Working Paper

The Problem of Attention Management in Innovation for Sustainability

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Foreword

Incremental improvements of existing systems will not be enough to achieve the scale in the reduction of energy and material consumption and their associated environmental impacts that would be required to counterbalance the twin pressures of population growth and economic development. Radical innovations will be needed including new transport, industrial and urban systems.

From this perspective, global environmental sustainability requires a shift to a new "techno-economic paradigm". Such a new paradigm cannot at present be described comprehensively even in qualitative terms (and it can be reduced even less to simple tabulations of environmentally critical technologies). The reason for that is that many essential features of the interactions between technology and environment at present are uncertain. We are unsure about the temporal and spatial scales of environmental change, about the exact causation mechanisms of these changes, how past and current patterns of development and use of technologies influence environmental change, and especially how all these factors interact in the future. Uncertainties and surprises are thus not only genuine elements in technological evolution (and the formation of past techno-economic paradigms), but even more so in the way technology and environment interact.

There are at least two types of uncertainties in the interactions between technology and the environment. The first one is uncertainty about technical change. It deals with the unknowns of performance and functions an emerging technology may ultimately assume, what kind of modes of social usage it will entail, and what the cumulative long-term effects of these modes of usage might be. The second uncertainty deals with environment proper: not only current environmental problems are frequently ill-understood, there is yet more uncertainty concerning possible future environmental problems. To illustrate this, just imagine how difficult it would have been to anticipate changes in stratospheric chemistry (ozone depletion) at the time CFCs were introduced as benign replacements of propellants and refrigerants in the 1920s.

Facing uncertainty, which is the main characteristic of the interactions between technology and environment, it is thus necessary to improve the capacities of broadening our portfolio of technological alternatives; to learn continuously about the evolving characteristics of the interactions between development and environment; and to strengthen what Herbert Simon termed "metatechnologies" (technologies of decision procedures). A new techno-economic paradigm must, therefore, above all, entail new modes of production and distribution of environmentally valuable knowledge, allowing the system to acquire and monitor information continuously and to reassess both environmental and technology policy objectives. Here, new methods of learning and observation technologies, capable of producing data on a global scale (such as the Global Ocean Observation System), as well as the old (but changing) methods of "research by accident" matter. In our view, the most important problem deals, perhaps, no longer with the lack of available knowledge. It deals rather with information handling, filtering, and distribution. This perception is based on the Simonian recognition that the scarce resource is no longer knowledge but attention.

The issues of production and distribution of environmentally valuable knowledge are being addressed in a series of informal discussion meetings of the Technology and Environment (T&E) network established at IIASA within the framework of the Environmentally Compatible Energy Strategies (ECS) Project. The T&E network is organized to produce a series of discussion papers on various aspects of the problem at hand (research by accident, attention management, new economics of technological learning, large scale observation systems, origins of technological "lock-in"), and is aimed at establishing an interdisciplinary base to discuss the interactions between technology (or rather of technological change) and the environment.

This paper by Harvey Brooks is the second of this series. Brooks argues that the problem of attention management is one of the main challenges in the transition to environmentally sustainable development paths. The design principle that attention is scarce is very different from a principle of "more information is better". Brooks discusses the issue of "attention management" in various contexts, including R&D and innovation management, scientific communities, and technology policy. The question arising from this analysis is whether dependence on personal contact, tacit knowledge, and "serendipity" to inform the application of knowledge, could be gradually reduced by more systematic exploitation of some of the tools of modern information technology. As shown in another paper of this series (by Tom Schelling), the attention management problem that Brooks outlines is especially important when the knowledge required for actions and technology-planning resides in a different community from the ones with which the technology planner is usually familiar.

The Problem of Attention Management in Innovation for Sustainability

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1 Sustainability and Economic Incentives

One of the major challenges to science and technology policy in the coming decades is to understand the implications of the rising relative importance of sustainability as a relatively new criterion for the assessment of the innovation process. Since the criterion of sustainability entails a large element of a "public good" whose benefits are not directly appropriable to the private sector in terms of financial rewards to private innovators for their innovation, it is easy to assume that environmental quality is entirely a public good that has to be secured entirely through S&T investments by the public sector.

However, this is a misleading formulation of the problem. Even in an economy in which environmental goals are met primarily by "command and control" techniques either mandating specific levels of emissions or requiring the adoption of specific production technologies or consumer product specifications, there is plenty of opportunity for private innovation where economic benefits can be captured by the innovator through the marketing of products and processes which meets the requirements mandated by the public sector. Indeed, in such cases, the design and production of goods and processes is an economic activity which adds to the GDP and creates private employment just as much as the production of any other goods and services. There are, of course, also market opportunities for the sale of monitoring and measurement equipment directly to the public sector for use in enforcement activities.

There are no very good estimates of what fraction of private sector economic activity results from the meeting of environmental requirements, but it is usually estimated as at least 1–2%. Even in the early 1980s estimates were made that private sector economic activity directly traceable to environmental requirements had created about 1.5 million new jobs in the US economy. (These figures need to be updated as of the mid-90s. They are probably several times larger today.) In one sense, environmental quality can be looked upon as an economic good equivalent to commercial goods sold on the market. In the case of consumer goods, the "greenness" can be considered as simply another quality or attribute of the product like any other, but with the difference that, because of the mandate, the consumer may have to buy the product with that quality whether or not he considers it to be desirable. But that is already true of many other products, such as products not made with child labor or substandard labor practices.

To the extent that the goal of sustainability is achieved not by government mandate but by restructuring of economic incentives such as emissions charges, internalization of recycling costs in the product price, marketable emission or environmental impact permits, etc., the economic activity associated with sustainability is even further privatized, and the technical judgements required for meeting sustainability goals are even further delegated to the private sector, hopefully with the consequence of further reducing the economic costs of meeting these goals by in effect increasing the "productivity" with which environment quality is generated.

2 Sustainability and the Attention Management Problem

There may be certain features of incorporating the criterion of sustainability which increase the complexity of the innovation process, involving the participation of a larger number of economic actors, a wider range of intellectual expertise, and a different network of institutions and individuals than the more traditional innovation process.[1] For example, with innovations which follow the classic "technological life cycle" model,the fastest diffusion and the most intense innovative activities take place during the "consolidation" phase when the focus of the innovators' attention is on a dominant design embracing a very narrow range of parameters and hence a high level of technical specialization.[2] During this phase, in which the principal characteristics of the innovation and its accompanying production processes and institutional support mechanisms tend to become "frozen", the economic and institutional actors are forced to narrow their vision, and have the lowest receptivity to external information that does not conform to the dominant "paradigm" of the innovative activity. The challenge from a sustainability point of view is how to map the vast body of collective knowledge involved in the technical literature into the specific needs of sustainability at the very time when the horizons of the innovators are most limited by the tasks at hand as defined by the dominant paradigm. This challenge has been nicely defined by Dr. Lawrence L. Weed for the case of the application of the biomedical science literature to medical practice in the following terms:

> "Our confidence in our innate human capacity to make judgements as sound and reliable as our collective knowledge theoretically allows is simply unsupported by over 30 years of intensive research in clinical and cognitive psychology. Furthermore, there is extensive, often polemical as well as careful medical documentation that testifies to the rampant nonapplication or misapplication of medical knowledge to everyday clinical situations ... The difficulties follow from the limitations of unaided human minds in applying a very large body of knowledge, when any portion of that knowledge base is intermittently and unpredictably relevant in day-to-day work. Specialization represents an attempt to deal with the problem. Unfortunately it runs a foul of the persistent failure of real problems to fit within the socially and historically defined boundaries of medical specialties. Medical knowledge, viewed as a whole, is as highly

[1] Cf., for example, L. Soete and A. Arundel, eds., *An Integrated Approach to European Innovation and Technology Diffusion Policy: A Maastricht Memorandum*, May, 1993, especially Chapter 3, "The Long-Term Challenge: Environmentally Sustainable Development", pp. 47–64.

[2] Cf., Bruce R. Guile and Harvey Brooks, eds.,*Technology and Global Industry*, National Academy Press, 1989, especially the article by James Utterback.

> interconnected as the minds and bodies of its subjects. Tracing these interconnections wherever they lead in response to a real problem, as if following a map, is what medical problem solving requires.[3]

Very similar considerations apply to the huge volume of engineering, scientific, legal and institutional knowledge related to the problems of sustainability in technological development which must be brought to bear at the very time when the innovators are least likely to have their attention distracted by "peripheral" considerations beyond the scope of the dominant technological paradigm on which they have become focused by the requirements for staying ahead in a competitive market. Only if the information tools for accessing this enormous diverse literature are extraordinarily efficient is there any hope that this challenge of "attention management" can be surmounted. The problem is usually not that the relevant information does not exist, but that it is known only to a small community of specialists who could not appreciate its policy significance in the context in which it first arose, and not widely enough known in the broader scientific community but what it would be likely to appear as a surprise from a policy viewpoint.

We can take as an example the unanticipated discoveries in the case of the nuclear weapon system.[4] It is clear that there was fairly detailed knowledge of the biological effects of doses of fast neutrons, and it was also known that fission bombs would produce a large flux of fast neutrons, but these two well-known facts were not known to sufficiently overlapping communities so that it came to the forefront of attention in a short-term decision context. The "scientific community" is not a monolithic community of people who know everything there is to be know about nature. It is a huge congeries of only partially overlapping communities, where, when a problem is generated in a new context (a novel commercial technological innovation), there is no way the appropriate knowledgeable community can be identified in relation to the narrow innovating community.

The problem is essentially what Herbert Simon has called "attention management." The human mind is very limited in the number of things it can hold at the forefront of attention at any one time. While this span of attention can be somewhat augmented by posing the question more or less simultaneously to groups of people with different technical backgrounds, the number of people involved at the point of decision is usually too small for this augmentation factor to amount to much, especially if there is pressure to reach a decision in a hurry for political or economic reasons. This situation is, of course, further complicated by issues of proprietary or even national security secrecy. The decision to drop the bombs on Hiroshima and Nagasaki was especially highly pressurized in this respect, both to the urgency of the decision and to the limited circle in which it could be discussed.

Similarly, in the case of the greenhouse effect, a small community had been concerned with this for quite a long time. Roger Revelle got his graduate student to start measuring carbon dioxide concentration on Mauna Loa beginning in 1958, and Bert Bolin in Sweden started similar measurements about the same time. This was not just idle curiosity; they expected some effect and they thought it might be important from a societal point of view. It had been predicted theoretically nearly a century ago. Had this long-time series not been available by the 1970s, the possibility of a greenhouse effect would probably have remained a theoretical speculation not to be taken seriously by anybody who mattered

[3] Weed, op. cit., p. xvi.

[4] Thomas Schelling, *Research by Accident*, WP-95-40, IIASA,Laxenburg, Austria, 1995.

as far as policy was concerned.

The complexity introduced by the relevance of an increasingly diverse range of only partially overlapping "epistemic communities" has been further exacerbated in recent years by the gradual shift of the environmental problems generated by economic activity from "point sources" associated with industrial production in large manufacturing plants to distributed sources associated with the use and ultimate disposal of consumer products, building materials, sewage systems, intensive agricultural land use, and an expanding service sector. This shift has been only recently documented as a result of the emergence of the new discipline of "industrial metabolism" which deals with the overall materials balance associated with all economic activities in a region, usually a watershed.[5] This involves a far greater multiplicity of actors and possible policy leverage points than the regulation of corporate polluters, and thus puts even greater demands on the appropriate distribution of information and the management of attention.

3 Attention Management and the "Proof Problem"

The problem of "attention management" is still further complicated by what might be called "burden of proof problem". This is the problem that the different overlapping technical communities referred to in the preceding section often have very different values when it comes to the information threshold required to attract their attention to different kinds of facts and information. Typically the engineering community engaged in technological innovation requires a much higher burden of proof to convince itself there is a cause for concern that its innovation has potentially damaging environmental consequences than would be the case for the members of an environmental NGO to whom the protection of a particular aspect of the environment is matter of the highest priority. Where a 1% probability of damage might be regarded as totally "negligible" from the standpoint of an engineer already deeply engaged in the "consolidation" phase of a technological innovation, it might be totally unacceptable to a member of an environmental NGO, who would insist on much more extensive research before the innovator could be allowed to proceed even with the early stages of development. To the environmentalist, technology may be assumed guilty until proved innocent beyond question, while to the engineer the innovation may be assumed innocent unless proved guilty beyond a similar shadow of doubt. For the most part the debate proceeds with the use of highly qualitative and ambiguous terms such as "reasonable", "probable", or "possible", only to discover that when these terms are quantified in practice gaps in definition of several orders of magnitude may appear, with 1% chance of damage being "probable" to the environmentalist and "negligible" to the engineer. This is also further complicated by issues involving the slope of the damage vs. probability curve and questions of the reversibility of the damaged produced, or the costs of reversing it.

In the real world, in matters of sustainability and environmental damage, when there is a direct confrontation between the proponents of and opponents of an innovation, the

[5]Cf., for example, William L. Stigliani and Peter R. Jaffe, *Industrial Metabolism and River Basin Studies: A New Approach for the Analysis of Chemical Pollution*, IIASA RR-93-6, September, 1993; Robert U. Ayres and Udo E. Simonis, eds., *Industrial Metabolism: Restructuring for Sustainable Development*, United Nations University Press, 1992; William L. Stigliani, "Regional Material Balance Approaches to Long-Term Environmental Policy Planning," draft Research Proposal, 1994.

question is seldom posed, what evidence would it take to convince you that your fears (or hopes) are unfounded. This is important for eliciting the real extent of opposition or commitment. In some cases, the true answer may be: even if you proved it was harmless I would oppose it, or, no matter what evidence of damage you bring forth I believe in it.[6] In fact, Douglas, Thompson, Wildavsky and others have developed a cultural typology of knowledge which maintains that attitudes towards technology and the environment have deep-seated cultural origins that bear little relation to objective evidence and that therefore the question posed in the preceding sentence will in effect never be answered honestly.[7] To the best of my knowledge, however, the suggestion has never been tested carefully in an empirical experiment with persons from different backgrounds.

4 Systemic Strategies Towards Sustainability

Another phenomenon related to attention management is the implicit policy in much of environmental regulation to partially or completely "grand-father" existing technologies that are already deployed on an appreciable scale (constituting "sunk costs"). This was done most notably in the case of auto emission regulations in the United States and to some extent in connection with fossil-fuel fired electric generating facilities. Analyses show that almost 50% of auto and power plant pollution originates in old automobiles and "grandfathered" power plants. Recently, some steps have been taken in California for power companies to buy up ancient automobiles and take them off the road in return for some offset credits of their contribution to air pollution. I do not know the details of this, or how the overall economics balances out. However, it seems that this would represent a first step towards the kind of "systems" approach advocated in Chapter 3 of Reference 1.

It appears though, that this kind of trade-off approach among sources of pollution could be carried much further than it has been so far, for example by subsidizing plants to write-off the undepreciated cost of old plants in return for closing them completely as a substitute for fitting them with end-of-pipe controls that are less effective and have a shorter useful life. Even more important might be a scheme making use of the waste streams from one type of production facility as useful inputs to other types of manufacturing facilities in the same general area.[8]

A more ambitious systemic strategy of the same type would be to allow tax credits to facilities in developed countries that invest in cleaner facilities in rapidly growing developing countries where it can be shown that a bigger return in total emission reduction per unit of investment would be achieved. This would be especially effective in case a universal carbon tax were implemented in connection with greenhouse gas emissions in all countries. It would be particularly effective in the case of electric generation plants, which are now absorbing about one-half of the total capital investment in some of the more rapidly developing LDC's. Rather than spending large sums to achieve small incre-

[6]Bernard Davis, ed., *The Genetic Revolution: Scientific Prospects and Public Perceptions*, The John Hopkins University Press, Baltimore and London, 1991, chapter by Harvey Brooks.

[7]This position is summarized in a chapter by Aaron Wildavsky in reference 5, and also somewhat questioned in the chapter by Brooks. A more complete discussion of the cultural theory is given in Michael Thompson, Richard Ellis, and Aaron Wildavsky, *Cultural Theory*, in *Political Cultures Series*, Aaron Wildavsky, series ed., Westview Press, Boulder, San Francisco & Oxford, 1990.

[8]Wolf Häfele *et al.*, give examples of such schemes for energy production of facilities in their chapter in W.C. Clark, *et al.*, *Sustainable Development of the Biosphere*, Cambridge University Press, 1986.

mental improvement in emissions in a developed country, the same money could be used to achieve much greater improvement in LDC's while contributing to their development and accelerating the diffusion of cleaner power plant technologies.

5 By Way of Conclusion

It is important to emphasize that there is no such thing as a perfectly clean – and therefore fully sustainable by itself – technology. There are only varying degrees of environmentally friendly development, and a sustainable development process probably consists of deployment of a mix of technologies. Only the heterogeneous mix is sustainable, and then only in the long-run, not the component technologies independently. Determining such a sustainable strategy requires much more sophisticated processing of information from a much wider range of sources involving much wider networks of expertise than is necessary for present technological innovation in individual industries and companies. The necessary systemic integration of information can only be built up gradually through a process of collective learning which we still can visualize only dimly and imperfectly.