Structuring policy problems for plastics, the environment and human health: reflections from the UK

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How can we strengthen the science–policy interface for plastics, the environment and human health? In a complex policy area with multiple stakeholders, it is important to clarify the nature of the particular plastics-related issue before trying to understand how to reconcile the supply and demand for evidence in policy. This article proposes a simple problem typology to assess the fundamental characteristics of a policy issue and thus identify appropriate processes for science–policy interactions. This is illustrated with two case studies from one UK Government Department, showing how policy and science meet over the environmental problems of plastics waste in the marine environment and on land. A problem-structuring methodology helps us understand why some policy issues can be addressed through relatively linear flows of science from experts to policymakers but why others demand a more reflexive approach to brokering the knowledge between science and policy. Suggestions are given at the end of the article for practical actions that can be taken on both sides.

Keywords: science–policy interface; knowledge brokering; problem structuring; plastics policy

1. INTRODUCTION

In a previous Theme Issue of this journal, Robert Watson outlined many of the challenges at the interface between science and policy.[1] Discussing the role of national and international assessments, Watson (2005) outlines how science can—with appropriate participation from all the key stakeholders—provide the evidence that forms the basis for policy discussions. International assessments such as those on stratospheric ozone depletion, climate change, biodiversity and science and technology for agriculture make important contributions to the global store of knowledge. They set the high-level agenda, bring the topic to a wide audience and focus expert discussions on the main issues.

Equally important, however, are the day-to-day operations that characterize the policy process, from strategy formulation through policy development to policy delivery. In spite of the publication of guidelines on the use of science in policy (HM Government 2000, 2005), Nutley *et al.* (2007) note that it is a source of frustration to both researchers and policymakers that robust evidence, presented clearly, does not always have the desired effect on policy processes (see also Scott *et al.* 2005; ERFF 2007; McNie 2007; Bielak *et al.* 2008). This article focuses on the ongoing interactions between scientists and policymakers, drawing in particular on my experience at the interface between scientific research and environmental policy in the UK.[2]

How policies are developed will vary from country to country, depending on the politico-administrative system that has emerged and any supra-national agreements that may be in force (Albæk 1995; Jasanoff 2005). A useful analytical framework is provided by Sarewitz & Pielke (2007) who focus on reconciling the supply of, and demand for, scientific evidence in policy. In a thorough review of the challenges associated with this, McNie (2007, p. 18) notes that this reconciliation is not a single event, but it is '. . . about process: facilitating our exploration and assessment of the question: are we doing the 'right' science to better respond to society's needs?' The challenge in this article is to unpack these processes in detail by looking at some of the ways science and policy meet inside a government department. The first section outlines some of the complexities of plastics policymaking in the UK. The second limits this complexity using an issue typology to characterize policy issues. Using this problem-structuring approach helps explain why there is no one 'science–policy interface': instead, there are many different ways in which policy and science interact. The third section describes two of these in short case studies that analyse the organizational processes put in place to reconcile the supply and demand for evidence relating to plastics waste. Finally, the implications of applying a problem-structuring approach are summarized in some practical suggestions for both science and plastics policy.

2. THE POLICY ENVIRONMENT FOR PLASTICS, THE ENVIRONMENT AND HUMAN HEALTH

As an employer of around 220 000 in the UK across 6000 businesses, the plastics industry is a major

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player in the UK economy: the total annual value of the plastics processing sector alone is estimated to be £12.4 billion (HSE 2008). Plastics is one of the seven key waste materials identified in the UK's Waste Strategy 2007: the total amount of plastic waste arising is estimated to be 5.9 million tonnes (mt) per annum: 2.3 mt from household and other municipal sources, 2.5 mt arising in the commercial waste stream (1.9 mt from packaging) and 0.8 mt and 0.1 mt from industrial and agricultural waste streams, respectively (Defra 2007*a*, Annex D).

In spite of the size of the industry and the other contributions plastics make to the British economy, there is no single plastics policy. Instead, it is shared between at least five government departments and driven by both international obligations and European directives. The Department for Business, Enterprise and Regulatory Reform (BERR) seeks to ensure the success of UK business, focusing on industrial productivity and the contribution of the plastics industry to the British economy. BERR sponsors the Polymer Innovation Network, one of the Materials Knowledge Transfer Networks designed to bring together '...the views of all in business, design, research and technology organisations, trade associations, the financial market, academia and others...' (Materials KTN 2008). The Department for Environment, Food and Rural Affairs (Defra), whose overarching goal is the delivery of a low-carbon economy (Defra 2008*a*), develops policy around the environmental impacts of plastics arising from plastic waste on land or at sea. Defra also leads UK policymaking under two major EU directives affecting the plastics industry. The Energy Using Products Directive covers eco-design and end-of-life waste management requirements for all energy-using products except motor vehicles (http://ec.europa.eu/energy/demand/legislation/eco_design_en.htm). REACH, the European directive on the Regulation, Evaluation, Authorisation and Restriction of Chemicals, makes specific provisions for monomers, polymers and some of the additives used in plastics manufacture (http://reach.jrc.it/docs/guidance_document/polymers_en.pdf). Human health issues relating to plastics are addressed by the Department of Health (public health), the Medicines and Healthcare Products Regulatory Agency (a wide range of medical devices containing plastics), the Health and Safety Executive (health and safety within industries producing and handling plastics) and the Food Standards Agency, which is charged with implementing the Materials and Articles in Contact with Food Regulation 1987 and subsequent amendments (HM Government 1987).

Each organization works closely with bodies that deliver policies such as implementing regulations about water quality, reducing the health impacts of chemical hazards, imposing charges for waste and negotiating voluntary energy efficiency standards. Both individually and jointly they sponsor a variety of groups designed to bring together industry, policymakers, academic research and non-governmental organizations around particular issues. Within this complex organizational environment, different types of policy are formulated, appraised, implemented and evaluated. The next section examines these using a problem typology, which describes the nature

of the policy problem and thus helps understand how best to link science and policy to deal with it.

3. DIFFERENT POLICY TYPES GIVE RISE TO DIFFERENT INTERACTIONS BETWEEN SCIENCE AND POLICY

A policy can be defined as '...a set of patterns of related decisions to which many circumstances and ...influences have contributed' (Hogwood & Gunn 1984, p. 24). Public policy can result in concrete plans, which themselves may result in specific proposals for action including regulation, economic instruments, such as subsidies or taxes, or programmes of legislation with accompanying organizations and resources. But it does not only encompass these sorts of legislated actions. 'Policy' may also result in voluntary negotiated standards such as the tripartite negotiations between government, retailers and industry to limit the use of plastic carrier bags. It also covers risk governance such as understanding the impacts and potential hazards of novel plastics, decisions about the allocation of public funds via research prioritization, the provision of information via (for example) ecolabelling strategies and marketing to 'win hearts and minds' (Collins *et al.* 2003, p. 3). However, it is made, policy cannot be characterized by a single decision point. Instead, it is a series of decisions—one of which may be crucial in determining the ultimate direction of the policy—but all of which contribute to how it is planned and implemented.

Different policymaking processes require different tools. Hogwood & Gunn (1984, p. 62) point out that '...different policy issues will require different policy approaches. Some...will always require a highly political, pluralist, bargaining and incrementalist approach...(while)...other issues—probably only a small minority—will both require and lend themselves to a much more planned or analytical approach'. However, UK Government guidelines on the use of scientific advice in policy do not pick up on this. Instead, they state simply: 'Individual departments should ensure that their procedures can anticipate as early as possible those issues for which scientific advice will be needed, particularly those which are potentially sensitive. They should also ensure that research is commissioned as early as possible into what are known or likely to be key areas of uncertainty' (HM Government 2000). They give little indication of *how* to involve the relevant experts and other stakeholders and to determine which approach is appropriate.

Hisschemöller & Hoppé (2001) proposed a typology for analysing policy problems, depending on whether there is consensus on the questions policy is addressing and certainty about the relevant knowledge (table 1). It is pertinent to the issue addressed in this article—how to reconcile supply and demand for science in policy. Here, policy demand is expressed via the questions it asks of science about an issue. Science supply is expressed through the knowledge it provides in answer to the question. With this framework, we can analyse how different types of policy problems give rise to different relationships between science and policy.

Table 1. Structuring policy problems. Adapted from Hisschemöller & Hoppé (2001), Snowden & Boone (2007) and Shaxson (2008).

		is there consensus and clarity in the policy question...	
		no	yes
...and clarity about the relevant knowledge	no	unstructured problem policy issues are 'complex' domain of emergence	moderately structured problem policy issues are 'knowable' domain of experts
	yes	badly structured problem policy issues are 'chaotic' domain of rapid or symbolic responses	well-structured problem policy issues are 'known' domain of best practice

(a) Well-structured problems

A well-structured policy problem is characterized by '... clear cause and effect relationships that are easily discernable by everyone... the right answer is self-evident and undisputed' (Snowden & Boone 2007, p. 2). The questions for policy are well known, and the evidence is well understood. This is the domain of best practice and published guidance, which policy does through regulation or by agreeing voluntary nego-tiated standards. For example, once legislation on water quality is in place, the policy question of whether or not a particular industry should be penalized for a release of chemicals into a water body is well structured—it can be resolved by the yes/no answer of whether the chemi-cal load in the water has breached agreed limits. Because the question is clear and the answer can be known with certainty ('Is the chemical load above regu-lated limits'?), science has a clear and leading role to play in policy's decision-making process.

However, only a few policy problems are likely to be classifiable as well structured: those where the question is unambiguous and the relevant evidence is clear. For many issues, the evidence may be contested by different interest groups who have reservations about its robustness or challenge the assumptions on which it is based. In our water quality example, questions might be raised about whether water sampling techniques lead to false-positive results. If this is the case, we need to reassess how well the problem is structured. This leads us into the second domain: that of moderately structured problems.

(b) Moderately structured problems

A moderately structured problem occurs when the policy questions are agreed, but either there is a degree of uncertainty over the best way to answer them, or a piece of knowledge that should form the basis for a particular policy process is missing or ambig-uous (Vesely 2007). The problem can be described as knowable (Kurtz & Snowden 2003) because while a cause-and-effect relationship may exist, it is not visible to everyone. However, once the relevant specialists have been gathered and set a clear question, their analy-sis helps policymakers converge on answers: this is the domain of experts. Our policymakers concerned with the chemical leak will need science to use its expertise to choose the most appropriate indicator species to rep-resent the health of our putative water body. However, if evidence emerges suggesting that low-dose effects of the leaked chemical are cumulative in the food chain, then

policymakers will need to ask whether—given the goal of maintaining water quality—they are still basing their decisions on the best available evidence.

Science plays a prominent role in this domain, but can only do so because policy has set clear questions that are amenable to solution through research-based and other analytical techniques. Having said that, a clear question does not mean that there is only one sol-ution. Contributions made by different disciplines such as the natural sciences, economics, law, statistics and social science all need to be taken into account, even when their conclusions may oppose each other. Where value for money is the over-riding consideration, the ulti-mate arbiter will be cost–benefit analyses of the possible solutions. In other cases, decisions may give greater weight to evidence from research programmes or expert advisory groups. Where different actors have different interests, policymakers will be faced with '... different solutions for the problem (which) may have far going implications for the distribution of costs and benefits' (Turnhout et al. 2007, p. 224).

The danger in this domain is that evidence is sought from a narrow range of sources, leaving both policy-makers and experts blind to novel solutions and un-aware that the wider context of the problem has changed. Both may continue to assume a degree of structure for a problem that has become either badly structured or unstructured.

(c) Badly structured problems

Badly structured problems arise where divergent views are expressed about a variety of issues in a seemingly chaotic way (Shaxson 2009). There may be agreement on what the evidence is, but the different values held by different interest groups will cause them to disagree over what the evidence means or even what question it is really answering. Searching for cause and effect becomes meaningless because new evidence causes con-fusion rather than clarity. Science may be prominent in this domain, but instead of providing answers, it brings attention to new possibilities that society may find very challenging. The early debates around nanotechnology could be described as badly structured: rapidly emerging and sometimes conflicting scientific information about nanomaterials provoked a value-laden public debate about 'grey goo' fuelled by diverse sources such as the Prince of Wales (Highfield 2003) and science fiction (Phoenix & Drexler 2004). In this domain, poli-ticians may need to respond rapidly if they perceive

there to be a crisis (Snowden & Boone 2007): alternatively, they may respond by defining vague or symbolic goals such as 'sustainability' (Turnhout *et al.* 2007) without necessarily describing them in detail.[3] Different horizon scanning and futures techniques can be used in this domain, playing an important role in examining what might happen and what the preferred outcomes might be and describing the possible future contexts within which policy can plan to deliver the needed changes (Bochel & Shaxson 2007).

(d) *Unstructured problems*

With unstructured problems, there is agreement neither on what the real policy questions are nor the state of the knowledge on which policies are based. 'Conflicting values and facts are interwoven, and many actors become involved in the policy process' (Hisschemöller & Hoppé 2001, p. 51). This results in a domain, where cause and effect can only be seen in retrospect, once the different points of consensus have emerged (Snowden & Boone 2007).

Scientists may be frustrated that a strong message, clearly communicated, does not promote consensus about an issue, which they believe to be 'closed'. This indicates a misperception of the problem structure: many plastics issues such as plasticizers and brominated flame retardants, for example, are unstructured. Scientific information on phthalates and bisphenol A, for example, can never form the basis of a societal consensus about how they should be used and whether that use should be regulated. Their widespread use in everyday products (Koch & Calafat 2009) combined with information on low-dose effects of the chemical to both human health (vom Saal & Welshons 2006) and wildlife (Oehlmann *et al.* 2009) means that the context of the policy question is not 'what levels are safe'? but 'what levels are safe *enough*'? Ethical issues are involved in determining what 'enough' means to different parts of society, implying that however much research is done, the definition of 'safe enough' is not a question that can ever be answered by plastics science alone. There is no clear tradeoff between the benefits to society of using plastics and the hazards to human health and the health of the natural environment of phthalates or bisphenol A (but see Andrady & Neal (2009) and Thompson *et al.* (2009*a*,*b*)). Nor can we predict the 'right' method for deciding what that tradeoff might be. Cost–benefit analysis and other forms of research—standard tools for dealing with moderately structured problems—cannot be used to deal with unstructured problems because of disagreements about the assumptions on which they are based. In the unstructured domain, policymakers cannot impose a solution based only on science, even interdisciplinary science. Instead, scientific research is one voice that policymakers listen to as they negotiate different values and rival interests, diverse views and rival claims about whose knowledge counts, until consensus emerges or they arrive at a practical solution (RCEP 1998).

(e) *Problem structuring: summary*

Table 2 summarizes how different problem structures will give rise to different relationships between science and policy. Misunderstanding the structure of the problem will mean that scientific advice is unlikely to be translated into policy in the way initially envisaged. Both scientists and policymakers may consider a problem to be well structured if there is a clear gap in one part of the evidence, which could be rectified by better communication across the divide—often referred to as the 'deficit model' of science–policy interactions. However, if others consider that the problems are broader, ethically complex or controversial, then the policy environment becomes unstructured. Science is only one of many voices competing to be heard, and if it is the only voice that policymakers listen to, then they will limit themselves to a small part of the evidence base. While a part of the overall policy problem may be moderately structured and thus potentially amenable to solution through the supply of scientific expertise, it is likely to be nested within a wider set of problems with different structures and demands for different types of evidence. The boundaries of the problem will be diffuse, and it will be difficult to separate it from other problems (Hisschemöller & Hoppé 2001). The organizational arrangements put in place to reconcile the supply and demand for evidence in policy need to recognize this fact. If not, the processes of making policy will limit the range of evidence policymakers can listen to, limiting their range of potential choices.

The next section looks at two groups of people who collect evidence to inform policymaking around plastic waste in the UK. The first case study assesses the processes for developing and implementing indicators of the effects of plastic litter on the marine ecosystem: crossing the boundary between well- and moderately structured problems. The second shows how the move to a life-cycle approach to policymaking around land-based plastics waste has led to the development of an organizational structure, which is flexible enough to deal simultaneously with moderately and unstructured problems. This involves moving to a 'knowledge brokering' approach, which is outlined briefly prior to the case studies.

4. BROKERING THE INTERACTIONS BETWEEN SCIENCE AND POLICY: TWO CASE STUDIES OF THE SCIENCE–POLICY INTERFACE

In his book *The Honest Broker*, Pielke (2007) describes four idealized roles of science in policy and politics, which can be filled either by people or by organizations. Pure scientists have no interest in the decision-making process and simply share fundamental information about an issue. Science arbiters serve as an expert resource, providing the answers to clearly specified questions. Issue advocates make the case for one alternative over all others, either transparently or by stealth. The fourth role (examined here) is the Honest Broker of Policy Alternatives, who engages at the interface of science and policy to clarify the scope of choice for decision-making (Pielke 2007, p. 2) and help shed light on what the science means for policy.[4]

Many external organizations perform this translation function—from international assessments to think-tanks, research institutes and consultancies.

Table 2. Different types of policy problems give rise to different relationships between science and policy.

typology	key issues	examples	relationship between science and policy
problem is well-structured: policy issues are known	policy has already set clear questions to be answered. Cause and effect are clearly defined and can be anticipated	using indicators of water quality to determine regulatory breaches by a plastics manufacturer	science leads policy by establishing best practice guidelines, giving policy a clear steer on what to do
problem is moderately structured: policy issues are knowable	policy has set clear questions, but cause and effect have not yet been firmly established so there is no agreement on the best way to answer them	developing indicators of marine pollution by man-made plastics such as the OSPAR Ecological Quality Objective relating to plastic debris in the stomachs of fulmars (Noordzeeloket 2007) developing resource-efficient methods for cracking low-quality plastics into monomers that can subsequently be reprocessed	policy identifies a clear need for science, which uses research and expert advice to provide answers. It may lead to the formulation of best practice guidance and regulations, or to an understanding that the problem is in fact more complex than anticipated
problem is unstructured. Policy issues are complex	policy has set the question (how can we make plastics more sustainable?) but there is no consensus around what that actually means. Cause and effect are only visible in retrospect, once consensus has emerged	plasticizers—there is no policy consensus about how to weigh up the economic, environmental and human health impacts of plasticizers improving household recycling of plastics, which relies on knowledge of personal consumption and disposal behaviours and how to influence them	science is one of many voices in the emerging debate: over-reliance on science will lead to poor policy choices. Policymakers need to negotiate competing values and interests of different stakeholders. Consensus may emerge, or the issue may die away of its own accord. It is only really possible to fully define the problem in retrospect
problem is badly structured. Policy issues are chaotic	cause and effect cannot be determined: information emerges rapidly from many sources. Goals are largely symbolic or set in response to a crisis	novel materials such as nanomaterials: there may be a great deal of science, but social and ethical debates have not had time to catch up with science, so the wider implications are poorly understood.	science challenges policy, but the future direction of the technology is unclear, its social and ethical impacts are unexplored and public attitudes are unfixed (Gavelin *et al.* 2007). Policy can help coalesce debate around key questions or values

Much has been done to understand how to use them to improve the supply of evidence (McNie 2007), but relatively little attention has been paid as to how the demand for evidence in policy is conditioned by organizational arrangements within government departments. To see how this demand is formed and expressed, we need to look in detail at the work of groups led from within the policy environment which advise on commissioning and using evidence.

(a) Case study 1: developing indicators for the health of the marine ecosystem: plastic litter in the marine environment
Marine policy in the UK is driven by several EU directives such as the Marine Framework Strategy Directive (MSFD: http://eur-lex.europa.eu/LexUriServ/ LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF), international conventions such as OSPAR (http://www. ospar.org) and the Convention on Biological Diversity (http://www.cbd.int) and the UK-specific legislation coming into force under the Marine Bill. The publication of *Safeguarding our Seas* (Defra 2002) committed the UK to adopting an ecosystem management approach to the seas and oceans and to an integrated assessment of the state of the seas (Defra 2005a), including the development and use of indicators of good environmental status.

No single body is charged with developing indicators or proposing new ones. The UK Marine Monitoring and Assessment Strategy (UKMMAS) was set up in 2006 with the goal of ensuring the cost-effective provision of the information needed to support policy and management decisions to develop the UK marine vision. It is delivered through a number of groups working together at the science–policy interface as shown in figure 1.

The Marine Assessment Policy Committee (MAPC) provides policy direction to the body charged with implementing the UKMMAS: the Marine Assessment and Reporting Group (MARG). MARG
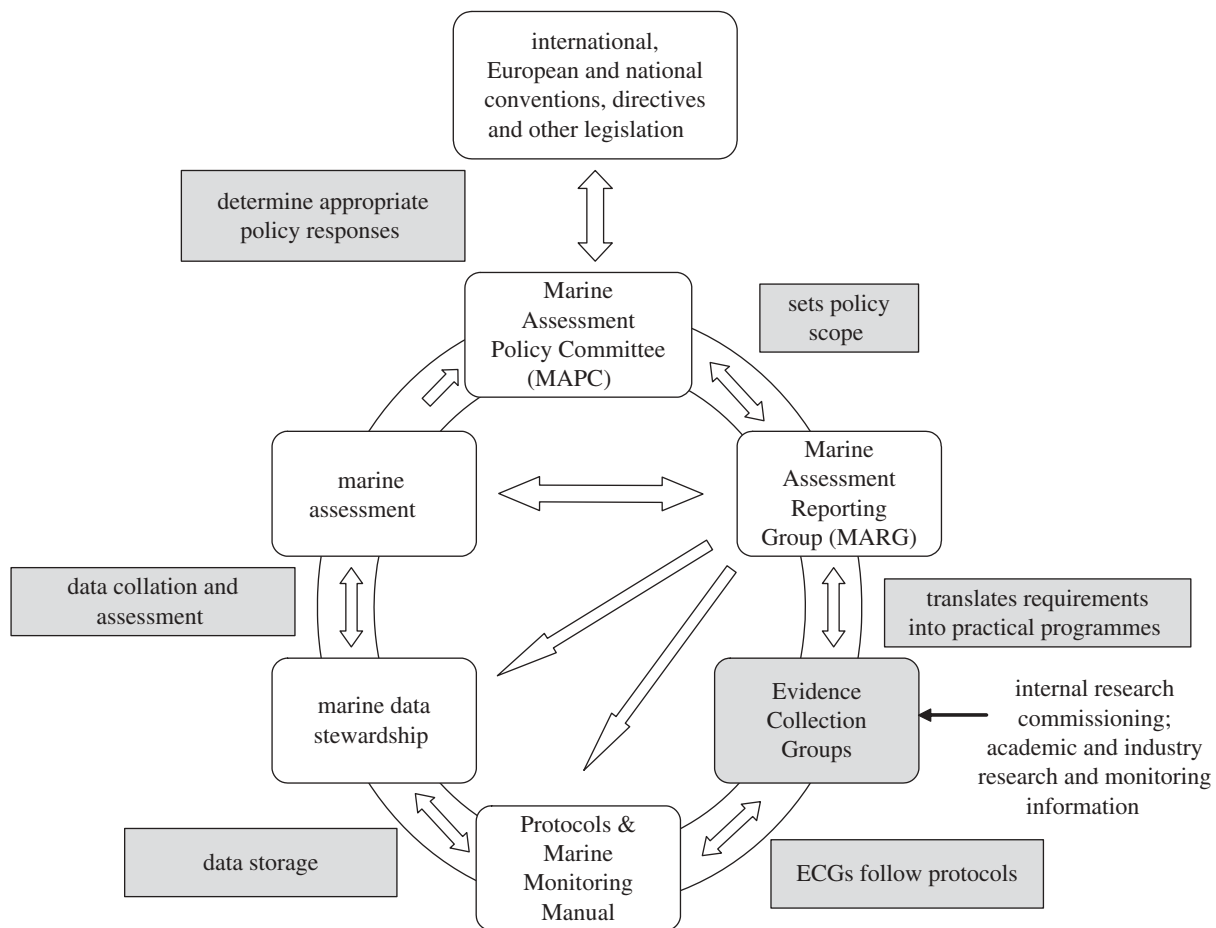
Figure 1. The science–policy interface for the development of marine indicators in the UK. Adapted with permission from MARG (2006).

identifies how assessments will be carried out to meet policy needs; directing programmes, reviewing outcomes, quality assessing protocols for data collection and storage and suggesting changes to monitoring programmes. Several Evidence Collection Groups (ECGs) report to MARG: these are drawn from academic science and marine monitoring organizations involved in data collection, analysis and storage. Information is generated from collating the data, and this contributes to the evidence base from which policy decisions are made. Part of their terms of reference includes being informed by emerging research and technology, promoting awareness of new research and development and identifying new requirements (see TOR3 at http://www.defra.gov.uk/environment/water/marine/uk/science/pdf/csseg-tier3tor.pdf). Although marine policymakers will use their informal networks to commission ad hoc pieces of research to answer pressing policy questions as they arise, these are more likely to be based on secondary analysis and interdisciplinary synthesis than on new primary data. In terms of a more formal system for feeding 'new' science into policy, the ECGs are the route via which science can press to refine existing indicators or develop new ones.

Given that the goals for the marine environment have been clearly specified, the problem of indicator development must have a degree of structure to it. An existing, though still draft, OSPAR indicator relates to the presence of plastic pellets in the stomachs of fulmars as a proxy indicator for the presence of plastic litter in the marine environment (Ryan *et al.* 2009; Noordzeeloket 2007). But what if—as is often the case in policy—a new piece of evidence emerges about the long-term effects of plastic litter (e.g. Thompson *et al.* 2009*b*; Barnes *et al.* 2009) or leached chemicals from plastic debris on other organisms in the marine environment (e.g. Teuten *et al.* 2009)? Whether this should be added into the list of indicators that policymakers use to assess the state of the seas is a moderately structured problem because it can be answered using research and expert advice to answer the questions: should the indicator relate to presence or harm? To which species? Why is that particular organism suitable as an indicator species for that particular ecosystem? Our new piece of science about the long-term effects of plastic litter on the marine environment will be picked up by the ECGs, but this does not guarantee that it will emerge as an indicator. Instead, it will feed into discussions about the full range of indicators needed to inform marine policy, how cost-effective it is to monitor it, how the data will be stored and how it will be weighed up against all the other indicators being considered. In addition, it is not only academic science that can bring evidence to these groups. Initiatives such as Fishing for Litter (www.kimointernational.org) may be examined to see whether this is an effective way to inform judgements about the extent and types of plastic debris in the marine environment, though as discussed by Ryan *et al.* (2009), these opportunistic techniques suffer

from sampling problems and the resulting evidence needs to be treated with caution.

The ECGs may be the point at which science can apply pressure, but they do not have a direct influence on policy. Instead, the entire UKMMAS needs to be seen as the science–policy interface, maintaining the relationship via forums at different levels. The ECGs are made up of those responsible for the technical aspects of monitoring programmes. Their representatives feed into MARG, which is made up of people in both policy and technical roles. These people in turn feed into MAPC, which is composed of senior policy leads with budgetary control. However, in contrast to the next case study, the feedback loop is fairly closed, reflecting the moderately structured nature of the problem of developing indicators.

(b) Case study 2: making policy for land-based plastics waste: the move to a life-cycle approach

Policymaking around land-based plastics has shifted direction over the past decade. From seeing waste as an 'end of pipe' problem to be dealt with once the waste has been created, policymaking has moved to an approach that considers how to promote sustainable consumption and production (SCP) of products and materials (Defra 2005*b*). This integrated product policy approach to plastic-containing products (http://ec.europa.eu/environment/ipp/home.htm) places more weight on waste prevention, recycling and resource efficiency; focusing on priority materials, products and sectors under the overarching goal of a low-carbon economy (Defra 2007*a*,*b*). This involves measures to change the way products and services are designed, produced, used and disposed of—and how any waste is subsequently prepared for reuse, recycled, subjected to energy recovery or otherwise treated prior to landfill.

Policy processes relating to plastics are driven by several European Directives such as REACH (case study 1), the 2002 European Directive on Waste Electrical and Electronic Equipment (WEEE: http://ec.europa.eu/environment/waste/weee/index_en.htm), the 2004 Packaging Directive 94/62/EC on packaging waste (http://europa.eu/scadplus/leg/en/lvb/l21207.htm) and by international agreements such as the Basel Convention on the transhipment of waste (http://www.basel.int/). Plastics policies also need to contribute to innovation and economic performance (Defra 2008*a*), informed by research into improved resource efficiency and the evidence emerging from social science research on understanding and influencing pro-environmental behaviour (http://www.defra.gov.uk/evidence/social/behaviour/index.htm). The list of policy's interest groups contains plastics scientists from a variety of different disciplines in industry and academia, product designers and manufacturers, the British Plastics Federation, the Polymer Innovation Network, retailers of plastic-containing products, users of plastic packaging such as supermarkets, waste management companies, environmental and human health interest groups and local authorities who are responsible for waste collection. It also contains the policymakers dealing with plastic litter in the marine environment in case study 1. Some of the

technical issues may have a degree of problem structure to them, such as how to reduce emissions from energy from waste plants, monitoring leaching from landfill (see Teuten *et al.* 2009; Oehlmann *et al.* 2009) or how to use the presence of plastic debris as an indicator of the health of the marine environment. However, the introduction of new technologies such as bioplastics, combined with emerging evidence on human health and environmental effects of conventional plastics, means that the range of interest groups in this debate is wide and constantly changing. Given their competing values, interests and priorities, the overall policy problem of plastics waste must, therefore, be described as unstructured. Realizing this, the team that deals with evidence for land-based plastics policy has developed a far more open structure than that dealing with marine indicators. The next few paragraphs outline its history and approach.

Sustainable Consumption and Production was elevated to a strategic priority for Defra in 2005. This instigated the creation of a small group to deal specifically with SCP policymakers' need to understand what evidence would inform a life-cycle approach and pull together diverse strands of existing evidence. Early work by this evidence base team supported the idea that SCP policy should focus on a products and materials approach—resulting in the formation in early 2008 of the Sustainable Products and Materials Programme. The evidence teams that had previously worked separately on the evidence for SCP and Waste issues were brought together to support this approach (Shaxson 2009).

Previous work elsewhere in the department described the context within which this new team would operate. Drawing on a new understanding of what we mean by robustness in the evidence base for policy (Shaxson 2005; Defra 2008), Defra set out the four functions of evidence-based policymaking: scoping, assembling, procuring and interpreting evidence for policy (Defra 2006). These are shown in figure 2.

A report by Ashridge Centre for Business and Society (ACBAS 2006) encouraged the team to take a more relational approach to the provision of evidence, focusing on building multi-stakeholder networks rather than relying solely on expert academic advice. Key aspects of the team's approach are described in Shaxson (2009): how these are linked together within a revised governance structure is currently being actively addressed.

(i) Working closely with policy colleagues to scope the questions, rather than relying on expert-driven research programmes (Defra 2007*b*; Wilson *et al.* 2007). To do this, the evidence team needed to develop new knowledge management techniques including a suite of workshop-based tools, which encouraged policymakers to engage stakeholders in developing and managing the evidence base (Bielak *et al.* 2008).

(ii) Restructuring research reports to ensure that policy-relevant issues are clear and accessible to non-specialist policymakers; separating these from the technical information and detailed analysis required for peer review and quality assurance. The
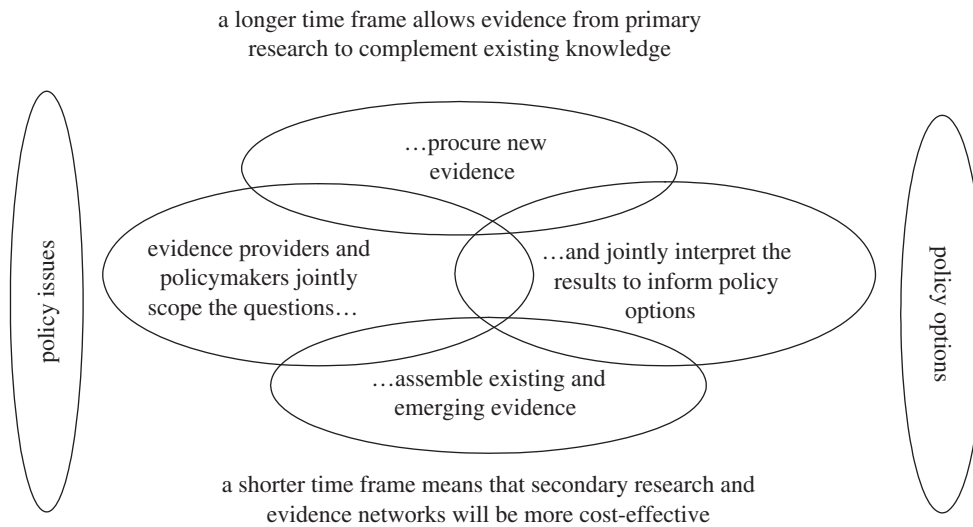
Figure 2. The four functions of evidence-based policymaking. Adapted with permission from Defra (2006).

'enlightenment function' described by Weiss (1977) will not happen to any great extent if reports are not read. The team is also helping produce even shorter (one-page) analyses of the policy implications from the reports. These do not repeat researchers' recommendations, but represent the best available collective knowledge about what a particular piece of research means for a particular aspect of policy at a particular time. Revisiting previously completed research to synthesize and understand its relevance in a changed policy environment is an important part of the team's work (http://www.sd-research.org.uk/post.php?p=816).

(iii) An approach to 'sensing' emerging evidence by taking a more distributed approach to the provision of expert advice. Instead of relying solely on formally constituted programme-level expert advisory groups, the team is experimenting with two new approaches. First, internal research managers and technical experts present informally to university researchers and interdisciplinary research networks, explaining current policy goals and listening to what is emerging from academia. This information may not yet be peer-reviewed, but it stimulates policy to think further into the future and broadens its horizons. Second, the strategic overview normally offered by a formal advisory body will instead be done by bringing project steering groups and other advisors together on an infrequent but regular basis, ensuring that the entire SCP&W agenda is informed by a representational rather than a more traditional task-based approach.

(iv) Explicitly taking a knowledge-brokering approach to managing the SCP and Waste evidence bases; creating and managing multi-stakeholder networks, developing cost-effective tools to improve knowledge management in a resource-constrained policy environment and looking across evidence bases within Defra and elsewhere. Instead of relying solely on external organizations, the team felt that driving the knowledge-brokering

approach from within Defra could help improve policy's receptivity to new and emerging evidence.

The team's structure is described in figure 3.

5. CONCLUSIONS AND SUGGESTIONS

> Science Departments must engage with diverse audiences . . . in ways tailored for each audience. This means paying greater attention to the changing contexts in which information is received and used, and consequently the mechanisms required to produce and transfer scientific information. For policy audiences in particular, the relevance of the science to the issues of the day, and the crucial importance of timing, underline the need for interactive knowledge brokering approaches that can deliver synergistic combinations of 'science push' and 'policy pull'.
> (Bielak *et al.* 2008, p. 201)

What can we conclude for policymaking around plastics, the environment and human health? My conclusions all stem from the proposition that many plastics-related policies fall into the category of unstructured or badly structured problems. Individual components of a particular policy may be researchable (moderately structured) or relate to the implementation of best practice (well structured). However, policymakers need to reconcile the economic and social benefits plastics bring to society as well as their potential hazards to human and environmental health (Thompson *et al.* 2009*a*,*b*). Doing this in a debate that is heavily value laden and ethically charged means that policy cannot rely on scientific research alone to provide unambiguous answers. Instead, plastics policymaking demands the pluralist, bargaining and incrementalist approaches applicable in the unstructured and badly structured domains and mentioned at the outset of this paper.

My first conclusion is that policymaking around plastics demands a knowledge-brokering approach and that it is possible to change the way evidence teams operate
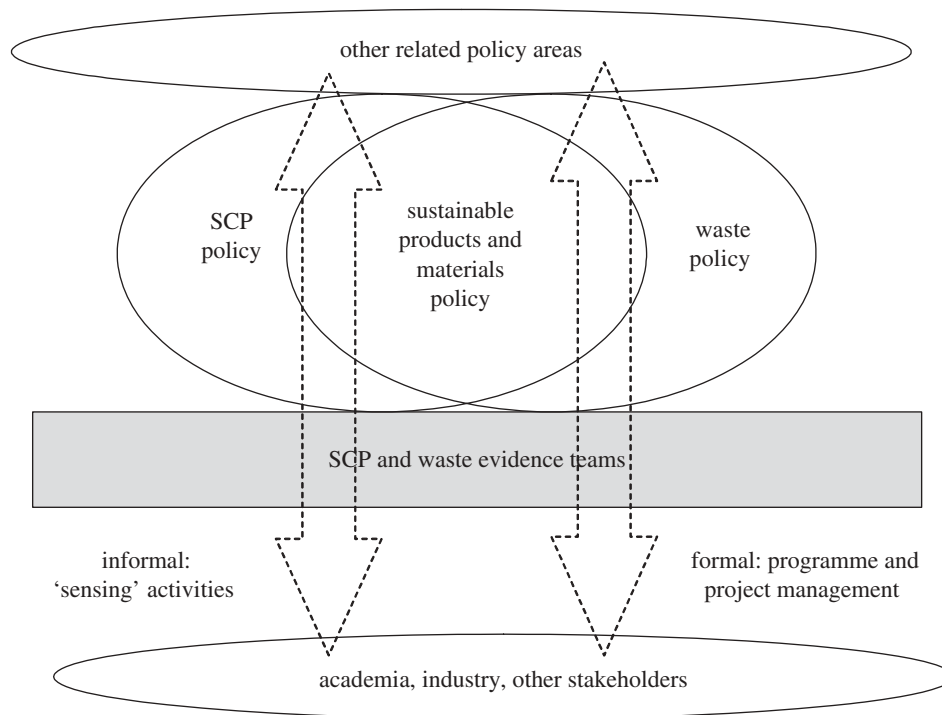
Figure 3. Knowledge brokering by the SCP and Waste evidence team.

within government to become more responsive to the needs of unstructured problems. Table 2 showed how different problem structures give rise to a diverse set of relationships between science and policy. The case studies build on this to illustrate the adage that form follows function: the structure of the brokering process must reflect the structure of the problem. A structured policy problem can be addressed by a relatively linear (though certainly two-way) flow of information, but an unstructured problem has multiple interfaces between multiple stakeholders. The teams in case study 2 have moved from being conventional research managers to devising new methods for scoping, assembling, procuring and interpreting evidence for SCP and Waste policy. However, implementing a knowledge-brokering approach within a government department requires organizational structures, knowledge management tools, governance and budgeting arrangements whose characteristics we are only just beginning to understand.

My second conclusion is that science can continue to improve the way it interacts with policy by becoming more involved in the processes of interpreting what a piece of scientific evidence means for current policy discussions. This does not mean losing objectivity: it is about understanding how the evidence is likely to be used in the policy environment, using it to challenge received wisdom in policy circles, to enrich policy's understanding and to help scope opportunities for change. There is a real role for *short* reports aimed directly at a policy audience, and for knowledge brokers sitting within departments to help researchers and policy teams jointly interpret these into even shorter policy-relevant summaries (Shaxson 2009), being clear where disagreements arise and why. There is also a need for scientists to take value judgements on broad issues, using evidence that may not yet have been through peer review, but which is nevertheless potentially useful to policy. The Marine Climate Change Information Partnership's Annual Report Card (http://www.mccip.org.uk/arc/2007/PDF/ARC2007.pdf) is a good example of this. Many marine policymakers have a scientific degree, but are operating in an environment where rapid decisions need to be made. The Annual Report Card, only four pages long, offers judgements based on a combination of peer-reviewed evidence, emerging evidence and expert opinion. It presents these as degrees of confidence in a statement about the current and likely future effects of climate change on different aspects of the marine environment. Based on reviews done by marine scientists from 18 organizations, it highlights important developments and explores issues that may be new to policymakers. It is possible to click through the website version to the peer-reviewed reports for clarification and find out which organization to turn to for a rapid update. However, the heavily summarized nature of the printed card itself is welcomed by marine policymakers who use it as a decision support tool while being well aware that the information it contains will be updated in future.

Third, I believe we need to be more imaginative about where this brokering function can take place. A Theme Issue such as this can perform two roles in the policy process. One it performs almost by default, but the other needs more thought before it will be effective. There is its traditional role—contributing to the ongoing enlightenment of policymakers about the science of plastics, the environment and human health. The science in this Theme Issue will continue to inform policy for years to come as scientists who read these articles serve on departmental expert advisory committees, research policy issues, review

others' work or teach students who go on to careers in industry, government or academia. Having said that, it may be possible to use such a Theme Issue in a way which is less traditional but which has a more immediate effect on policy. In the early stages of commissioning this Theme Issue, I suggested that it would be useful to turn the launch of the electronic version into a knowledge-brokering event with heavily summarized reports, workshops, seminars and other activities designed to bring authors together with policymakers to interpret the science contained in these pages and create a basis for more coherent policy action. However, as a proposal that meshed research, science communication, knowledge management and consultancy, it sat outside the remit of every funding body which the editors and I approached.

Finally, there is an opportunity to address many of these issues simultaneously by using the science in this issue to help develop an enhanced Road Map for policy around plastics, the environment and human health in the UK. The Milk and Dairy Road Map (Defra 2008*b*), the first of 10 to be published, used life-cycle analysis to build a picture of the environmental effects of liquid milk 'from cradle to grave'. It is an example of good evidence-based policymaking in practice—using the best available knowledge to build credible commitment from a wide range of interest groups, accompanied by an obligation to update the evidence base and an associated budget. A Plastics Road Map would deal with a policy issue that is inherently less structured than that of liquid milk: life-cycle analysis alone would be insufficient to analyse all of the issues. We would need to think hard about the science–policy relationships, which oversee production of a Plastics Road Map, ensuring that we do not rely only on a limited group of experts whose approach presupposes that the problem is structured. On the other hand, we would need to be pragmatic about how to work in the unstructured domain; developing cost-effective techniques to mesh life-cycle analysis with approaches more appropriate to considering health, social and ethical issues. We would need to build on our emerging understanding about how to access the best available knowledge around complex, unstructured issues and broker it into policy. A Plastics Road Map would not attempt to 'close down' discussion about plastics policy using expert advice alone. Instead, it should be seen as the start of a process involving a wide range of stakeholders including the cutting edge of plastics science (see Thompson *et al.* (2009*a*,*b*), and other papers in this Theme Issue). The process would open up a broad debate that would, in the long term, help a robust dialogue emerge about how to reconcile the relative costs and benefits of plastics to society, the economy, the environment and human health.

ENDNOTES

[1]'Science' is taken to include the breadth of natural and physical sciences, social sciences, economics and statistics and the arts and humanities. 'Evidence' includes all of these as well as information from public opinion and other sources.

[2]For the past 5 years, I have worked as a consultant to policy teams in several UK Government departments in the area of science policy and strategy. My focus has been on the practical and organizational aspects of implementing an evidence-based approach to policymaking.

[3]A crisis response effectively 'moves' the problem into the well-structured domain: a symbolic response moves the problem into the unstructured domain. For a detailed discussion of this, see Kurtz & Snowden (2003) and Snowden & Boone (2007).

[4]Note that the four roles do *not* map onto the problem typology outlined earlier. The fact that there are four problem types and four brokering roles is purely coincidental.

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