open to external view—the ways in which alternative viable directions for science and technology appear favorable under contrasting assumptions, conditions or perspectives. They offer richly detailed information concerning interactions between options, values, and knowledges. The resulting "plural and conditional" recommendations provide a more authentic reflection of the irreducible political complexities. Such recommendations are plural because, while they may rule out some, they outline a range of potentially justifiable actions. They are conditional because each recommendation is qualified by associated values, assumptions, or contexts.

Although possibly inconvenient to officials or managers attempting to prescribe decisions, responsible politicians or chief executives may actually welcome this deeper information. For every senior civil servant insisting that practical advice must take the form of a single sentence in a one-page briefing, there is a beleaguered Minister wondering how much their latitude for choice has been constrained (and *vice versa*). Despite the apparently greater humility and caution of this opening up approach, it can also—by clearly identifying pathways that appear unfavorable under *all* viewpoints—add to the robustness of decisions. Where engagement highlights alternatives, the resulting justification is also more credible. Choices are still made, but decisions are better informed, more transparent, and at the right level.

An opening up approach to public engagement can help nurture a richer, more vibrant, and mature politics of technology choice. It recognizes that different knowledges, values and interests favor different, equally feasible, directions for innovation. This is not postmodern "anti-science." Just because a number of directions are viable does not mean that "anything goes." In fact, this approach is more realistic about science and technology and celebrates its many possibilities. Just as what Robert Merton called "organized scepticism" is recognized as a fundamental quality in science, so pluralism and dissensus in public engagement can help build more rational social discourse about science and technology. And by making processes of closure more transparent, systematic opening up is also more consistent with existing procedures for democratic political accountability. Thus, public engagement helps to enable, rather than suppress, a healthier politics of choice.

It is through the progressive institutional and methodological innovations discussed in this paper that we may hope to meet the challenges of more honest, open, and deliberate steering of the continuing processes of scientific and technological choices with which we began. In particular, precaution offers a framework for increasing the breadth, diversity, and humility of our use of knowledge in the face of uncertainty over innovation. It reminds us that choices in science and technology are often conditioned by quite proximate political, economic, and institutional interests, and that we might therefore wish to balance this with more explicit attention to general values of human well-being and environmental integrity. Likewise, rather than simply fostering understanding, trust, or acceptance, public engagement offers ways to be

[8] Stirling, 2008.

more mature, explicit, and accountable when dealing with the implications of a plurality of possible choices. Where engagement yields divergent outcomes in different contexts, it opens the door to pursuit of a greater diversity of pathways, under different social and political conditions.

Only by acknowledging the limitations of current mainstream Enlightenment notions of progress, can we come to appreciate the real value of these new developments. They take us away from impoverished fixations with "how fast?" "how far?" and "who leads?" in a race along some preordained track. In their place, we engage with more open questions that do greater justice to the real multivalent genius of science and technology: "which way?" "who says?" and "why?" When mainstream policy debates on innovation in knowledge societies begin openly to empower this more challenging and overtly political kind of question, then we will know that we are truly moving from Enlightenment to Enablement.

References

Beck, U. 1992. *The Risk Society*. London: Sage.

Broers, A. 2005. *The Triumph of Technology: Lecture 1 of the 2005 Reith Lectures.* BBC, London. Transcript (16/7/6) at: http://www.bbc.co.uk/radio4/reith2005/lecture1.shtml

Department for Environment, Food and Rural Affairs (DEFRA). 2003. *GM Nation: Findings of a Public Debate.* London: Department for Environment, Food and Rural Affairs. At: [16/12/2008] at: http://www.gmnation.org.uk

Farman, J. 2001. "Halocarbons, the Ozone Layer and the Precautionary Principle." European Environment Agency, at: http://www.eea.europa.eu/publications/environmental_issue_report_2001_22/issue-22-part-07.pdf

Habermas, J. 1984. *The Philosophical Discourse of Modernity*. Cambridge: Polity.

Jasanoff, S. 2007. *Designs on Nature: Science and Democracy in Europe and the United States.* Princeton, NJ: Princeton University Press.

Millenium Development Declaration. 2000. *United Nations General Assembly Resolution* A/RES/55/2, 18th September 2000. At [30/3/6]: http://www.un.org/millennium/declaration/ares552e.pdf

Ministerial Declaration. 1995. Fourth International Conference on the Protection of the North Sea. Esbjerg: Denmark, 8–9 June.

Obama, B. 2009. Technology. Section of "*the Agenda*" posted on Whitehouse Website. At [4/9]: http://www.whitehouse.gov/agenda/technology/

OSPAR 1992. Convention for the Protection of the Marine Environment of the North-East Atlantic. At: http://www.ospar.org/eng/html/welcome.html

Stirling, A. 2008. "Opening Up and Closing Down: Power, Participation and Pluralism in the Social Appraisal of Technology." *Science Technology and Human Values* 33(2):262–294, March. At: http://sth.sagepub.com/cgi/content/abstract/33/2/262

———. 2009. "The Precautionary Principle." In J-K. Olsen, S. Pedersen, V. Hendricks (eds.), *Blackwell Companion to the Philosophy of Technology.* Oxford: Blackwell.

Modan, B. and S. Billharz (eds.). 1997. "Sustainability Indicators: Report of the Project on Indicators of Sustainable Development. United Nations Environment Programme. Chichester: John Wiley.