Ways of Knowing Novel Materials

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Nearly 30 years ago, David Collingridge articulated the fundamental dilemma of technological governance: in the early phases of technological evolution, many avenues of advance are available and promising, but too little is known about potential impacts to choose the best paths. Later on, when more is known about impacts, options are greatly restricted due to technological lock-in and vested interests. Overall, the evolution of technological systems creates increased certainty about impacts, and reduces options about how to deal with them.

In this view, innovation paths are chosen through unpredictable and largely ungoverned mélanges of scientific, technological, institutional, cultural and market influences. It is unfortunately not gratuitous to add that when such choices are made explicit by science advocates, they are almost always framed in terms of the inevitability of societal benefit, despite the claim that the path to such benefits is unpredictable.

Of course society has come to be skeptical of such claims of inevitable benefit, due to harsh experiences ranging from Thalidomide to DDT to chlorofluorocarbons to endocrine disruptors. These experiences have given rise to two philosophically distinct approaches to dealing with risk in the environment from an anticipatory perspective. The first is the scientific-rational approach: conduct research to characterize and predict the potential impacts of products or processes as a foundation for decisions about innovation paths and regulatory regimes. The second is the precautionary approach: given uncertainties about potential negative impacts of a product or process, err on the side of caution, prevention, proscription.

To caricature these approaches slightly, the scientific-rational approach seeks to solve the Collingridge dilemma by creating comprehensive, predictive knowledge to guide decisions, while the precautionary approach uses a vague heuristic to regulate in the absence of such knowledge. A good example of the former is the Intergovernmental Panel on Climate Change, which is meant to provide the scientific basis for the global response to climate change; an example of the latter is the 1958 Delaney Clause to the U.S. Federal Food, Drug, and Cosmetic Act, which prohibited any chemical that caused cancer in lab animals to be used as a food additive. Of course the scientific and precautionary approaches are not as distinct as they may seem; in particular, one cannot operationalize the dictum “err on the side of caution” without resort to some metrics or standards that are likely to be at least partly based on scientific knowledge.

A third approach to risk is simply to react on the basis of unpredicted adverse impacts. I won't say more about this approach except to note, first, that we can probably all agree it is the path we most want to avoid and, second, that it is nevertheless the path that we often end up taking, in deference to the power of Collingridge's dilemma. For example, the Commission's 2003 report *Chemicals in Products*[1] reacts to the reality that tens of thousands of synthetic chemicals have already been introduced into the environment.

Nevertheless, if the Commission, in fulfilling its mission of advising on "future possibilities of danger to the environment"[2] wishes to avoid the grueling political battles over sociotechnical change that we have seen in the past 50 years or so, while maximizing the societal benefits from novel materials and minimizing the problems, then the predictive and precautionary approaches will not get you there. They will, on the contrary, help create the next battlefields. The brevity of my comments prevents me from elaborating in detail on this point, but I will summarize the highlights.

As a starting point I want to make clear that I will not be addressing situations where major threats to environmental quality or human health are obvious and well understood. Perhaps an assessment of the behavior of some class of novel materials will reveal such a clear threat. But the more daunting, and probably common, challenge, and the one I will consider here, will be characterized by high uncertainty about how novel materials will behave in the environment, by contested assessments of risk, and by competing claims about future applications. So in this context let me make three observations bearing on prediction and precaution.

First, while science may characterize the uncertainties surrounding the behavior of complex systems, it generally does not reduce them. (Figure 1) Indeed, if, hypothetically, some class of novel materials becomes the focus of controversy regarding potential risks, we should reasonably expect that uncertainties about impacts will increase as a result of new research, not decrease. Research on risk in complex systems can rarely identify clear cause-effect relations that are reproducible among multiple studies. Such research has the effect of providing scientifically legitimated information for competing sides in the dispute—an excess of objectivity; a banquet of facts—thus exacerbating political dispute. The higher the stakes are—the more that people and institutions perceive themselves as potential winners or losers in the dispute—the greater the uncertainty becomes as more science is applied, more questions are asked, more results published.

Second, precaution is in the eye of the beholder. I employ the word "rational" with great care, but I think it not unreasonable to suggest that rational people do not advocate actions that they think will undermine the intent of their own decisions. I very much doubt that we will be faced with a controversy where some groups are advocating the development and application of a novel material whose impacts will unavoidably include thousands of deaths or widespread despoliation of the environment. Disputes over precaution occur where consequences are uncertain and ambiguous; where there are tradeoffs whose opportunity costs cannot be fully assessed. In my opinion the benefits of banning DDT have been a wonderful vindication of environmental science and activism, yet the World Health Organization is now proposing selective application of DDT in areas where malaria remains intractable, and in the U.S. some participants in the DDT debate believe its banning was a disaster from a public health perspective. The idea that "precaution" can be an operating principle for risk management is inherently political and politicizing: Whose view of caution? Caution relative to which individual interests or institutional frames of reference? Caution in terms of which view of how the world works, of how actions and consequences are causally linked?

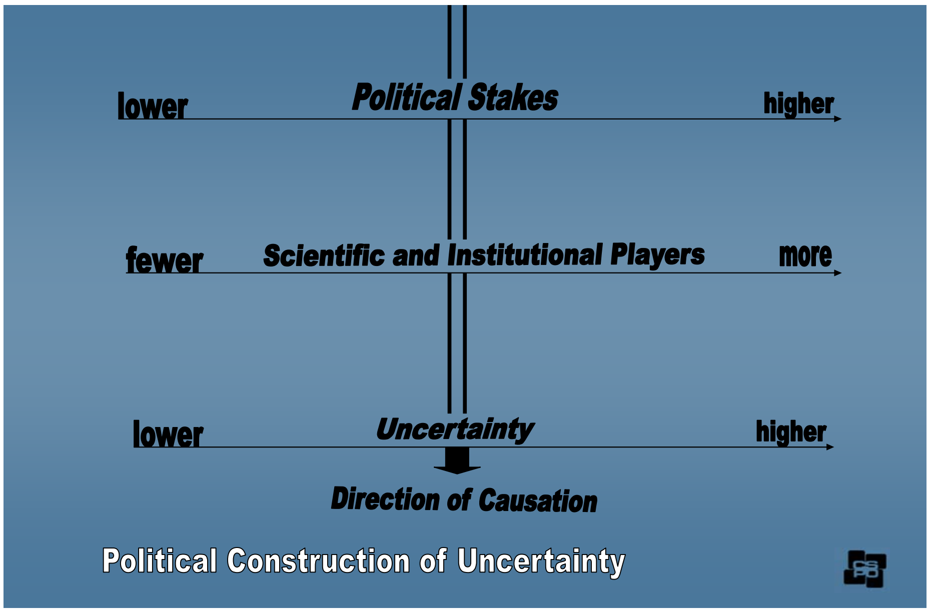

Figure 1

Which brings me to a third point: debates about environmental risks cannot be kept pure. How are we to balance uncertain environmental impacts against uncertain sociocultural, economic, or political impacts? A moment's reflection on controversies surrounding nuclear power, nuclear waste disposal, or genetically modified foods shows how futile it is to try to narrow either the analysis or the politics to a particular risk domain. Any effort to try to restrict discussion to a narrow definition of the environmental risks of novel materials is simply an invitation for those with other sociotechnical risk agendas to cloak their positions in the language of environmental risk, and legitimate them in the language of science. There will always, as I've suggested, be a robust combination of uncertainty and facts to nourish this process. This scientization of political debate camouflages the real issues and interests at stake, and thus has the effect of impoverishing democratic process.

Like it or not, the unfolding of a new area of innovation commits us to engage in a process of selecting which risks are acceptable and which are not. This selection process involves decisions in the midst of uncertainty, and trade-offs among incommensurable values and objectives. How shall we choose between nuclear power and fossil-fuel generated electricity? Or between conventional crops and transgene varieties? Or between novel materials and conventional ones? There is no general, integrated risk standard to apply, and if there were there would be no comprehensive scientific knowledge to support it, and no political forum to impose it. The problem is compounded in emerging domains of innovation, like novel materials, where products, processes, and risks exist mostly in the imagination.

Nevertheless, innovation paths are now developing, which means that risks are now being selected. Where, how, why, and by whom are these choices being made?—those are the key questions. Addressing them means looking at novel materials not just as possible sources of pollution, but also as sources of functionality that are attracting and advancing a variety of values and interests. Risks, that is, are the flip side of the functionality that motivates innovation. So, to understand the selection of risks, we need to look into the process by which "novel materials" become useful and useable products—into the innovation system itself.

Novel materials are now being explored and tested, and will be developed and applied, within a complex innovation enterprise that includes diverse institutions ranging from university laboratories to government regulatory bodies to corporate boardrooms to retail stores to activist organizations. Within those institutions, human agency is exercised continually, but the cause-effect chains that connect individual human decisions to the outputs of the innovation system are too complex and attenuated to specify. Nevertheless, the pace and direction of advancing knowledge and application do emerge from human choice, and they do reflect who is making the decisions—their interests, values, motives, incentives, constraints.

But innovation systems in general do not include mechanisms to make visible and accessible the role and characteristics of diverse decision makers and decision contexts. Decision processes and risk selection mostly remain invisible and in the hands of narrow sets of interests who, almost by definition, will construe their activities in terms of benefits not risks. Only in the context of political or ideological confrontation are more diverse voices entrained in the discussion, and this generally occurs after a given technology has entered society, when interests are hardened, options are limited, and change is difficult.

In the past couple of decades, growing insight into the dynamics of innovation systems has stimulated new approaches to technological governance aimed at resolving the Collingridge dilemma. These new approaches are rooted in the idea that, by making the human choice contexts implicated in innovation processes visible and open to multiple perspectives, conscious governance can emerge at earlier stages, when more options are available and when uncertainty about future impacts is higher. This work was pioneered by Arie Rip and colleagues in the Netherlands, who termed it "constructive technology assessment," and has more recently gained beachheads here in Britain, for example with work done at Lancaster and Demos on "upstream engagement," and in the U.S., for example with a project I've been involved with, which we term "real-time technology assessment." The goal of these efforts, most broadly, is to inject pluralistic reflection into the innovation process as a means of improving the public value of new technologies.

But where does the public value of a technology come from? Who defines it, and how? Here I want to make a point about successful technologies that is not widely appreciated.

In his classic 1959 paper "The Science of 'Muddling Through,'" Charles Lindblom explained how public policies come about in a highly contested and uncertain political environment where neither cause-effect chains nor objectives can be agreed upon. In such cases, he observed, "the test [of good policy] is agreement on policy itself, which remains possible even when agreement on values is not" (p.83). Lindblom goes on to say: "Agreement on policy [is] the only practicable test of the policy's correctness" (p. 84), while concluding that the outcomes of a policy cannot be the proper judge of how good the policy is, because different groups want different outcomes, and because the system is too complex to specify how the policy is connected to the outcomes. Thus, the ability of the policy itself to organize competing political perspectives is the measure of how good the policy is.

I'll briefly illustrate with an example. Acid rain emerged as an environmental problem in the U.S. in the 1970s, pitting the economic interests of the Midwestern industrial states against the environmental quality of the northeastern states. (Figure 2) Ten years and a billion dollars of research later, facts and uncertainty abounded, and the politics remained intractable.

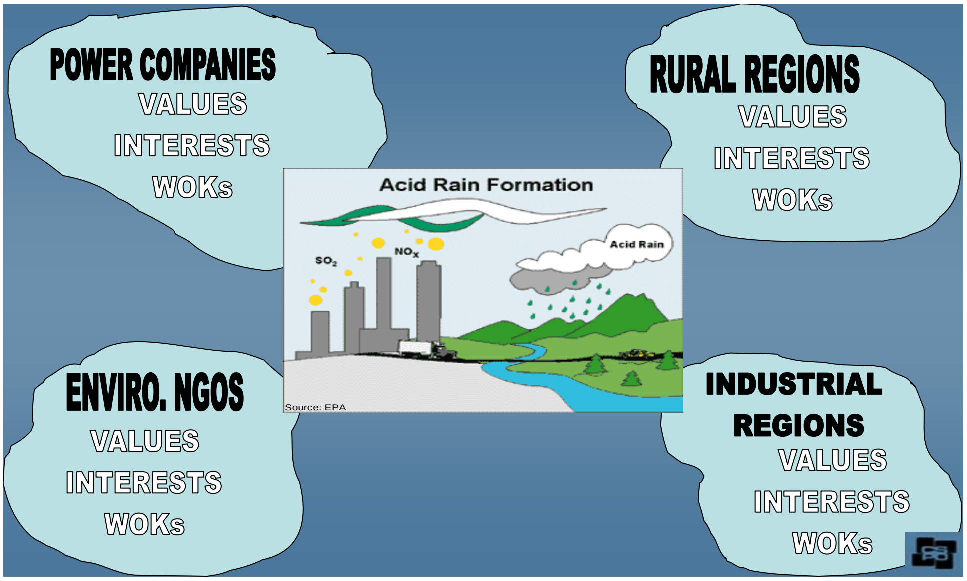

Figure 2

Then, in 1990, a policy innovation—tradeable emissions permits—broke the political logjam that had been preventing action. This policy innovation, which we also might call a "social technology," acted to organize contending values, interests, and ways of knowing around a particular well-specified course of action. (Figure 3) A key point to emphasize here is that the political agreement to take action on acid rain occurred amidst ongoing scientific uncertainty and controversy.

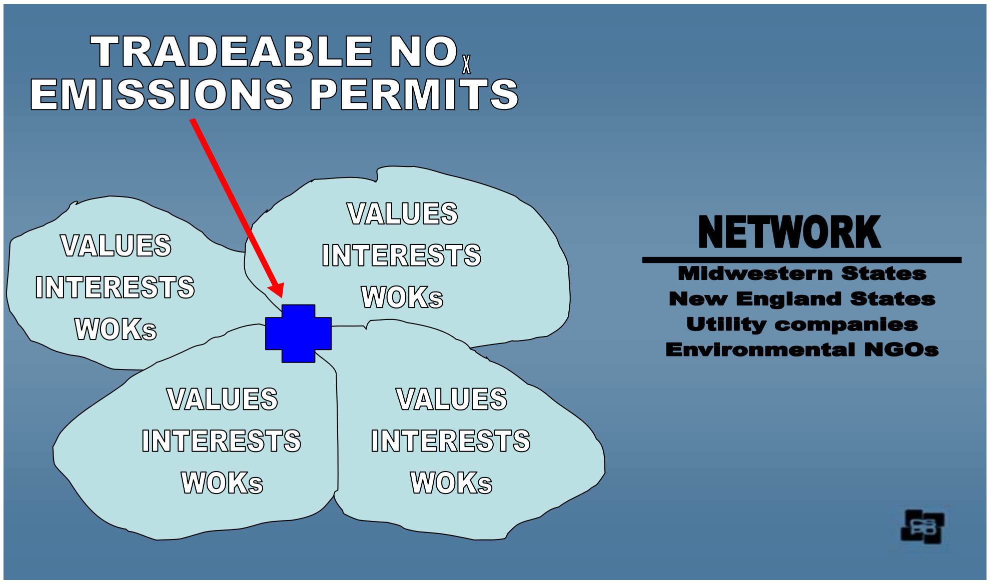

Figure 3

Policies are efforts to create a cause-and-effect chain linking specified actions to desired outcomes. The same can be said for technologies. So you can substitute “technology” for “policy” in Lindblom’s argument: “The test of a good technology is agreement on the technology, which remains possible even when agreement on values is not.” The test of the “goodness” of a technology is agreement about the technology, not the outcomes of its use—although one way that technologies are obviously distinguishable from policies is that they are likely to be much more reliable in achieving the narrow goals for which they are designed, even if broader outcomes are unpredictable and unintended.

So I want to think about technologies—the products of the innovation system—not as sources of risk to be assessed, but as nuclei around which segments of society may organize to accomplish goals and select risks. Diverse sets of actors, institutions, and interests organize around some technologies; some technologies seem to attract only limited constituencies, some seem to catalyze intractable conflict.

One factor that determines whether a technology is a good organizer or a bad one is what it actually does. Given recent controversies here in Britain, childhood vaccinations may seem like an unfortunate example, but nevertheless an amazing network of often-contending interests, values, and ways of knowing have organized around vaccines in the U.S. to ensure their widespread use. (Figure 4) The existence of this network is made possible by the great reliability with which vaccines achieve their narrow purpose—prevention of childhood disease. But this effectiveness in turn also allows many different institutions and actors to advance their own interests.

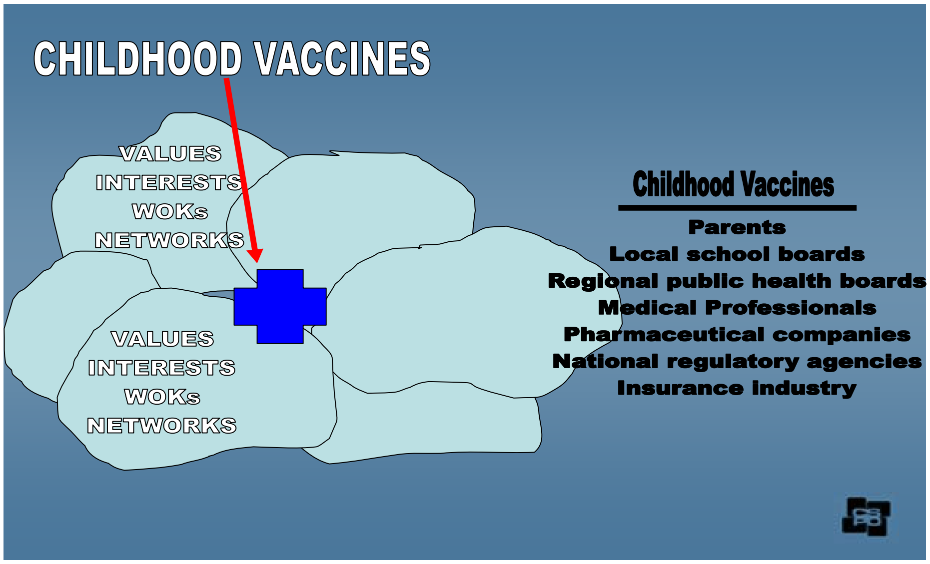

Figure 4

I'll show one final example. The invention of non-ozone-depleting hydrochloro-fluorocarbons (HCFCs) allowed competing interests and ways of knowing to organize around the goal of reducing the production and use of chemicals that deplete stratospheric ozone, as embodied in the 1987 Montreal Protocol. (Figure 5) The typical portrayal of this story is one of science compelling behavioral change, but a careful analysis of the history here reveals a subtly different, and more plausible story: new technology allowed multiple risk perspectives to be satisfied <u>without</u> demanding significant behavioral change.

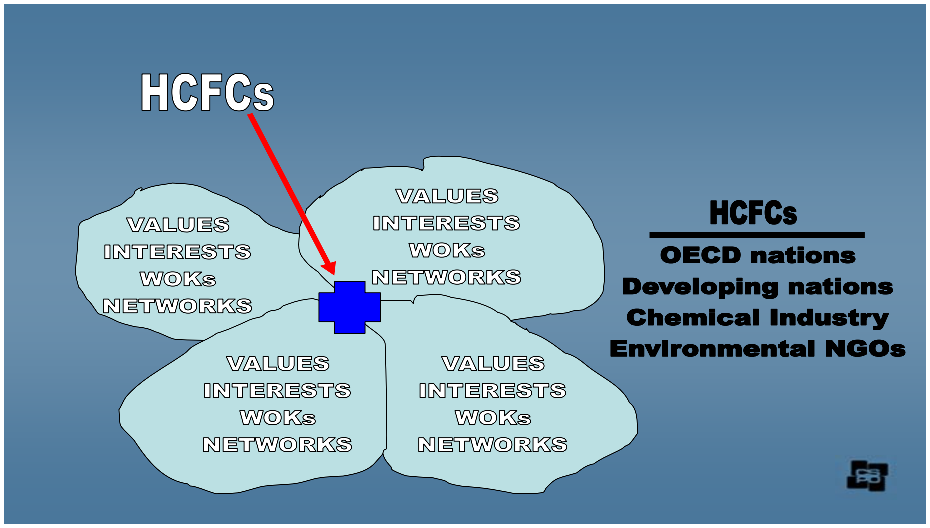

Figure 5

So if we understand innovation systems as risk selectors, and technologies as political organizers, then the heart of the Collingridge dilemma—uncertainty about future paths and impacts of innovation—becomes irrelevant—in theory at least. The challenge becomes one of ensuring that adequately pluralistic decision processes are at work within the innovation system, so that many ways of knowing risk, of knowing novel materials, can influence the shaping of innovation paths. I want to emphasize that multiple interests are served through the process of specifying futures that nonetheless remain unpredictable. With this in mind let me close with a few thoughts on how such a challenge might actually be met.

If the Commission chose to explore this perspective, then the basic unit of analysis would not be novel molecules, but the decisions made about the selection, exploration, and application of novel molecules. A starting place might be foundational research that focuses on identifying and characterizing the institutions involved in the novel materials R&D, specifying the activities of these institutions, and elucidating their interrelationships. Such a mapping of the novel materials innovation system would analyze trends in funding, publication, citation, collaboration patenting, and commercialization to understand the directions, velocities, and locations of scientific advance. It would seek to identify emerging choices, about materials, processes, and applications, that might strongly influence downstream innovation It would seek to understand the social structure of these emerging innovation paths: Which institutions are involved, and how are they justifying their involvement? Who is attracting resources? Who is working with whom; what types of cross-sectoral alliances are being formed? And crucially, what kinds of claims are being made about potential products and processes, and what resources are being devoted to advancing those claims? The methods and tools for carrying out this type of mapping are well developed and in common use.

The problem with a category as broad and inchoate as "novel materials" is that it is too general and too abstract to stimulate or simulate the types of political activity that emerges when real technologies hit the streets. As I'm sure the Commission is well aware, scenarios are increasingly being used in domains as disparate as regional environmental planning and corporate strategic planning to investigate choice options in light of uncertain and contingent futures. Based on the information emerging from the innovation system mapping program, multiple scenarios of diverse technological futures can be developed. Such scenarios need not have predictive value; rather, they combine technical plausibility with narrative concreteness. They can be the basis for productive, pluralistic reflection to make visible the risk selections implicit in early stage technological choices, to illuminate the political meanings of such choices, and, crucially, to expand the realm of imaginable choices. By applying a broader array of values, interests and ways of knowing to decision making, such deliberative exercises can help reveal avenues of innovation that satisfy Lindblom's criteria of success, and identify other paths that are likely to be divisive and might best be avoided.

As I've said, these types of approaches, aimed at making risk selection explicit in the innovation system where it is typically implicit and even unconscious, are only being introduced in limited settings and on an experimental basis. Their viability is supported theoretically and anecdotally, but whether they can be productively introduced across an entire realm of innovation is not known. I would note by way of analogy that in the U.S. a nationwide structure for governing human subjects research has been integrated into the federally funded research and development enterprise, so there is some precedent for institutional change aimed at comprehensive improvement of the reflexive capacity of innovation processes. Thus, integrated innovation system mapping and scenario-based deliberative activities could be a required component of all major programs dealing with novel material R&D, but needless to say fulfilling such a requirement would demand a significant investment in human and fiscal resources. My own very casual sense is that the intellectual infrastructure to support such an effort is much better developed here in the UK than it is in the US.

The study of environmental controversies shows quite clearly that reduction of uncertainty is neither a necessary nor a feasible prerequisite for effective governance of technological risk. I've tried in my brief comments to offer to the Commission a different lens to view this problem as it embarks on its study of novel materials. Innovation is a defining activity of the human species, and risks are a defining attribute of innovation. The challenge is to choose them consciously, fairly, and wisely.

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[1] http://www.rcep.org.uk/chreport.htm
[2] http://www.rcep.org.uk/about.htm