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ENGLISH VERSION

ABOUT THE IPTS REPORT

The IPTS Report was launched in December 1995, on the request and under the auspices of Commissioner Cresson. What seemed like a daunting challenge in late 1995, now appears in retrospect as a crucial galvaniser of the IPTS' energies and skills.

The Report has published articles in numerous areas, maintaining a rough balance between them, and exploiting interdisciplinarity as far as possible. Articles are deemed prospectively relevant if they attempt to explore issues not yet on the policymaker's agenda (but projected to be there sooner or later), or underappreciated aspects of issues already on the policymaker's agenda. The long drafting and redrafting process, based on a series of interactive consultations with outside experts, guarantees quality control.

The clearest indication of the report's success is that it is being read. An initial print run of 2000 for the first issue (00) in December 1995 looked optimistic at the time, but issue 00 has since turned into a collector's item. Total readership rose to around 10,000 in 1997, with readers continuing to be drawn from a variety of backgrounds and regions world-wide, and in 1998 a shift in emphasis towards the electronic version on the Web has begun.

The laurels the publication is reaping are rendering it attractive for authors from outside the Commission. We have already published contributions by authors from such renowned institutions as the Dutch TNO, the German VDI, the Italian ENEA and the US Council of Strategic and International Studies.

Moreover, the IPTS formally collaborates on the production of the IPTS Report with a group of prestigious European institutions, with whom the IPTS has formed the European Science and Technology Observatory (ESTO), an important part of the remit of the IPTS. The IPTS Report is the most visible manifestation of this collaboration.

The Report is produced simultaneously in four languages (English, French, German and Spanish) by the IPTS; to these one could add the Italian translation volunteered by ENEA: yet another sign of the Report's increasing visibility. The fact that it is not only available in several languages, but also largely prepared and produced on the Internet World Wide Web, makes it quite an uncommon undertaking.

We shall continue to endeavour to find the best way of fulfilling the expectations of our quite diverse readership, avoiding oversimplification, as well as encyclopaedic reviews and the inaccessibility of academic journals. The key is to remind ourselves, as well as the readers, that we cannot be all things to all people, that it is important to carve out our niche and continue optimally exploring and exploiting it, hoping to illuminate topics under a new, revealing light for the benefit of the readers, in order to prepare them for managing the challenges ahead.

Preface

The Joint Research Centre (JRC) is an important asset of the European Commission, and in order to make even better use of it I have recently redefined its mission, such that from now on it will be to provide technical and scientific support to the conception, implementation and monitoring of community policies. As a Commission service the JRC serves as a point of reference for the EU in the domain of science and technology. Close to decision centres, it can serve Member States' common interests, whilst preserving its independence from particular interests, whether public or private. In the context of the Fifth Framework Programme the JRC's work is guided by three themes:

- *serving citizens*
- *enhancing sustainable development, and*
- *contributing to assuring European competitiveness.*

In order to be better able to fulfil these aims the JRC has been restructured, making it more effective in its role of providing scientific and technical support to European political decision makers. Moreover, the new structure will allow closer collaboration between the various institutes that comprise it, for example improving the synergies between the activities of its 'think tank', the Institute for Prospective Technological Studies (IPTS), and the scientific and technical work that is the main task of the other institutes.

This restructuring entails, in particular, the creation of a new institute within the JRC, dedicated to aspects related to Health and Consumer Protection. This is also in line with the research priorities defined by the European Commission in agreement with the European Council and Parliament. This new institute will be supported by the activities already being carried out within the JRC, such as the BIOSAFE programme, which supplies information concerning safety and regulations in the biotechnology field, and the development of new forms of radiotherapy against cancer within the framework of BNCT (Boron Neutron Capture Therapy).

I am convinced that these changes will better enable the JRC to confront the challenges of the coming century through improved management of its resources, greater sharing ideas and better use of its innovations. In short, they will better equip the JRC to carry out its mission of supporting political decision makers.

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Isla de la Cartuja
E-41092 Sevilla, Spain
Tel: +34-95-448 82 97
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EDITORIAL

Dimitris Kyriakou

On last July's editorial we alluded to different ways of addressing 'externalities' – a term referring to consequences of actions taken by economic agents which do not accrue to the agents themselves, but to others, or often, to society as a whole (or a suitably defined geographic subset).

We suggested that one solution, often associated with the British economist Pigou, to this discrepancy between private and social preferences, is to impose taxes/subsidies to bring individual preferences in line with social ones. A less obvious one, dating from the early sixties, dubbed the Coase theorem after its inventor, was largely responsible for getting Ronald Coase the Nobel award in Economics, in the early nineties. The Coase theorem states that for two economic agents A, B when A's actions generate a negative externality for B, and transaction costs are zero for both parties, it is optimal in terms of social welfare to allow the two agents to negotiate a payment to resolve the issue - either through A's compensating B for the damage A's activity inflicts upon B, or through B's compensating A for the benefits A will forego by discontinuing the activity.

We also indicated that in the case of positive transaction costs, the theorem states that optimality would dictate the allocation of the property right to the side with the higher transaction costs. We also indicated that the key issue then becomes the allocation of property rights, suggesting that it is not easy to disentangle the invisible hand of the market from the hidden fist of the state.

The role of the state however enters in a different way, too. Assume that each economic agent has its own preferred level of acceptable pollution. Assume also that agents are mobile across jurisdictions and that there are pollution spillover effects – all quite realistic assumptions. If in each jurisdiction, the enfranchized group decides on the target level of acceptable pollution - and concomitant compensation - through some majority rule mechanism, then mobile minorities may opt to move into jurisdictions inhabited by agents with pollution preferences similar to their own.

Assuming that initially 'pollution-lovers' were in the minority in most, if not all, jurisdictions, deregulation of polluting activity and reliance on property rights allocation and bargaining accompanied by high mobility, may have the perverse consequence of allowing 'pollution-lovers' to become the majority in some of those jurisdictions, whereas before they controlled very few, or none, of such jurisdictions. Through cross-jurisdictional spillovers, those pollution lovers could force environmental degradation on the other jurisdictions as well.

One solution would call for the inclusion of all injured parties in the decision-making process, enlarging the jurisdiction and enfranchising all those affected by pollution.

We have now come full circle: the enfranchising of all parties necessitates their being represented by their government, which, if the jurisdiction has grown sufficiently in size through the inclusion process, brings us back to the Pigouvian tax, in the form of compensation paid by polluter to hurt party, with the government being one of the parties in the transaction.

Government cannot be avoided on this issue; if it is pushed out the door, it comes back in through the window. As the desirable size of the jurisdiction expands government can reappear as the representative of the population of the jurisdiction, and by revealing its Pigouvian mantle underneath the Coasian one show that those two can be viewed as two sides of the same coin.

Enhancement of Terrestrial Carbon Sink Potential: A Possible Contribution to Mitigating Global Warming

Claus Brüning, *European Commission DG XII-D-02*

Issue: The terrestrial biosphere is thought to represent a major sink for anthropogenic atmospheric emissions of carbon dioxide (CO_2). Some recent estimates suggest that as much as 25% of total global carbon dioxide is locked into the terrestrial biosphere. Enhancing the biosphere's carbon sink potential may therefore be an option for reducing the rising concentration of atmospheric carbon dioxide and so mitigate predicted global warming.

Relevance: The parties listed in Annex I of the Kyoto Protocol agreed to reduce their overall emissions of greenhouse gases by at least 5% below 1990 levels in the commitment period 2008-2012. This agreement includes the option of giving credits for sinks (considered as negative emissions) in the terrestrial biosphere, but limited to human afforestation, reforestation and deforestation activities (Art. 3.3). However, the partial sink categories of the protocol may be insufficient.

Introduction

Climate researcher Klaus Hasselmann, Director of the Max-Planck-Institut (MPI) for Meteorology in Hamburg and a project co-ordinator of EC's Environment and Climate Programme, was one of the first scientists to warn that recently observed global warming trends have a discernible human related forcing component. Climate model calculations show, that global warming is closely related to rising atmospheric concentrations of greenhouse gases (GHGs) as consequence of man's activity. Since pre-industrial times the atmospheric concentration of CO_2, the most important GHG, has increased from 280 to 360 ppm and will rise further. According to the Intergovernmental Panel on Climate Change (IPCC) total anthropogenic emissions add up to 7-8 $GtCy^{-1}$ (1 $GtCy^{-1}$ = 1,000,000,000 tons) of carbon per year. Burning fossil fuels and deforestation are two of the largest contributors to the emissions figures. If recent global warming trends continue, the impact on natural and agriculture and ecosystems in many regions of the world can be expected to be severe and to affect almost all sectors of human life, from tourism to water supply. To avoid these potentially devastating consequences, both the climate research community and the public are calling for urgent political action to cut GHG emissions.

Climate model calculations show a link between rising concentrations of greenhouse gases and global warming

The balance of evidence of human interference with climate supported by climate research has forced policy makers to take the threat of climate change seriously. Finally, after lengthy negotiations, the efforts culminated in the third session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto. Here, for the first time the parties agreed on legally binding commitments (Annex I countries only) to reduce GHG emissions by 5 % on average (the EU has unilaterally committed itself to a voluntary 8 % reduction), compared to the 1990 level in the commitment period 2008-2012.

The scientific uncertainties

In order to meet the GHG reduction targets there are basically two options: either to cut atmospheric emissions or to enhance GHG sinks in the terrestrial biosphere. The sink option is based on the assumption that the terrestrial biosphere is able both to take up and store significant portions of CO_2 from atmosphere. Estimates by the IPCC suggest that the terrestrial biosphere currently takes up about 25% (1.8 $GtCy^{-1}$) of the global annual emissions of CO_2. The margin of error associated with this estimate, however, is of the same order, which to some extent undermines the credibility of the approach. Even less is known about the storage capacity and possible saturation levels of the terrestrial biosphere.

A third alternative is to make use of the GHG storage potential of the oceans. There are a number of direct and indirect options available. Deep-sea disposal of CO_2 is one possibility but production of liquid CO_2 or dry ice is expensive and transport costs are high. Moreover, deep-sea injection of CO_2 would acidify the water into which it was injected and create CO_2 lakes at the bottom of the sea. The environmental implications could be severe. A second (indirect) method often discussed is the enhancement of the biological activity in the upper ocean layer by fertilizer. By this method the concentration of organic particles transported into the deeper sea ('biological pump') would be increased thus enhancing carbon flux in parallel. Although the carbon in the deep-sea is 'safely buried', decomposition processes will reduce the oxygen content of deeper ocean layers. In summary, these options are costly and the environmental impacts and risks associated with these options are unpredictable. The precautionary principle makes using the terrestrial biosphere the most pragmatic way of mitigating the greenhouse gas problem for the time being.

Although enhancing the carbon sequestration potential of the terrestrial biosphere poses less of a risk to the environment, it is nevertheless difficult to quantify the sources and sinks. There are three reasons for this uncertainty:

- The amount of carbon accumulated by the terrestrial biosphere is small compared with the overall carbon turnover (the exchange between the terrestrial biosphere and the atmosphere is about 60 $GtCy^{-1}$ in both directions).
- The processes in the soil, plants and atmosphere controlling the gas exchange between the reservoirs are complex and not very well understood and therefore difficult to model.
- There is a mismatch between the size of the problem and scales involved. The size is global, but measurements dealing with the problem are mainly local. Local measurements have to be extrapolated (called 'up-scaling') taking into account the large geographical and temporal variations (dimensions have to be upscaled from metres to continental scale, times from hours to years). Unfortunately, records of consistent observations of carbon fluxes with sufficient temporal, horizontal and vertical resolution (also required to calibrate the models) do not yet exist.

On the other hand the implementation of new measurement technologies and methodologies has now made it possible to separate ocean and

In order to meet the GHG reduction targets there are basically two options: either to cut atmospheric emissions or to enhance GHG sinks in the terrestrial biosphere

Using the GHG storage potential of the oceans is costly and its environmental impact is unpredictable

The complexity of the systems involved and the mismatch in scale between the measurements taken and the models used, places limits on our current understanding of the behaviour of carbon sinks

Even the behaviour of forests is more complex than previously thought; under certain climatic conditions some types of forest can even become carbon sources

Another concern is that carbon sinks may not lock up carbon over the long term, but simply store up the problem for future generations

land uptake. The initial results indicate that the forests in the Northern Hemisphere present a strong sink in the early 90's. The magnitude is of the order of 0.8 $GtCy^{-1}$ but varies from year to year. The origin of the sink in the Northern Hemisphere is not fully understood. It could be related to increased nitrogen deposition associated with industrial and agricultural activities. Nitrogen plays an important role in the nutrient balance of ecosystems. It acts as a fertilizer and enhances productivity. The fertilization effects of increasing atmospheric CO_2 concentrations could also contribute, but how the biosphere responds to this fertilization from the species level all the way up to the ecosystem level is not known. Re-growth of forests and the lengthening of the growing season (observed by satellites) provide another possibility. Most of these effects have occurred simultaneously during recent years and it remains difficult to identify and quantify the contribution of each process to the regional or global carbon budget.

The largest source of uncertainty, however, is the response of the carbon pools of the terrestrial biosphere to climate change. Past records show that the annual atmospheric growth rate of CO_2 is not steady with time. Climate fluctuations following El-Niño events, change of ocean circulation and volcanic eruptions have modulated the CO_2 growth rate in the past (equivalent to an annual uptake/release variation of 2-3 $GtCy^{-1}$).

Although forests are generally believed to be carbon sinks, this may not be true in all cases. There is recent evidence that boreal forests are highly vulnerable to climate change and can switch from being a carbon sink to a carbon source depending on climatic conditions. Recent results also indicate that tropical forests accumulate larger amounts of carbon than previously thought, but again, estimates show a wide spread depending on forest type and climatic conditions. The underlying processes, in particular those affecting the soil, need to be better understood.

The sink approach

Prior to the Kyoto conference there was a broad consensus within the European climate research community that the problem of global warming should be tackled at its roots by cutting emissions and not to go for the sink enhancement strategy. The main concern is that the carbon sequestration potential of the terrestrial biosphere is limited and that the carbon sequestered is not 'buried safely' over the long term. It will, sooner or later, reach a saturation level and re-emission to the atmosphere within a few decades becomes likely. Therefore the sink enhancement strategy provides only a temporary 'political' solution, but could in fact simply shift the problem to later generations. Furthermore, as discussed above, the carbon exchange between the atmosphere and the terrestrial biosphere and the bio-geochemical processes involved are complex, highly variable in space and time and are still not very well understood. This is the reason why both measurements as well as model calculations of the carbon sequestration of the terrestrial biosphere show a wide spread. At the current state, detailed estimates of changes in the terrestrial carbon stocks, as requested by the Kyoto Protocol are available for some local areas but not at a global scale. Science knows even less about the long-term consequences, feedback mechanism and possible 'surprises' related to distortions of the global carbon cycle and its impacts on marine and terrestrial ecosystems.

A large source of carbon dioxide emissions, directly related to the human interference with the terrestrial biosphere is often forgotten in discussions. Land-use change and deforestation,

especially the conversion of natural forest into farmland, significantly contribute to the overall rise of atmospheric CO_2. On average 1.6 Gt of CO_2 are released to the atmosphere annually, accounting for more than 20% of global anthropogenic carbon emissions. These facts made most scientists recommend made GHG emission cuts without the sink option. Alternatively, the conservation of natural forest should have highest priority, summarized in the session statement of Greenhouse gas Workshop in Orvieto, Italy, 10-13 November 1997, organized by the European Commission:
'Although probably accumulating carbon at a lower rate, the large carbon stocks of pristine forests represent carbon accumulated over many centuries. This carbon can only be replaced over a similarly long time-scale. Therefore, preservation of pristine forests should take priority over afforestation programmes where possible.'

Scientific agenda after Kyoto

Although the parties agreed in Kyoto to include GHG source and sink options in the Protocol this was strictly limited to the forest-related categories of afforestation, reforestation and deforestation. The consequences of the Protocol have been analysed e.g. during a workshop organized by the European Commission and the IGBP Terrestrial Carbon Working Group. The scientific community came to the conclusion that the partial sink categories agreed upon are insufficient. Instead they recommended using the full carbon budget of the terrestrial biosphere, monitored over sufficiently long time scales as the appropriate basis for a carbon accounting system. Furthermore, the sink approach of Kyoto Protocol has a number of loopholes and opens ways for a 'creative' accounting system. (Refer to the articles listed in the references for a more detailed analysis of the Kyoto Protocol). In summary, the contribution of the carbon sequestration potential of terrestrial biosphere, even towards a temporary solution of the global warming problem will remain small due to the limited carbon sink categories agreed upon.

Although climate scientists still have reservations, and still give preservation of natural forests highest priority, the Kyoto agreement on terrestrial sinks is also a big challenge for climate research to fill gaps in our understanding of their characteristics. The EC is supporting a number of research projects such as EUROFLUX, ESCOBA and Eurosiberian Carbonflux in the framework of the Environment and Climate Programme in the field of GHG research. The aim of these projects is to develop tools and methodologies to make it possible to understand the processes and quantify the sources and sinks better. Within EUROFLUX a network of carbon monitoring stations has been established along a European axis at a number of representative forest sites. The long-term measurements of the carbon exchange between forests and the atmosphere together with the application of new model-based methodologies will allow better estimates of the European carbon balance in the future. The EUROFLUX methodology provides the basis for a global carbon monitoring network to be established. The integration of carbon flux data between the terrestrial biosphere and the atmosphere at a continental scale is the aim of the Eurosiberian Carbonflux project. This will be achieved by joint field experiments carried out by Russian and EU research teams over Europe and Siberia. Aircraft measurements at different heights in the atmospheric boundary-layer, complemented by ground-based observations, provide the basis for data integration. The objective of the ESCOBA project is the investigation of the global carbon budget by using sophisticated measurement techniques and inverse modelling methods. These techniques will help to better quantify and distinguish

The partial carbon sink categories agreed upon at Kyoto means that the terrestrial biosphere will be able to make only a minor contribution to the global warming problem

A number of projects are underway to develop tools and methodologies needed to understand the processes involved in sources and sinks and to quantify them more accurately carbon up-take between the terrestrial biosphere and the ocean. Since more data of better quality on a global scale will soon become available, inverse modelling techniques will help to identify the carbon sources and sinks more precisely.

That the European Commission (EC) has taken the challenge of climate change research on board is shown once more in the 5th Framework Programme, which includes the Key-action 'Global change, climate and biodiversity' as part of the programme 'Preserving the ecosystem'. This focuses on climate-related environmental problems and gives GHG research a high priority. This key-action also supports new elements such as infrastructure and long term monitoring programmes of environmental parameters to meet the demands of researchers in this area more closely. This new approach will put European research at the forefront of international efforts on this crucial issue.

Keywords

Kyoto Protocol, carbon sequestration, terrestrial carbon sinks, forests

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Contact

Claus Brüning, European Commission DG XII-D-02
Tel.: +32 2 295 44 84, fax: +32 2 296 30 24

About the author
Claus Brüning received a diploma degree in meteorology in 1982 and a Ph.D. degree in oceanography from the University of Hamburg in 1987. He has worked at the Max Planck Institute for Meteorology in Hamburg, Germany, the European Centre for Medium Range Weather Forecasts (ECMWF) in Reading, UK, and the University of Hamburg. Since 1995 he has worked for the European Commission in DG XII-D-02, the Climatology and Natural Hazards Unit of the Directorate General for Research and Technology. His responsibility is the implementation and follow up of research projects related to 'Basic processes in the climate system', area 1.1.1 of the Environment and Climate programme.

Patents Citing Scientific Literature: is the Relationship Causal or Casual?

Martin Meyer, *SPRU*

Issue: Recent research reports on a rapidly growing tendency for US patents to cite scientific papers. But is a citation linkage also a causal link? Previous work has given only a very general indication of relationship between science and technology in a very general manner.

Relevance: In times of strict budgetary discipline even basic research needs to provide documentary evidence of industrial relevance. However, it is important to avoid a mistaken impression that knowledge transfer from scientific research to patents is a direct process and one that is easily measured by the number of citations. Although case-by-case analysis shows the limitations of this particular bibliometric technique, it nevertheless reveals the importance of results, tacit knowledge and skills acquired through scientific research.

Introduction

Previous studies of front page references from patents citing research papers (e.g. Narin et al., 1995 and 1997) seem to suggest a growing relationship between science and technology. But how do they measure the science-dependence of a technology? The implication is that any given technology is more science-based than others if it has more references per patent of scientific research papers. The validation of this method rests on a comparison of citation-based bibliometric rankings and expert rankings of different technology fields. Close agreement was found between rankings based on the number of scientific literature citations per patent and peer rankings of the science dependence of the technologies in question (Carpenter and Narin, 1983). But to what extent can this measure be useful to policy-makers?

Budgetary discipline means policy-makers need more concrete measures to show that basic research does yield results applicable in industry and is therefore beneficial to the economy. Various studies have used patent citation analysis to document the importance of public, scientific research on a very aggregated level and make a general case for continued governmental funding of science. Patents initiated and stimulated by basic research activities are potentially a direct indicator of industrial relevance of basic research. If the method cited could be validated not only on the macro-level, but also on the micro-level of actual scientific and technological activity, policy-makers would have a practical tool for evaluating and depicting the use of basic research projects financed out of public sources. The benefit of a more 'precise' measure would be the ability to trace the links between an

Studies have shown an increase in the frequency of research paper citations in patents, suggesting that citation frequency may be a means of assessing the degree to which basic research is converted into tangible products individual discovery and a particular innovation and thereby identify (and later reward) functioning knowledge transfer.

This study investigated citations on data-sheets of US nanotechnology patents, a field with a total production of around 5,000 papers and 2,000 patents

Hence, as a reflection of the stimulating flow of knowledge from science to industry, it has been suggested that patent citation studies may serve as a credible justification of basic research. Research of this kind 'would greatly heighten the quality of information and public awareness of the nature and extent of the contribution of academic research to technical change', as Pavitt (1997, p.14) puts it. However, it is necessary to corroborate these measures more carefully first and investigate the question whether a citation linkage really equals a causal link.

Case Selection

Interviewing the relevant actors necessarily restricts the scope and scale of an investigation. In this situation, even more attention must be paid to the selection of the patents to be examined. Assuming that there is a higher probability of finding direct connections between basic research and patents in a young and science-based area, this study investigates citations on data-sheets of US patents in the emerging field of nanotechnology. If a causal link exists it may be expected to be apparent in this field, which has a total production of around 5,000 papers and 2,000 patents (Meyer and Persson, 1998). Nanotechnology was also chosen because it constitutes more a cluster of technologies than a single technology. The term nanotechnology encompasses cutting-edge developments in a number of generic technologies that are novel in nature because of the changing conditions and properties of structures at the nanometre scale. By choosing patents from this area one could not only cover a dynamic and novel science-based area, but also cover a range of generic technologies to avoid sectoral biases as much as it is possible in a small survey like this. Therefore, the cases include patents related to electronics, materials, and biotechnology. Moreover, to avoid biases from certain assignee-inventor structures the sample reflects the variety of inventors and assignees and the different institutional affiliations of the inventors. Individual assignee-inventors (case 9), weaker (case 4) or stronger ties (cases 1-2, 5) of external inventors to their assignees were also included. Table 1 gives an overview.

In the patent sample used in this study, the papers cited did not, in most cases, reflect concrete input to the invention

Findings

The data from the cases show that there is indeed a general link between science and patents. Many of the inventors indicated the general importance of scientific papers. One of them even said that citing scientific research papers would indicate the basic research character of his patent. In other cases, researchers referred to their general experience in research and teaching or said they used papers in special cases.

However, in the patent sample used in this study, the papers cited did not, in most cases, reflect concrete input to the invention. For the cases presented here, the references do not give any hint of what might have been the idea which inspired the invention, even though it might have been stimulated by a publication. For example, in case 2, the idea to the invention came from further downstream, in an article in a magazine for physicists.

Most of the patents in the sample do not contain more than a handful of citations of scientific papers. Occasionally, for instance in case 9, one could find citations of patent abstracts and patent search reports in the section 'other references'. Another inventor (case 10) mentioned that the patents he cited contain further references to relevant literature. Both

Table 1. Selection of patent cases

Case	US Patent No.	Invention patented	Field	Assignee	Inventor
1	5,566,197	Tunable gain coupled laser device	Electronics	Multinational company	University/PSR
2	5,367,274	Quantum wave guiding switch	Electronics	Multinational company	University/PSR
3	5,418,197 and 5,420,083	SiC whisker and particle reinforced ceramic cutting tool material and Whisker and particle reinforced ceramic cutting tool material	Materials	Large firm	University/PSR
4	5,603,958	Pharmaceutical Carriers	Materials	Foreign company	University/PSR
5	5,427,767	Nanocrystalline magnetic iron oxide particles-method for preparation and use in medical diagnostics and therapy	Materials	University-affiliated institute owned by industrial company	University/PSR
6	5,559,353	Integrated circuit structure having at least one CMOS-NAND gate and method for the manufacture thereof	Electronics	Multinational company	Industrial researchers, in-house
7	5,298,760	Performance of location-selective catalytic reactions with or on the surfaces of solids in the nanometer or subnanometer range	Materials	Multinational company	Industrial researchers, in-house
8	5,543,289	Methods and materials for improved high gradient magnetic separation of biological materials	Biotechnology	Inventor who exploits patent in his firm (SME)	Industrial researchers, in-house
9	5,470,910	Composite materials containing nanoscalar particles, process for producing and their use for optical components and Method for producing metal and ceramic sintered bodies and coatings	Materials	PSR	PSR researchers, in-house
10	5,250,207 and 5,500,141	Magnetic Ink Concentrate	Materials	Multinational company	Industrial researchers, in-house

Patent applicants gave various reasons for citing research articles, including giving their work a 'basic research' character, and justifying and substantiating claims

In the cases we looked at the scientific literature cited rarely seems to be the original source of the idea that brought about the invention

patents and papers cited in patent documents can be distinguished according to their affirmative or negational character. Without talking to the inventors, one cannot tell just from looking at the data-sheet references whether they support or restrict a claim made.

Looking at the evidence from the cases studied, the most frequently mentioned reason is justification and substantiation of claims. Front-page non-patent references mostly reflect state-of-the-art literature in order to document and highlight the novelty and uniqueness of the invention patented. Correctness of one's work is another important motive for citations in patents. Case 10 illustrates the patent examiner's role as 'the primary source of references in that he or she develops them in course of searching for prior art' (Campbell and Nieves, 1979; p. 9.63). Here, the inventor had to modify his claims after the patent examiner had confronted him with material restricting parts of the original claims.

This implies that other individuals than the inventors influence patent citations. Other cases substantiate the idea of external influence on citations. These influences are, in this sample, either the patent departments of large firms or the specialized patent attorneys on behalf of high-technology SME's who make suggestions for adding references and thus making the patent 'water-proof'. Considering this kind of evidence, one should begin to doubt that there is a direct, 'antecedent' relationship between cited paper and citing patent. In the cases we looked at the scientific literature cited rarely seems to be the original source of the idea that brought about the invention.

In addition, in the citations looked at in this survey, there seem to be more differences between various technological fields than between the different assignee-inventor combinations. The electronics-related patents have a higher level of non-patent references than do the materials-related patents investigated.

Table 2 lists the observations from the cases with regard to background and input to the invention and the influence of external sources. In many cases, inventors did say that scientific research papers had played a significant role as an underlying factor in the invention process. But only a few, isolated examples of direct inputs to the invention were mentioned. Case 7, for

Table 2. Findings from the cases

Background of and input to invention	Reported in cases...
Often inventions based on general experience in research and teaching	1-2, 4-6
Research papers important as background information to inventors	3, 5, 7
Inventions stimulated by articles in downstream specialist journals not cited	2
Research papers cited in special cases only	4, 9
External influence on patent citations	**Reported in cases...**
Examiner most important by finding material restricting claims	10
Patent attorney	8
Patent department	6, 7

instance, is a patent that resulted from a basic research project in which a few papers were also written, one of which was cited. For this sample as a whole, however, there are too few linkages to speak of a direct relationship between cited paper and citing patent. There is no causal link. If one wants to speak of a relationship, it is not more than a very casual one.

Analysis

The evidence collected in the study supports the view that there is a general connection between science and technology, but it points out that citation linkages hardly represent a direct link between cited paper and citing patent. This general conclusion does not imply that scientific activities would not be of importance to technological development. The cases show the opposite. Scientific findings are important background knowledge playing an important indirect rather than direct role. The inventors interviewed pointed out that their inventions were often based on general experience in research and teaching. General experience could be seen as another term for tacit knowledge, which is conveyed chiefly through personal interaction in a scientific and/or technological environment. In science-based fields the ability to absorb tacit knowledge seems to be linked to a certain degree of scientific education. Most of the inventors interviewed had some kind of researcher training. This just underlines how important scientific training is for inventive activity. Some of the inventors in this survey have intermediary positions between science and technology in the sense that they are employed and financed by an industrial enterprise and have an academic position in the university system. This as well emphasizes the significance scientific activities have in supplying human capital. In this context, the cases support prior work suggesting that patent citations to scientific literature are a general indicator of science-dependence of a field justifying basic research activities.

Although a survey of just ten cases cannot raise sufficient empirical doubt to reject an analysis of patent citations to scientific research papers as a means to trace back knowledge links, it reminds us of the limitations this method has. This study calls for care to be taken when assuming such a relationship to be a causal knowledge link. Rhetoric of this kind could imply a one-to-one linkage that cannot be observed. Policy-makers should be aware of this limitation if they want to rely on this method in their policy formulation and evaluation.

They can use this method to illustrate the science-dependence of technological fields and have a mediated justification for basic research expenditure in certain fields. If the focus is on direct knowledge transfer this method clearly does not work. The direction of the knowledge flow cannot be determined simply by counting patent citations to scientific papers. Any reference other than that of a patent examiner citing a scientific paper is not a reliable indication of scientific input into technology. It is also extremely difficult to locate the cognitive source of innovations by using citations as they do not usually indicate the intellectual origin of an invention. What one can establish here is an interrelationship between science and technology varying among areas. In some fields it is stronger (more citations of publications per patent), in other fields weaker (fewer). This would argue for sector-specific technology transfer policies. Different fields have different frequencies of interaction. This might result in different forms of exchange and may require different transfer mechanisms. The citations analysis may give some hints as to what requirements such a mechanism has to meet in a

The inventors interviewed pointed out that their inventions were often based on tacit knowledge, in the form of general experience in research and teaching, rather than specific scientific input

Counting citations is also limited by the fact that not all technology is patented. Software, for instance, is a field with little patenting

Nor are citations a reliable way of distinguishing between 'evolutionary' and 'revolutionary' patents, as continued engineering of an earlier patent may nevertheless continue to cite the original research

certain science-technology field. As it also points to fields in which there is little interaction between science and technology it may induce further investigations as to whether more exchange between academic and industrial research could enhance the further development of a technology.

What one should not do with this method is to make comparisons and draw conclusions about the effectiveness and efficiency of knowledge transfer amongst fields. Even from this limited survey it is possible to see indications for different patterns of citations frequencies according to fields. Other studies confirm this on a broader empirical basis (e.g. Meyer-Krahmer and Schmoch, 1997). In addition, one must bear in mind that not all 'technology' is patented. Software, for instance, is a field with little patenting. Sectoral trends, such as 'know-how' and 'speed to market' as the preferred method of attaining competitive advantage, may distort a comparison. Thus, Pavitt (1997, p. 14) points out that patents as a direct measure 'are an incomplete and distorted reflection of the contributions made by academic research to technical change' with the result that 'they should not be used to make comparisons between fields or institutions.'

Policymakers might be interested in distinguishing between 'revolutionary' and 'evolutionary' patents – with 'revolutionary' patents being more likely to originate from basic science and 'evolutionary' patents more likely to result from continued engineering of an earlier basic patent. Nevertheless, evolutionary patents may continue referring to the original research. Revolutionary and evolutionary patents would have different functions in terms of justifying science spending. While revolutionary patents could illustrate the more immediate economic effects of science spending, evolutionary patents could document (in a more mediated manner) the pay-off of an original investment in basic research. If so, could a citation system distinguish between the two? Van Vianen et al. (1990) showed for chemical technologies that there were two different kinds of patents, patents citing to non-patent literature extensively and patents not citing to documents other than patents at all. However, before labelling them 'revolutionary' and 'evolutionary' respectively, one should have a closer look at the age of the references found and the kind of journals the 'revolutionary' patents cite. One should also investigate what kind of other patent documents the 'evolutionary' patents cite in order to ensure they relate to the 'revolutionary' patents. Further research is required to make more substantiated judgements on this matter. However, one should bear in mind that the causality issue as discussed in this paper would apply in a similar manner.

The idea underlying this study is to investigate the link between science and technology by using information given on the front page of patents. Using patent citations is one way of following up this relationship. However, the data sheets of patents contain more information one might want to utilize. Another approach towards investigating knowledge-transfer between science and technology would be tracing back the link between assignee and inventor. Looking at the assignee structure of patents would already give some useful hints about the stage of commercialization of a technology.

This, however, leads to a number of practical problems implying a restricted application of this method only. Inventors are just listed with their name and their private address. Thus patent data sheets do not contain any information as to whether or not the inventor is affiliated to a university or, alternatively, employed by an industrial company. One needs to find other databases to fill out this information gap, such as bibliometric databases. Pursuing this approach, one would encounter matching problems. For instance, people sharing the same name could lead to an incorrect inventor-affiliation. For reasons like this, university research output seems to be researchable only on a case-by-case basis (e.g. Numminen, 1996). But also this approach can lead to results of interest to policy-makers. For instance, one could measure the innovative significance of a university for the region it is situated in and thus illustrate its impact on regional development. Another way of measuring the influence of university research on inventive activity in a region would be to see to what extent university researchers themselves apply for patents. Schild (n.d.) has applied this approach in her study of inventive activity in East Gothia and found it 'far more fruitful' than using citations, which confirms the results of this paper.

Finally, one should not forget that the kind of citation studies that were discussed can justify past expenditure only. They do not tell us what tomorrow's blockbuster technologies come from. If previous 'efficiency' is financially rewarded and 'failures' fiscally punished, a country's research base could become skewed. And this does not necessarily mean that the research base will be well placed to meet future challenges.

Keywords
science, technology, citation, patents, non-patent references, nanotechnology

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Contact

Martin Meyer, Science Policy Research Unit
University of Sussex, Brighton, UK
Tel.: + 358 40 523 17 72, fax: +49 231 593 773, e-mail: **msmeyer@hotmail.com**

About the author

Martin Meyer is a member of SPRU, the Science Policy Research Unit at Sussex University, Brighton, England. He studied business administration, economics and sociology at the University of Dortmund, Germany, and Uppsala University, Sweden. His master thesis was about nanotechnology and its industrial applications. His present research focuses on the emergence of novel technologies and related S&T networks. Currently he is a guest researcher at the Department of Technology and Social Change at Linköping University, Sweden, and the Institute of Strategy and International Business at the Helsinki University of Technology in Espoo, Finland.

Liberalization of European National Gas Markets: A Ball in the Courts of the EU Member States

Irving Spiewak, Antonio Soria, Stéphane Isoard, *IPTS*

Issue: Following the trend set by electricity markets, gas markets in the EU are being liberalized in a move towards an internal market for natural gas.

Relevance: A recent gas market directive has been approved that provides common rules for the Member States toward the creation of an internal EU market for natural gas, but large part of the implementation of gas-market liberalization is being left to the discretion of individual Member States, which have to take into account several factors in planning their actions.

Introduction

Liberalization of gas markets is a general term that covers a series of Government actions to increase competition and efficiency, and hopefully reduce gas prices. These actions may include the privatization of Government companies, forced break-up of monopolies or licensing of competitors, unbundling of vertical integration into production, transport and marketing companies, and granting of access to transport at non-discriminatory prices to gas producers and customers.

Regulation of the electricity and gas sectors in the United States, and more recently in the United Kingdom, has been greatly liberalized in the direction of providing greater access of energy users to competing energy suppliers. The European Commission has issued a directive on liberalization of electricity markets that is being implemented by the Member States. More recently a gas market directive has been approved that provides common rules for the Member States toward the creation of an internal EU market for natural gas but with some room for subsidiarity. It is now up to the Member States to determine how rapidly and completely such a market will be implemented.

The objective of increased competition in natural gas supply is to reduce energy prices and thereby increase the competitiveness of energy-intensive European industries. At the same time, substitution of natural gas for coal and petroleum-based fuels will improve efficiency and reduce CO_2 and other undesirable emissions to the atmosphere. These are all important EU goals. On the other hand, there are potential losers from this competition in the coal mining industry and in the less competitive companies in energy supply

Liberalization covers a range of government actions, including privatization, break-up of monopolies and unbundling vertical integration into production, transport and marketing companies

The overall aim of liberalization is to increase efficiency through greater competition, and so allow price reductions to consumers

Demand for gas has grown much faster than for competing fuels as a result of factors including technological innovation and liberalization of the electricity market

In the UK an overall decrease in real gas prices of about 25% to small customers and over 50% to large customers has occurred since the privatization of British Gas

and transport. A fully liberalized gas market may discourage long-term gas purchase contracts and therefore increase risk for the large investments needed for major pipelines.

The natural gas technologies rely heavily on complex, expensive, infrastructures necessary for production, transport and distribution, inducing economies of scale to the various steps. The gas pipeline industry has therefore been historically considered a natural monopoly, similar to the electric utility industry and the telephone system. In return for monopoly status, these industries have assumed responsibility for high quality public service to customers within their jurisdiction, the public service obligation. The revolution in electronic and information technology has made it practical to unbundle the various elements of service and to introduce varying degrees of competition to these industries.

Efficient and economical operation of the natural gas industry within the European Union is believed to be important to improve the competitiveness of energy-consuming industries, to the benefit of all consumers, and to contribute to environmental improvement. Innovations in the gas turbine industry within the last 20 years, making it possible to provide flexible, low-cost, electricity generating plants with net fuel efficiencies approaching 60% in the most advanced models (in comparison to the 35 to 40% efficiencies of competing coal and oil plants) have created an important new market for gas. There has been a rapid growth of natural gas consumption as the preferred fuel for new power plants and for cogeneration (combined heat and power production). The growth in gas consumption for electricity production in the EU 15 between 1992 to 1995 averaged 14% per year (Eurostat, 1997). Steps by the European Commission to liberalize the electricity sector will increase investment by private power producers in gas fuelled power plants and increase their demands for gaining access to competitively-priced fuel.

Models for Gas Industry Liberalization

The USA provides the first prototype for gas liberalization (see Box 1). A number of ad hoc Federal actions between 1978 and 1992 transformed the industry from a collection of heavily regulated monopolies to a highly competitive market. The overall impact on the society is considered to be positive.

This was followed by the UK gas industry liberalization, where Parliament approved the privatization of the national monopoly, British Gas, in 1985. The Gas Act of 1986 created new rules for the privatized industry and a regulatory agency, Ofgas. Tariffs to users under 68000 cu.m./yr were regulated but larger users could negotiate tariffs with BG. The Electricity Act of 1989 split up the national electric utility and authorized the use of gas in power plants. In 1993, BG was required to separate its marketing and transport activities, and in 1997 the company decided to split into Centrica, a marketer and BG, a transporter. (Estrada, 1995 and Financial Times European Energy Report). During the years, the competitive market has been made available to additional groups of customers, and is expected soon to cover all customers.

The quantity of gas transported has increased by 75% from 1986. Gas prices in the UK declined only slowly until the second half of 1995, when a large reduction took place in the industrial sectors, apparently coinciding with production capacity increasing faster than demand. An overall decline in real gas prices of about 25% to small customers and over 50% to large customers has occurred since the privatization of British Gas

(Stern, 1997). A spot market in gas is developing slowly. However, UK gas prices may suffer some increase after the new gas connector pipe to Belgium is opened, allowing sales to the higher-priced Continental market, although liberalization of European markets and competition from UK gas may reduce prices there too, and so limit any upward tendency of UK gas prices.

The negative impacts of this process included a reduction in British Gas employment from 91500 in 1986 to 67000 in 1993 and 36000 before the 1997 split. Presumably, employment in new companies compensated for part of this drop. The British Gas shareholders did well until 1990 but thereafter the share prices performed poorly. (They have recently recovered.) The future health of the many competing gas suppliers is not assured; the fittest are likely to benefit at the expense of the weaker companies. The success of natural gas in penetrating the electric supply industry is mirrored by declines in coal mining (probably not strongly affected by gas deregulation *per se*). (Robinson, 1994 and Stern, 1997).

There remain some issues still being sorted out:

- Whether the quality of service can be maintained, especially to small consumers.
- Resolution of the long-term take-or-pay contract commitments assumed by British Gas at a time when it had a public service obligation to serve 100% of the market.

Box 1. The U.S. Experience

The Federal Power Commission (later the Federal Energy Regulatory Commission, FERC) was authorized to regulate 'interstate' gas wellhead and pipeline prices from 1954. Pressure for low prices led to insufficient exploration and production, resulting in supply shortages in the 1970s, which coincided with the oil price shocks. The Natural Gas Policy Act (1978) initiated deregulated prices for 'new' gas and required interstate pipelines to transport gas for local distributors. In the crisis atmosphere of the time, perceiving long-term oil and gas shortages and price escalation, pipeline companies negotiated high-priced long-term take-or-pay contracts with producers. When oil prices collapsed in 1986, a surplus of gas developed, the 'gas bubble', and prices fell. In the interim, 1984-85, FERC had ordered pipelines to be opened to all shippers (including the spot market) on a non-discriminatory basis but had provided no relief to the pipelines for the take-or-pay exposure (Some relief was granted later.). In 1992 FERC ordered complete unbundling of production, storage, transport and sales, this time with protection to the pipelines for their transition costs. The US is also open to gas imports from Canada, currently accounting for 13% of national consumption.

The outcome of this process has been relatively stable average producer prices since 1987 with an ample gas supply, and falling prices to large industrial and utility customers who have gradually shifted almost completely to the spot market. Two major 'hubs' for gas storage and marketing have developed with highly computerized infrastructures for real-time price quotations and sales of futures, unused pipeline contract capacity, and other instruments to increase flexibility and minimize risks to large consumers. Spot prices are quite volatile and extreme increases have been experienced in very cold weather. Due to the fortunate co-incidence of sufficient resources and improving supply technology, as well as the financial and engineering infrastructure mentioned above, the response of this type of gas market to supply constraints has never been tested.

On continental Europe supply in most countries is dominated by vertically-integrated, monopolistic gas companies

To summarize, the liberalized UK industry was able to increase gas supply in response to demand, but significant gas price reductions were achieved only several years after many suppliers entered the market, and the price reductions were unequally distributed among the classes of users. There have been some losses in employment locally, though not sector-wide or economy-wide, and some losers among shareholders.

The EU Gas Market

The Continental governments and the national gas industries have responded very slowly to market reform proposals. Their situations are quite different from the above models. Where the USA/UK are largely self-sufficient in resources, on the Continent only the Netherlands and Denmark are self-sufficient. About 43% of the EU gas supply is imported from the state-dominated national gas companies of Russia, Algeria and Norway. The competitive, unbundled private industries of the USA/UK contrast with the transportation monopolies of all but Germany and Italy and the dominance of vertically-integrated national gas companies. The various EU governments regulate their gas industries in quite different styles and with somewhat different priorities, making it difficult to create a level playing field and common rules for the EU gas industry.

Some EU Member States have taken steps to allow their electric utilities freedom in gas purchases from sellers other than the local pipeline monopoly. The situation in Germany deserves special mention as the largest gas user in the EU and the transit point for most Russian gas. The gas industry is in the private sector. While pipeline companies can compete in principle, in practice Ruhrgas has dominated the industry. In recent years, Wingas, a partnership of BASF (the large chemical company) and Gazprom (the huge Russian gas monopoly) has constructed competing pipelines and has provided real competition to Ruhrgas. The status of the gas industry in the major consuming countries is summarized in Table 1.

From Table 1 it is apparent that, apart from the liberalized UK, there is little correlation of gas price with either industry structure or domestic production. In fact, the lowest industrial gas prices on the Continent appear to be in France, which has little domestic production and perhaps the strongest national gas monopoly. The gas price picture for household customers shows both France and Germany somewhere in the middle.

The Directive Concerning Common Rules for the Internal Market in Gas

The EU has issued a directive that partially liberalizes the internal gas market (EU Council, 1997). The directive requires Member States to implement the directive by about the year 2000. At that time, electricity generators and industrial customers with annual gas usage per site above 25000 cubic metres will be allowed to choose eligible suppliers other than the local gas distributor. Each Member State is required to grant this third-party access to the extent of 20% or more of its gas market, reducing the industrial customer usage threshold if necessary. The market opening should be increased to 28% 5 years later and then to 33% after 10 years. Undertakings in the gas transmission sector would be required to keep separate, transparent books that separate gas production and distribution from transmission, and to publish or quote non-discriminatory prices for the unbundled services. The directive would authorize Member States to adjudicate take-or-pay contract claims in the event of major financial impacts and to create exceptions if public service obligations are at risk. Exceptions are also provided for regions where gas supply has only recently been introduced or where competing suppliers are not practicable. The European Union, after many years of trying, has issued its first step toward a Common Gas Market.

Austvik (1997) has analysed the probable price impact of this liberalization. He predicts that, as long as the number of gas suppliers continues to be small and the gas supply and demand are in reasonable balance, the gas prices will continue to be set largely by the competition with alternative fuels, as is presently the case. This is confirmed by recent industry predictions quoted by the Financial Times. Should an oversupply situation create a buyer's market, as occurred in the USA and the UK, gas-to-gas competition would depress prices. Austvik points out that this market is also significantly affected by non-uniformity in Member State fuel taxes.

The Debate on an EU Internal Gas Market

While Western Europe's gas pipeline industries are physically integrated in a well-structured grid, the European Commission has been unable to create a harmonized internal gas market with free trade across national borders and consistent

Table 1. Summary of the Gas Industry Status in the Major EU Gas Consuming States Eurostat, 1997

Country	1996 Price* ECU/GJ	1996 Imports %	1995, % of Gas for Electricity	Comments
Belgium	3.16	100	17.4	Distrigaz, the national gas company, is partially privatized. Belgium is a gas hub for Europe.
France	2.68	93	1.9	GdF is the public sector monopoly.
Germany	3.90	79	12.1	Private-sector competitive industry. See above text.
Italy	3.26	65	19.7	Privatizing SNAM, the national pipeline company, and AGIP, the national oil/gas producer.
Netherlands	2.80	10	26.1	Gasunie (50% state/50% private) has pipeline monopoly but competitors are imminent.
Spain	3.12	95	8.4	Gas Natural is the privatized state monopoly. The government is moving toward liberalization.
UK	1.97	2	14.8	Privatized and liberalized. See above text.
EU-15	2.99	43	16.0	

* The prices were the average prices to large industry without taxes.

A recent EU directive requires Member States to implement limited competition by around the year 2000, with large consumers being permitted a certain degree of choice of supplier

One barrier to a harmonized internal gas market is the extent to which third party access may be granted to existing pipeline in order to boost short-term competition national regulations. A key sticking point appears to have been the extent to which third party access (TPA) will be granted to use the existing pipelines to move gas, or from another point of view, the extent to which short-term market competition will be encouraged in preference to take-or-pay contracts (i.e. contracts which require payment for the gas even if the purchaser decides not to use it) that focus on long-term commitments.

It is argued that achieving diverse sources of gas imports to satisfy growing demand requires the raising of large amounts of capital to build long pipelines or liquefied natural gas (LNG) facilities. Debt financing of these large projects can be supported only by firm long-term sales contracts. The adequacy of investment flows in a low-priced market with somewhat uncertain prices is a concern that may affect the public service obligation. Protecting against supply disruptions is another issue to be considered in this context. Some of these concerns are recurrent to utility liberalization programmes (for example, universal service obligation for telephone companies) and can addressed in a number of ways, with varying degrees of efficiency and effectiveness. Other issues remaining to be dealt with include:

- The impact on pipeline companies of take or pay contracts if there are major shifts in the regulations.
- The appropriate tax structure for intra-EU gas sales, considering the way national differences in tax systems might affect inter-fuel competition.
- The differing view points of EU Member States which are net producers and those which are net consumers.
- The desirability of a Europe-wide gas regulation agency in the event of a common market for gas being created.

Long-term Outlook

The gas directive appears to catalyse convergence in Member State gas policies in incremental steps and to promote overall market efficiency and supply security. Each Member State is free to proceed toward a liberalized gas market at a rate and to the extent deemed in the national interest. Should the majority of the gas consuming states pursue co-ordinated policies of rapid liberalization, this could create a *de facto* internal EU gas market. The efficiency of this market is likely to be enhanced if a consistent set of fuel taxes could be implemented within the EU.

About the authors
Irving Spiewak holds a Master of Science degree in Chem. Engineering, from the Massachusetts Institute of Technology. Before joining the IPTS as a Visiting Scientist, specializing in technology watch in solar thermal energy and other renewables he worked as a research scientist and program manager at Oak Ridge National Lab, USA, and a research scientist at the Weizmann Institute of Science, Israel. His research interests include the energy/environment field.

Keywords

market liberalization, natural gas regulation, European gas market, energy policy

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Contacts

Irving Spiewak, IPTS

Tel.: +34 95 448 83 86, fax: +34 95 448 83 39, e-mail: **irving.spiewak@jrc.es**

Antonio Soria, IPTS

Tel.: +34 95 448 82 94, fax: +34 95 448 82 79, e-mail: **antonio.soria@jrc.es**

Stéphane Isoard, IPTS

Tel.: +34 95 448 83 66, fax: +34 95 448 82 79, e-mail: **stephane.isoard@jrc.es**

About the authors

Antonio Soria holds a doctorate in Energy Engineering. He has being working in the JRC at its Ispra and Seville sites. His main area of interest concerns energy technologies, energy economics and environmental implications of energy use.

Stéphane Isoard holds a master's degree in Economic Modelling and a post-master's degree (DEA) from the University of Paris I Panthéon-Sorbonne in Mathematical Economics and Econometrics. Before coming to the IPTS, he carried out assessment studies on public energy policy and on the implementation of macro-econometric models, in the work of ERASME research group (Ecole Centrale Paris) related to the Commissariat Général du Plan projects. He is currently researching for a Ph.D. in Modelling the Diffusion of New Energy Technologies (particularly renewable energies) and in quantitative analysis of Energy R&D policy.

The Challenges of Tourism at the Turn of the Century: the Importance of Sustainability

Hanna B. Hoffmann, *VDI-TZ*

Issue: After decades of immense development, by the year 2000 tourism will be among the world's largest industries. Its enormous growth brings with it tremendous benefits, but also considerable threats to the environment in its broad sense, including the natural, social and built environment.

Relevance: Many deficits in the field of tourism such as the lack of standardization of definitions, market research and planning, adequate policies and legislation, information on tourism's possible implications and cooperation between key players have been aggravated by exponential and often uncontrolled growth.

Challenges in the field of tourism

In the past 40 years, international tourism has grown rapidly; from 1950 when 25 million tourists generated ECU8 billion in receipts, to 1990 when around 460 million tourists generated ECU260 billion (Table 1). In addition it is estimated that there are almost three times as many domestic tourists. Tourism is today the world's largest employer, employing 212 million people worldwide, that is, one in every nine jobs. In the EU it employs 7 million people and accounts for over 5 per cent of Gross Domestic Product and foreign trade.

Tourism is the world's largest employer, employing 212 million people worldwide, that is, one in every nine jobs, and over 7 million people in the EU

According to the World Travel & Tourism Council (WTTC), between 1995 and 2005, Travel & Tourism will:

- Double in size in nominal terms
- Increase its output by more than 50 per cent in real terms
- Add one new job every 2.5 seconds
- Create 125 million new direct and indirect jobs

However, besides the opportunities to be gained with tourism development, such as job and income generation, there has also been a significant increase in the threats and conflicts arising from its often uncontrolled growth. Tourism was once perceived as a clean, non-resource-consumptive economic activity, free of the environmental impacts attributed to manufacturing, mining and intensive agriculture. Since the 1970s this benign view of tourism has been increasingly questioned.

In order for tourism to carry on flourishing the resources which it uses intensively must continue to be available (i.e. pristine landscapes and coastline, unpolluted seas, and so on). This highlights the value of nature for tourism -beyond its intrinsic value. The negative consequences of

Table 1. A statistical overview of tourism in the past and next five decades*

Year	1950	1990	1995	2000**	2005**	2010**	2020**	2050**
Int. tourists (mn)	25	460	617	750	n/a	937	1 bn	1,6 bn
Output (ECU)	8 bn	260 bn	3.4 trn	n/a	7.2 trn	n/a	n/a	n/a
Jobs (mn)	n.a.	190	212	n/a	338	n/a	n/a	n/a

* Source: WTO, 1992; WTTC, 1995; Lanfant, 1995; ** Estimates: for 2020 + 2050 - WTO in diPerna, 1997.

high-volume tourism can be summarized in two main effects: massive usage of resources (water, energy, soil, landscape, etc.) and massive emissions (waste, wastewater, noise, air emissions, etc.). Today environmental compatibility is high on the list of essentials for holiday locations. Tour operators are asked to offer unspoiled landscape and nature. By exceeding carrying capacities on the physical, social and ecological levels, tourism is destroying its own basis and is endangering its own long-term future.

In Europe, the impacts of tourism are exacerbated by the concentration of tourist activities into a short holiday season and relatively small areas. Much of the damage done to the environment as a result of tourism is caused by the pressure of the volume of visitors arriving at destinations which are not used to supporting people in such great numbers. Growth in visitor numbers also puts severe strain on the local capacity of specific geographical areas such as coastal areas, mountains and wetlands. Wetlands for example are among the world's most threatened and exploited habitats. The rate of their destruction has been very rapid in the last 40 years, particularly in the Mediterranean basin and in coastal regions.

A tourist boom can also have a significant impact on the local community. While communities often want the benefits of tourism, they may often lack a realistic understanding of what is involved in achieving this development and the likely impacts of tourism. The influx of tourists on small islands for example is often highly seasonal with a dramatic peak in the summer. During this period, visitors often outnumber the native population, which puts undoubted pressures on the local culture and resources. Concerns amongst the island population about how to handle large tourist numbers, how to distribute economic benefits and about the future of tourism are frequent.

At the same time the economic importance of tourism for islands must be recognized. Tourism is often vitally important in sustaining the population. Consequently the issues of how to manage tourism are complex.

Despite these issues, measures aiming at tackling (adverse) tourism impact have only slowly emerged and most are either fragmentary and/or remain at a theoretical level. This is to be observed with regard to many legal as well as voluntary approaches which show shortcomings in the form of a lack of commitment to objectives, action and deadlines, aggravated by the insufficient involvement and participation of many actors. Managerial measures, drawn up by management staff of areas exposed to increased tourism influx, are mostly tailor-made for areas

The negative consequences of high-volume tourism can be summarized in two main effects: massive usage of resources (water, energy, soil, landscape, etc.) and massive emissions (waste, wastewater, noise, air emissions, etc.)

While communities often want the benefits of tourism, they may lack a realistic understanding of what is involved in achieving this development and the likely impacts of tourism

limited in space and scope. As there is barely any exchange of experience or consultation taking place amongst the key players involved, other areas are unable to benefit from experiences made at, ideally, reduced cost.

Tackling the challenges from tourism

In view of this, sustainable tourism development and management will not be achieved unless a new approach to tourism is taken, adopting a holistic viewpoint and sustainable practices, hence generating an equal share of the benefits and costs for all stakeholders. A new partnership between tourism, local communities and the environment is needed, including necessary changes in attitudes, behaviour, and management. Tourism must be considered, planned and managed in a much more integrated way than it has been to date, involving all stakeholders from the start, thus enhancing (local) capacity building. Strategic alliances between the various stakeholders are needed to jointly encounter the challenges of future tourism.

Integrated Total Quality Tourism Management is a holistic approach to tourism development and management

A new approach to tourism development and management - Integrated Total Quality Tourism Management (ITQT) – has been developed to respond to these challenges[1]. ITQT is a holistic approach to tourism development and management which integrates socio-cultural, environmental and economic aspects in a more comprehensive way than currently generally recognized. It involves a genuine bottom-up approach and aims to generate the 3-tier benefit SEE (Socio-culturally enriching, Environmentally sustainable, Economically viable).

For a model of development to be considered sustainable it must be socio-culturally enriching, environmentally sustainable and economically viable

The concept of ITQT proposes a sustainable approach to tourism, generating multiple benefits. However, tourism is not necessarily desirable or feasible for every place. Therefore, each community should examine according to the aspects outlined by the World Tourism Organization (1993) if the project in question is feasible, sustainable and desirable with regard to socio-cultural, environmental and economic aspects. Table 2, below, summarizes methodologies, strategies and various tools used by ITQT. From the full range of powerful management tools available, just a few have been selected here by way of example: Environmental Impact Assessment (EIA), Carrying Capacity Analysis (CCA), Life-Cycle Analysis (LCA), Environmental Audits (EA)). However, this does not imply that the tools indicated here are considered the most efficient *per se*. The decision made as to the tools to be selected should take the specific context into account and decide what is most appropriate for it.

Tourism as a 3-fold benefit generator

A genuinely sustainable approach needs to be socio-culturally enriching, environmentally sustainable and economically viable.

Socio-culturally enriching: To be sustainable, development needs to include the people who implement, manage and control it. It would be difficult, even impossible, to establish a workable model of a sustainable business community if individual commitment to the spirit of sustainable development is not ensured through understanding of its goals. Maximizing the awareness and involvement of all concerned, thus encouraging a new ethic, must therefore be a prerequisite for action. A community should not only share a common geography, but the same values and expectations.

Environmentally sustainable: To be sustainable, development needs to include the natural environment, on which it depends.

Table 2. Executive Summary Action Plan - ITQT Methodologies, Strategies and Tools

methodologies / strategies and tools	METHODOLOGY 1 Tourism as a 3-fold benefit generator (SEE)	METHODOLOGY 2 Integrated long-term planning, management and monitoring	METHODOLOGY 3 Stakeholder Theory	METHODOLOGY 4 Stimulation of sustainable business communities and practices	METHODOLOGY 5 Development of a new ethic	METHODOLOGY 6 International communication and networking
STRATEGIES	Choosing a truly sustainable path based on a 3-fold approach	Anticipatory, preventive and visionary approach	All key players involved in decision-making, management and monitoring	Communication and enhancement of implementation of Agenda 21	Change in mind, attitude <u>and</u> behaviour	Synergistic effects through worldwide connection
GENERAL TOOLS	Any project including and stimulating a 3-fold approach	Instruments for impact analysis such as EIA, CC, LCA, etc.	Socialisation, Actor-ization, Dialogue-ization	Agenda 21 for the Travel & Tourism Industry	Self-regulatory activities such as codes of conduct	Internet/ Networking

Source: Hoffmann, 1995

Renewable and non-renewable resources must be managed with sensitivity and common sense and in a way that takes a very long-term view. A new classification of priorities is required, i.e. one that does not always place the environment second, but makes it an important element of day-to-day business. The real and wider damage of ecological disruption must be quantified and internalized in the cost of consumer goods.

Economically viable: To be sustainable, development must include a commitment to promoting economic prosperity. This is essential if the funds needed to protect the natural environment and to sustain the population living in are to be generated.

Integrated long-term planning, management and monitoring

An anticipatory, preventive and visionary approach is needed to planning, management and monitoring. When discussing importance of maintaining a high-quality environment in sustaining tourism activity it is appropriate to consider 'thresholds' or 'critical loads' of tourism activity. A given environmental impact (or combination of impacts) can be tolerated up to a point beyond which the environmental resource suffers and ceases to be a positive attraction and the tourism activity that relies on it has to substitute other resources or decline.

When considering the impact of tourism it is necessary to take into account the physical and environmental carrying capacity, as well as the level at which tourism adversely affects the life of residents, or diminishes other tourists' enjoyment

Various critical loads or 'carrying capacities' should be considered such as:

- The 'physical carrying capacity', i.e. the absolute limit on tourist numbers that a resource can cope with.
- The 'ecological carrying capacity', i.e. the level of visits beyond which unacceptable ecological impacts will occur, either as a result of the tourists themselves or the amenities they require.
- The 'host social carrying capacity', i.e. the level beyond which unacceptable change will start affecting the social ways of life of the residents.
- The 'tourist social carrying capacity', i.e. the level beyond which visitor satisfaction drops unacceptably as a result of overcrowding.

It is equally important to monitor tourism's adverse impact continuously, by quantifying and internalizing the costs, in order to obtain a realistic picture of the situation and a solid basis for future plans. As an answer to the possible extinction of 40% of known species in the next 50 years and the recognition of the close link to tourism, the 4th conference of the parties of the biodiversity convention took Travel & Tourism into account for the first time. 170 countries agreed on establishing a common framework and guidelines for sustainable tourism. A protocol is planned for the next conference in 2000, including an eco-balance aiming at quantifying the damage caused by tourism.

Stakeholder Theory

The Stakeholder approach attempts to include everybody with a stake in the issue so that all their needs are considered when setting objectives and everybody is engaged in finding and implementing solutions. A dialogue should be developed to ensure that all parties are involved and contribute. Resources should no longer be considered goods for which no one has specific responsibility. If it is recognized that the environment is being degraded everybody should feel responsible for taking the first step to protect it. Strategic alliances and networking are needed to jointly take care of fragile areas of great value.

This can be achieved with the help of:

- 'Socialization', meaning that each member of the community not only welcomes and accepts the measures taken, but also contributes and helps to implement them.

- 'Actorization', meaning that relations with interest groups and the exchange of opinions are established and harmonized in order to mobilize these groups for joint ventures and long-term plans to establish efficient networking.
- 'Dialogue-ization', meaning that the dialogue between industry, government and science is stimulated in order to minimize multi-interpretations of facts and to encourage information exchange, advanced research and creation of a platform for dialogue.

Concluding remarks

In view of the rapid growth of tourism and the concomitant opportunities and dangers, together with factors such as an ever increasing number of stakeholders and the depletion of natural resources and extinction of species, there is an urgent need for integrated and preventive approaches as well as for strategic alliances and networking among the various stakeholders in order for joint responsibility to be established for fragile areas of special value, whilst at the same time creating income and job opportunities.

Integrated Total Quality Tourism Management has been proposed as a holistic approach to tourism development and management. Building on methodologies such as the stakeholder theory, it aims to preserve the environment whilst allowing sustainable socio-economic development. The challenge is to use strategic alliances in a preventive way rather than as end-of-pipe solution to avoid disastrous and irreversible effects implying immense costs and losses.

The Stakeholder approach attempts to include everybody with a stake in the issue so that all their needs are considered when setting objectives and everybody is engaged in finding and implementing solutions

Keywords
tourism, sustainable development, Integrated Total Quality Tourism Management, stakeholder approach, strategic alliances, biodiversity

Note
1- Developed by the author in cooperation with the World Travel & Tourism Environment Research Centre in 1995, Integrated Total Quality Tourism is a propietary name.

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Contact

Hanna B. Hoffmann, VDI-TZ

Tel.: +49 211 6214 516, fax: +49 211 6214 484, e-mail: **hoffmann@vdi.de**

About the author

Hanna B. Hoffmann is currently working as an Environmental Consultant at the VDI Technology Center, Future Technologies Division in Dusseldorf. She holds a degree in economics with a specialization in Strategic Company Management and Marketing from the University of Geneva and a European Master in Environmental Management with specialization on sustainable tourism awarded in cooperation with the World Travel & Tourism environment Research Center. Her research interests include sustainable (tourism) development, cleaner production, integrated environmental management and climate issues.

Environmental Sensors in Waste Management

Simon Proops, *CEST*

Issue: As part of an increasing sentiment among European consumers that environmental protection is important, concern about the impact of landfill is growing. Sensor technology makes it possible to measure and control inputs to landfill sites and pollutants arising from them. However, the exploitation - or uptake - of such technology has been lower than expected in the waste management sector.

Relevance: Coordinated European science and technology policies can help improve exploitation of sensor technology, and lead to future development of more innovative waste management processes. Setting unambiguous targets for the release of pollutants from landfill sites, in both leachate and landfill gas, may aid uptake.

Market Pull - European Waste Management

Much of the cost of traditional (i.e. landfill and sewage plant) treatment methods comes from minimizing the nuisance for those living in the vicinity, i.e. odours, traffic, etc. This translates into higher costs for operators seeking planning permission. Improving detection of inputs and outputs of landfill sites can help landfill operators reduce this nuisance, and thus the 'not in my back yard' (NIMBY) resistance to such facilities. In addition, new waste management techniques such as composting and recycling will rely heavily on sensors to monitor and optimize processes. However, sensor research is being hampered by the lack of cooperation and cross-fertilization between researchers in the biological and medical sciences and those in micro electromechanical engineering and environmental sciences.

Initiatives in integrated waste management in the Netherlands and material reclamation in Austria, Sweden and elsewhere use sensors to develop innovative waste management practices. Worldwide, alternative waste treatment approaches such as bioremediation (the process by which living organisms are used to degrade hazardous organic contaminants or transform hazardous inorganic contaminants to environmentally safe levels in soils, subsurface materials, water, sludges, and residues) and other techniques such as "living machines" are being developed, particularly in the US. However, until systems are developed in bulk, to develop sufficient economies of scale in large markets, there is no incentive to develop new waste management techniques. Therefore, there is a role to stimulate and coordinate harmonized research and development in waste management.

Generally, with a few exceptions, waste management in Europe tends not to be a highly

Various types of waste control require accurate sensors to optimize processes and control safety. However, the development of such devices requires close cooperation between biological/medical researchers and electromechanical engineers

Waste management tends not to be a technologically sophisticated industry, partly because local authorities, who are mainly responsible for waste disposal, do not see waste as an area for developing new technology-based business

Sensors have a wide variety of potential applications, ranging from recycling and disposal, separation technologies, measuring the impact of transportation, and so on

Communicating the benefits of innovative waste management technologies to consumers could create a market pull for more innovative waste management

technologically sophisticated industry. While companies use geologists and geophysicists in planning their sites, they are often fairly lacking in innovative development of technology to address operational barriers or generate new business. This is due, in part, to the culture of their major customer base, which tends to comprise mainly local authorities. These see waste treatment as part of a social service rather than an opportunity area for developing new technology-based business. These customers tend not to be very demanding, so there is little perceived competitive advantage in developing and implementing innovative technology.

Lately, the waste management industry has been focusing specifically on developing close customer relationships. There are a wide range of techniques and technologies in practice across the European Union. Some countries such as the UK and Germany rely heavily on landfill as the preferred technique for a combination of historical and geographical reasons. Other states focus on a combination of landfill, recycling and incineration. Bioremediation is another innovative approach, but is still a relatively immature technology. In terms of developing the European policy on innovative waste management, it is important to consider improving landfill management as part of an integrated waste management programme. This would focus on more than just concerns over charging levels and topsoil, looking rather at the inward gradient - so as to contain rather than disperse leachate - long-term leachate collection and treatment systems (pumping to tailings or sewers), contaminated land applications, and touch on the continuing debate over co-disposal, in light of draft EU directives on reducing biodegradable arisings in landfill sites.

Impacts of present and proposed levies, such as the landfill tax, proposed raw materials tax and packaging recovery legislation, on landfill operations may also be considered. Experiences from the construction industry, in recycling some waste and disposal of other waste as 'landscaping' material, can be evaluated, and the use of sensors in developing integrated and diverse waste management practices that include waste minimization, recycling, landfilling, composting and incineration assessed. The use of sensors for waste stream segregation may also be profitably assessed, including using aromatic compounds and electronic nose-based id systems, vision systems and magnetic segregation technologies. The role of sensors in reducing the environmental impact of transporting recycled/recyclable goods may also be considered.

The main concerns of waste management policy makers include cost-effectiveness technological feasibility of solutions. There are also vocal local groups who may have certain perspectives on which waste management techniques are used in certain areas. However, coordination of research initiatives and a sharing of best practice can help create markets of critical mass that let affordable, innovative waste management techniques come about. The creation of sensor-based solutions and common standards across the EU means that generally accepted methods can be developed with knowledge that there will be few standards-based barriers to development of large markets.

To develop and stimulate innovation in this area, another key role that policy makers could play is to help disseminate innovative, technology-based waste management policies and make the use of more sophisticated sensing technologies a self-reinforcing cycle. As more comes to be known about conditions associated with waste management, the public will take a greater interest. In turn, this will lead to more public will to fund and develop innovations in sensors for waste management use. Increasing levels of sensitivity allows society to know more, but also whets the appetite for more information.

This cycle can be reflected in the development of legislation for waste management. As sensors become more sensitive and selective, legislation to limit levels of toxic analyte becomes enforceable. This legislation can be used, in turn, to stimulate operators to invest in applying new sensor technology. The main emissions from landfill sites are methane, from biodegradable fill such as paper and kitchen waste, and toxins from slowly degrading plastics and other chemical compounds in appliances, as well as detergents, oils and heavy metals. The first of these, methane, has been addressed by upcoming EU limits on methane emissions from biodegradables, to conform to the non-fossil fuel obligations (NFFO) agreed in Kyoto.

The time is right for similar action regarding other analytes. These will require consensus over levels and types of compounds that can be measured, as well as on what constitute dangerous levels to both health and the ecosystem. Emissions caps and tradable permits, as in the case of global pollution issues such as greenhouse gas emissions, may not be appropriate for local emissions issues, such as toxic compounds from landfill sites. While there is an imperative to reduce overall emissions of dangerous analytes, point site pollution, such as that from landfill sites, most directly effects those living in the vicinity of the facility. While NIMBY can quickly become BANANA (build absolutely nothing anywhere near anything), a coherent policy would recognize the need for waste management facilities, but encourage sensor development to monitor, control and reduce the risk associated with their operation.

Price cap models, in which regulations on target levels of pollutant and analytes are fixed once, and firms are rewarded or penalized in proportion to how far above or below them they are, should be explored.

Technology Push - Innovative Sensors

There is need to stimulate and co-ordinate policy in both sensor research and landfill and waste management. Sensor research policy should assess the effect of innovations and technical solutions such as the uptake of microbial biodegradation of toxic xenobiotic chemical compounds, the remote tracking of airborne compounds such as organophosphates using electronic noses, enzyme-linked immunoassay (ELISA) kits, or enzyme-based biosensors and identifying compounds using 'lab on a chip' or 'DNA chips.' Application areas in landfill management, recycling, composting and contaminated land remediation are plentiful. In addition, further development requires more detailed knowledge of chemical interactions such as bonding. Here, there is much scope for the involvement of researchers in chemical and biotechnical engineering in the development process of novel sensors. The most promising research directions in this involve novel chemical sensor technology based on detecting the changes in a polymer, or series of polymers, due to the impinging of an analyte molecule. By detecting the degree of swelling of an array of several polymers, the type of analyte can be deduced.

A range of technologies has already been developed and more is under development. However, landfill sensors currently require a trade-off between selectivity, sensitivity, scope and price. Current systems are available which detect total organic content (TOC) levels in industrial effluent, which correlates directly with the biological oxygen demand (BOD). These can

Availability of more sensitive and selective sensors could make legislation limiting the levels of toxic analyte more practical

A number of systems are currently available, for example systems to detect total organic content levels in industrial effluent, which correlates directly with the biological oxygen demand be easily adapted for use with landfill leachate. As legislation governing landfill and waste management becomes more stringent, simple monitoring of carbon for organic load on the environment, or simply presence of leachate within and below landfill sites, becomes less important. What is required, at low cost and in robust packages, are systems which detect certain specific hazardous analytes. Detection not only of the presence of gas or leachate, but also of the types of chemical compounds contained, as well as their concentrations, are required for effective landfill management.

To obtain the range of selectivity, sensitivity, detection of concentration, robustness and price applications of this type require, so-called sensor fusion may be the answer. This takes the outputs of a range of different sensors, and, via clever data processing, builds a picture of the types and concentrations of the analytes present. A major cost driver for many landfill operators is the employment of personnel to monitor conditions using the sensors developed. However, this can be replaced by developing smart arrays of sensors which monitor remotely, and then download data, either via land lines or mobile communications, to a monitoring base station. The bandwidth requirements of such a system can be minimized by signalling to the operator only when concentration levels fall outside pre-defined parameters.

The Specification Process for Sensors

A lack of harmonization of the specifications for sensors, typified by different companies in the same sector having different specifications for the same sensor, has hindered uptake and lead to a fragmented market. Thus small volumes of product tend to be produced, the unit price is high, new product development is beyond the means of most producers, compatibility with national and international standards is doubtful and the chances of building an export market are low. Generally, markets are built on standards, thus the technology moves faster than the standards, fragmentation occurs and technology is unavailable at reasonable prices. By pooling requirements, the resulting economies of scale mean companies can ensure that the technology that can meet their requirements will be developed affordably. Engaging users and vendors in the development process is also an important factor in ensuring real needs are met.

A lack of harmonization of the specifications for sensors, typified by different companies in the same sector having different specifications for the same sensor, has hindered uptake and led to a fragmented market

Standards lag behind sensor technology and are often hijacked by strong companies seeking to protect vested interests, leading to failure to achieve the best possible price/performance ratio, and delay in the purchasing decision until the standards have caught up. Standards often represent the evolution of public concern and interest over issues. As standards evolve, more detailed information can be obtained and public interest often increases.

Conclusions - Improving the Technology Exploitation

Several policy-level changes can improve the uptake of sensor technology in the waste management industry by aligning the technology-push with market-pull. An increased level of communication between developers of waste management policy and the science base in sensors, including both biological and electro-mechanical researchers, would result in both areas becoming more competitive and effective. The aim would be to ensure that the development of waste management policy is founded on sound science and a realistic appraisal of the technologies that will be available tomorrow for sensing and detection in waste management. In addition, an understanding of the emerging market opportunities in waste management can ensure that the research into the science of sensing can be drawn towards application areas that will represent the significant market opportunities of tomorrow.

Increased collaboration between the organizations responsible for collecting and disposing of waste - currently local authorities, or public/private combinations known as local authority waste disposal companies (LAWDCs)- across Europe could help to stimulate the development of innovative waste management practices, as well as offer the opportunity to benchmark best practice. The International Council for Local Environmental Initiatives (ICLEI) is one such organization attempting to build global networks on the local level. Significant lessons can be learned from Japanese efforts in this area, such as experiments in composting sludge from wastewater treatment plants prior to landfilling. Networks linking local authorities directly already exist. Some of these could be used to catalyse such collaboration.

One of the main factors in facilitating development of robust markets for environmental sensing and monitoring technology for landfill sites will be a clear consensus on toxicology of species and compounds that may emerge from such sites. There are clear threats in terms of local communities and, possibly, surface and groundwater contamination. There are also clear threats to traditional sewage treatment works if they become overloaded with industrial-strength pollutants, after, for example, heavy rainfall over landfill sites, that can cause sewage plant failure. Here, there is clear opportunity for the uptake of remote sensing and data logging and downloading devices in order to signal such threats to sewage treatment plants. However, until there is clear understanding of toxicology and associated risks —at local, regional and global levels— of compounds arising from landfill sites, the case for taking up and developing sensors, in order to offset the costs of environmental hazard insurance premiums, will remain difficult to make.

A successful collaborative project could help users, vendors and legislators understand each others' needs, position and constraints. It would form a shared view of the priorities for application of sensor technology, of how price/performance trade-offs work in specifying each solution and of who needs to be involved to achieve this. It would also catalyse relevant government and legislative groups, as well as industry, to align existing standards and legislation, in order to work towards a realistic view of how legislation would need to change in order to accommodate new thinking on toxicology and risk associated with arisings from landfill sites, both in operation and post-closure. A winning list of promising technologies to detect the target compounds identified during this process can lead to debate around price/performance trade-offs. This will then influence decision makers responsible for determining the type of analyte that needs to be monitored at landfill sites and the concentration levels deemed to be acceptable.

Better communication between developers of waste management policy and the science base of sensor technologies, including both biological and electro-mechanical researchers, would result in both areas becoming more competitive and effective

An important factor in developing robust markets for environmental sensing and monitoring technology is a consensus on the toxicology of species and compounds that may emerge from such sites

About the author
Simon Proops is a business analyst at CEST, where he has led a management study tour to MIT and has helped to run a Foresight workshop for a major spirits and wines producer. Before joining CEST, he ran a technical consultancy in Montreal, Canada for two years and has worked with Oki Electric Company and JA, the Japanese Agricultural Cooperative in Tokyo. He holds an MBA and a BSc. in physics.

Keywords

waste management, environmental sensors, landfill leachate, bioremediation, economies of scale, public opinion, legislation, collaboration, toxic compounds, acceptable levels, toxicology risk

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Contacts

Simon Proops, CEST
Tel.: +44 171 354 9942, fax: +44 171 354 4301, e-mail: **sproops@cest.org.uk**
Celia Greaves, CEST
Tel.: +44 171 354 9942, fax: +44 171 354 4301, e-mail: **cgreaves@cest.org.uk**
CEST, 5 Berners Road, Islington, London N1 0PW

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The purpose of this work is to support the decision-maker in the management of change pivotally anchored on S/T developments. In this endeavour IPTS enjoys a dual advantage: being a part of the Commission IPTS shares EU goals and priorities; on the other hand it cherishes its research institute neutrality and distance from the intricacies of actual policy-making. This combination allows the IPTS to build bridges betwen EU undertakings, contributing to and co-ordinating the creation of common knowledge bases at the disposal of all stake-holders. Though the work of the IPTS is mainly addressed to the Commission, it also works with decision-makers in the European Parliament, and agencies and institutions in the Member States.

The Institute's main activities, defined in close cooperation with the decision-maker are:

1. Technology Watch. This activity aims to alert European decision-makers to the social, economic and political consequences of major technological issues and trends. This is achieved through the European Science and Technology Observatory (ESTO), a European-wide network of nationally based organisations. The IPTS is the central node of ESTO, co-ordinating technology watch 'joint ventures' with the aim of better understanding technological change.

2. Technology, employment & competitiveness. Given the significance of these issues for Europe and the EU institutions, the technology-employment-competitiveness relationship is the driving force behind all IPTS activities, focusing analysis on the potential of promising technologies for job creation, economic growth and social welfare. Such analyses may be linked to specific technologies, technological sectors, or cross-sectoral issues and themes.

3. Support for policy-making. The IPTS also undertakes work to supports both Commission services and other EU institutions in response to specific requests, usually as a direct contribution to decision-making and/or policy implementation. These tasks are fully integrated with, and take full advantage of on-going Technology Watch activities.

As well as collaborating directly with policy-makers in order to obtain first-hand understanding of their concerns, the IPTS draws upon sector actors' knowledge and promotes dialogue between them, whilst working in close co-operation with the scientific community so as to ensure technical accuracy. In addition to its flagship IPTS Report, the work of the IPTS is also presented in occasional prospective notes, a series of dossiers, synthesis reports and working papers.

The IPTS Report is published in the first week of every month, except for the months of January and August. It is edited in English and is currently available at a price of 50 ECU per year in four languages: English, French, German and Spanish.

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The European Science and Technology Observatory Network (ESTO):
IPTS - JRC - European Commission
W.T.C., Isla de la Cartuja s/n, E-41092, Sevilla, Spain
tel.: +34-95-448 82 97; fax: +34-95-448 82 93; e-mail: ipts_secr@jrc.es

- ADIT - Agence pour la Diffusion de l'Information Technologique - F
- CEST - Centre for Exploitation of Science and Technology - UK
- COTEC - Fundación para la Innovación Tecnológica - E
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