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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 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 first, and possibly most significant indicator, of success is that the Report is being read. The issue 00 (December 1995) had a print run of 2000 copies, in what seemed an optimistic projection at the time. Since then, its circulation has been boosted to 7000 copies. Requests for subscriptions have come not only from various parts of Europe but also from the US, Japan, Australia, Latin America, N. Africa, etc.

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 ENEAand 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 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

Innovation is a determining factor in industrial competitiveness. In order to allow European research to have maximum impact on economic growth and to facilitate its translation into products and services -and thus jobs- mechanisms for promoting innovation, exploitation of the results of scientific work and the creation of innovative businesses must be developed.

SMEs are important innovation vectors and actors, and represent two thirds of employment in the European Union, and should benefit from ready access to the advanced technologies which they need, and the possibilities created by the EU's research programmes.

The plans for the Fifth Framework Programme for Research and Development, of which supporting innovation is one of the principal orientations, create a commitment to a horizontal programme for the involvement of SMEs in research activities.

European Community action is intended in particular to promote the participation of SMEs in research programmes through an effort to achieve administrative simplification.

This includes the creation within the European Commission's services of a 'one-stop shop' for all research programmes together and the support given to 'cooperative research' activities.

The idea is to launch a dynamic for the creation of activities involved in the dissemination of scientific and technical advances and the improvement of conditions for the creation and development of innovative businesses. This, by ensuring the European Union's future in markets through the exploitation of its scientific excellence, the EU can get back on the path to creating jobs and meeting the most important expectations of its citizens.

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ERRATUM

In the article "Towards Meeting CO2 Emmissions Targets: The role of the Carbon Dioxide Removal" (issue 16, july 1997) an error has been made. In figure 2 on Indicated Costs of Carbon Dioxide Mitigation, the unit on the y-axis has been expressed as - GtC-. This should have been expressed as - Costs (ECU/tC avoid).

EDITORIAL

The first article in this issue deals with wastewater reuse, and the divergence of opinions/regulations surrounding it. Broadly speaking and with several intermediate shades of grey in between, there are two camps. On the one hand, there are the proponents of the World Health Organization (WHO) guidelines, who stress the adequacy of the regulations proposed 1989, and the feasibility of following such guidelines in less developed countries where wastewater reuse is often common. On the other hand we have the supporters of the much more stringent (and more costly to adopt) 'California' guidelines, whose proponents champion their safety, doubt the adequacy of WHO guidelines, and downplay the risk of the costlier California guidelines being used in protectionist, trade-discrimination practices. Since wastewater reuse is practised in Europe (mostly, but not exclusively, in Southern European countries), and since Europeans (largely, but not exclusively Northern Europeans) import and consume produce from non-EU countries, possibly irrigated with wastewater, an integrated European pro-active approach would be desirable.

The second article deals with the impact of recent advances in combinatorial chemistry, which is destined to become a core technology for chemical as well as pharmaceutical companies. The article, besides explaining the mechanics of combinatorial chemistry techniques, underlines the domination of this field by US firms, and explains it by showing how the origin of these techniques may be traced to dedicated biotechnology firms, of which many arose and thrived in the US in the last twenty years. In Europe due to different market structures (capital markets and otherwise) as well as due to certain initial reluctance vis-à-vis certain aspects of biotechnological research raising ethical questions, the biotechnology market did not follow similar paths to its US counterpart. The lesson from the emergence of combinatorial chemistry, may be that failing to follow quickly certain technological trajectories, may result in lagging behind in other, highly desirable, technologies which arise in the future about which no qualms have been expressed.

The third article examines one of the ways that have been proposed for achieving greenhouse gas reductions, called Joint Implementation. This involves a deal in which countries with high costs of pollution abatement invest in abatement in countries with lower costs, and receive credit themselves for the resulting reduction in greenhouse gas emissions. The method has clear efficiency advantages (by getting the same reduction in a less-costly way), and may help the usually poorer host country achieve locally better performance than it could afford on its own, as well as promoting technology transfer. However certain ethical considerations need to be borne in mind, and it should be ensured that incentives for future developments towards cleaner technologies are not compromised by the availability of the Joint Implementation mechanism. Moreover, as in most other pollution reduction mechanisms, accounting and baseline definition problems are very thorny issues and need to be addressed carefully.

The fourth article highlights the need for collaboration and coordination in research and development in food safety issues in the EU - a need underlined by the recent bovine spongiform encephalopathy (BSE) (so-called "mad cow" disease) case. The EU and its research centres can set international collaboration in motion which will take advantage of the large scope for obtaining international economies of scale in food safety R&D, particularly with regard to the costly development process for the reliable and rapid tests needed to ensure public confidence in food products, as wells as enabling cross-fertilization of ideas and overcoming the limitations arising from the fact that relevant expertise does not usually reside in a single laboratory.

Finally the last article suggests that so-called smart materials and smart structures have many applications in transport, medicine, civil engineering, etc. Europe's slow adoption and awareness patterns regarding this technology are due to factors including the fact that policy frameworks not always conducive to innovation and commercial uptake, a failure to understand and identify key challenges, and the areas where policy intervention could have an impact. Contrary to what one may expect, the bottleneck is not basic research but rather in the translation of results from the laboratory to the marketplace. The multidisciplinary character of work on smart materials may also be responsible for their not receiving as much attention as perhaps they deserve.

6 Environment

Municipal Wastewater: Public Health and The Environment

Laurent Bontoux

Issue: The reuse of wastewater is increasing rapidly in Europe, mostly, but not exclusively, in southern European countries. The most important applications are the irrigation of crops, golf courses and sports fields, which are moreover cases where pathogens from the wastewater may come into contact with the public. At the same time Europe, and in particular the Northern European countries, import produce and flowers irrigated with reclaimed wastewater from countries on the southern littoral of the Mediterranean. As with many activities, these trends are occurring in Europe against the backdrop of heterogeneous regulation.

Relevance: The resolution of this issue requires a transparent European approach to protecting European consumers and tourists while preserving the single market and avoiding a new health scare as damaging as the recent 'mad cow' affair. Embarking on this work on time would also ensure that full advantage is taken of the reclamation and re-use of wastewater as a water resource and environmental protection option. Additionally, the development of clear European guidelines for the re-use of reclaimed wastewater would provide a quality benchmark for non-European countries, which is desirable in the perspective of the forthcoming Euro-Mediterranean Free Trade Area and in the context of a general improvement of quality of life in Southern Mediterranean countries.

The 1989 WHO 'Health guidelines for the use of wastewater in agriculture and aquaculture' are the only existing guidelines for wastewater reuse at international level

Analysis: The need for European wastewater re-use guidelines

Microbiological quality is the most contentious issue linked to wastewater re-use in irrigation. At the international level, the 1989 WHO 'Health guidelines for the use of wastewater in agriculture and aquaculture' (WHO, 1989) are the only existing guidelines for wastewater reuse. While reviewing the health risks and the (insufficient) epidemiological evidence available at the time, the only specific criteria the WHO proposes are microbiological. Table 1 presents these criteria. Work has now started on chemical guidelines (Chang et al., 1995).

The main justification for the 1000 faecal coliforms per 100 ml guideline is the comparison with the 2000 faecal coliforms per 100 ml used as the European standard for bathing waters. Protozoa are not included in the WHO guidelines because the technologies effective in achieving the nematode standard arguably also provide a certain removal of protozoa. Viruses are not considered and their presence is difficult to monitor on a routine basis.

These guidelines were intended to guide wastewater treatment design engineers in the choice of treatment and management technologies that will reliably achieve these standards. Since these guidelines have a world-wide scope, they were also designed to stand realistic chances of being applied in developing countries, where an unnecessarily stringent stance would most probably result in them being ignored (Mara and Cairncross, 1989). Today, the WHO guidelines represent the minimum below which everybody agrees that public health protection is not assured. The other end of the spectrum in the above mentioned debate is held by the very stringent 1978 California 'Title 22' guidelines, resulting from a high-tech, 'better safe than sorry' approach.

The California criteria stipulate conventional biological wastewater treatment followed by tertiary treatment, filtration and chlorine disinfection to produce effluent that is suitable for irrigation use. In support of this approach, Asano and Levine (1996) have reported two major epidemiological studies that were conducted in California during the 1970's and 80's. These studies scientifically demonstrate that food crops that were irrigated with municipal wastewater reclaimed according to the California approach could be consumed uncooked without adverse health

Environment

The stringent 1978 California 'Title 22' guidelines have been shown to ensure public health protection

Table 1. Recommended microbiological quality guidelines for wastewater use in agriculture[a] (WHO, 1989)

Category	Reuse conditions	Exposed group	Intestinal nematodes[b]	Faecal coliforms	Wastewater treatment
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consumers, public	≤1	≤1000[d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation

[a] In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account and the guidelines modified accordingly.

[b] Ascaris, Trichuris and hookworms.

[c] During the irrigation period.

[d] When edible crops are always consumed well cooked, this recommendation may be less stringent.

[e] In the case of fruit trees, irrigation should cease two weeks before the fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

Table 2. Microbiological quality guidelines and criteria for irrigation of the State of California (1978)

Reuse application	Irrigation technique	Faecal or total coliforms[b]	Wastewater treatment requirements
Edible crops	Spray	< 2.2/100 mL[a]	Secondary treatment, coagulation, clarification, filtration and disinfection
Edible crops	Surface	< 2.2/100 mL[a]	Secondary treatment and disinfection
Fruit trees and vine	Surface	No limit	Primary treatment
Fodder crops, production of fibres and seeds	Surface or spray	No limit	Primary treatment
Pasture for milking animals	Surface or spray	< 23/100 mL[a]	Secondary treatment and disinfection
Golf courses, cemeteries, motorway landscapes and other landscapes with similar public access	Surface or spray	< 23/100 mL[a,c]	Secondary treatment and disinfection
Parks, public gardens, playgrounds, school yards and other areas with similar public exposure	Surface or spray	< 2.2/100 mL[a]	Secondary treatment, coagulation, clarification, filtration and disinfection

[a] The California Wastewater Reclamation Criteria are expressed as the median number of total coliforms per 100 cm^3, as determined from the bacteriological results of the last 7 days for which analyses have been completed.
[b] The coliform concentration must not exceed 23 per 100 cm^3 in more than one sample per period of 30 days
[c] The coliform concentration must not exceed 240 per 100 cm^3 in more than one sample per period of 30 days

Are the WHO guidelines sufficient for public health protection? This question is at the centre of a heated international debate

effects. However, the nutrients removed by the tertiary treatment are not available for fertilizing.

The California guidelines also mention the possibility of derogations to Table 2 if the California Health Department judges that the 'commercial, physical or chemical' treatment of food guarantees the destruction of pathogens before human consumption.

Beyond the microbiological limit values, a few differences can be noted between the WHO and California guidelines. In contrast to the California approach, the WHO guidelines say that the most stringent microbiological water quality requirements can be met by a series of stabilization ponds. Microbiological monitoring requirements also vary: the WHO guidelines require monitoring of intestinal nematodes whereas the California criteria rely on the required treatment systems and the sole monitoring of the total coliform count to assess microbiological quality (Asano and Levine, 1996).

Are the WHO guidelines sufficient for public health protection? This question is at the centre of a heated international debate (Marecos do Monte et al., 1996). International organizations such as the World Bank and WHO call for epidemiological studies to defend the WHO quality guidelines. A large part of the answer probably lies in the treatment requirements associated to the limit values. In any case, and in spite of their safety, the stringency of the California standards are a barrier to their widespread adoption world-wide.

While the WHO point of view is often criticized as being too lax, the California approach is too technology intensive and expensive for developing countries. One must realize that in the case where raw wastewater is directly reused, a widespread practice in many developing countries (and beyond...), the WHO guidelines, merely by requiring treatment, are already a major step forward.

However, other requirements also seem to be necessary to complement the WHO guidelines. Based on an extensive analysis of existing guidelines world-wide, the need for developing health-related chemical criteria for land application of reclaimed wastewater has also been reported by WHO (Chang et al., 1995). This, added to the fact that the controversy between the 'WHO camp' and the 'California camp' has now been raging for a number of years means that the time has come to update the existing guidelines on an international basis. The door is therefore now open world-wide for a 'third approach' integrating the epidemiological knowledge base generated since 1989 and the latest technological development in wastewater treatment.

In the mean time, the issue has been growing in importance in Europe. Italy apparently led the way in Europe when it adopted wastewater reuse guidelines in 1977 under the cover of their 1976 national Water Law. In spite of being published one year earlier, the Italian guidelines essentially follow the California approach. In 1989, however, the region of Sicily published a local regulation taking a radically different tack, much closer to the WHO approach. As an added precaution, this regulation forbids the irrigation of vegetables that can be eaten raw with any type of reused wastewater. Reports on the recommended practice of wastewater reuse for irrigation seem to have been produced in Emilia Romagna and Puglia, two other Italian regions. Reportedly, their approach is a sort of half-way house between the WHO and California positions and in any case does not follow the supposedly binding requirements of the national Water Law.

In 1991 France enacted a comprehensive national code of practice under the form of recommendations from the Conseil Supérieur d'Hygiène Publique de France (CSHPF) (CSHPF, 1991). These recommendations use the WHO guidelines as a basis, but complement them with strict rules of application. In general, the approach is very cautious and the main restrictions given by the CSHPF are:

- The protection of the ground and surface water resources.
- The restriction of uses according to the quality of the treated effluents.
- The piping networks for the treated wastewaters.
- The chemical quality of the treated effluents.
- The control of the sanitary rules applicable to wastewater treatment and irrigation facilities.
- The training of operators and supervisors.

The CSHPF calls for strict observation of these restrictions to ensure the best possible protection of the public health of the populations concerned. In fact, the authorizations for wastewater reuse are granted on a case by case basis after review of a highly detailed dossier. So far, wastewater reuse in France is mostly used for environmental protection. So far, Spain does not have any national wastewater reuse guidelines. Draft guidelines were proposed in 1995, taking an approach closer to the California standards than to those of the WHO (Table 3). Nevertheless, the corresponding draft Royal Decree has still not been adopted. So far, a new 'White Book' on water is being prepared and is expected to be published in October 1997, incorporating wastewater reuse into the recognized available water resources.

The issue of wastewater reuse has recently been receiving increasing attention in Europe

The various guidelines currently existing in Europe follow different approaches

Table 3. Draft microbiological quality guidelines and criteria for irrigation in the proposed Spanish national regulation (1995)

Reuse application[a]	Irrigation technique	Faecal or total coliforms[b]	Wastewater treatment requirements
Crops that can be eaten raw	<1/l	< 10/100 mL	Secondary treatment, filtration or equivalent treatment and disinfection
Fruit trees and crops that are eaten cooked	<1/l	< 200/100 mL	Secondary treatment and disinfection
Industrial crops, cereals, fodder crops and pastures	<1/l	< 500/100 mL	Secondary treatment and disinfection
Lawns, wooded areas, and other areas with limited public access	<1/l	< 200/100 mL	Secondary treatment and disinfection
Parks, public gardens, lawns, golf courses and other areas with direct public exposure	<1/l	< 10/100 mL	Secondary treatment, filtration or equivalent treatment and disinfection

[a] In the case of spray irrigation, minimum distances to inhabited areas and public ways will be fixed.

In spite of the current lack of progress at national level, various initiatives have been taken at regional level. Andalusia (Castillo Martín et al., 1994) and Catalonia (Salgot et al., 1994) have issued comprehensive wastewater reuse guidelines essentially following those of the WHO and are encouraging the practice. In the Canary Islands, a hydrological plan has recently been issued considering wastewater reuse but no guidelines have been adopted. In 1992, the Balearic government published a decree regulating the discharge of liquid effluents from municipal wastewater treatment plants (Decreto 13/1992 of February 13 1992, published in the B.O.C.A.I.B. of October 17, 1992). This decree considers the reuse of wastewater for irrigation and requires less than 1 nematode per litre and less than 1000 faecal coliforms per 100 ml. In April 1995, a Plan for the Reuse of Treated Wastewater was prepared that follows the WHO guidelines. As in Italy, national and regional approaches differ.

In Portugal and Greece, a number of important wastewater reuse projects are in place but no guidelines have yet been adopted. In view of the dire straits of its own water supply situation, the UK is seriously considering wastewater reuse and is becoming interested in guidelines.

Because no regulation of wastewater reuse exists at European level, all this is creating a momentum in Europe to start international discussions on good wastewater reuse practices and guidelines. The only European reference to wastewater reuse is the article 12 of the European Wastewater Directive (91/271/EEC) (European Commission, 1991) stating: 'Treated wastewater shall be reused whenever appropriate'. This is not sufficiently precise to be useful in tackling the problems alluded to above. Adopting European guidelines, or at least developing a European rationale for wastewater reuse, would undoubtedly create an incentive to update and improve the WHO guidelines. This would in turn give wastewater reuse an increased respectability world-wide and help integrate it in standard water management practice.

Other advantages would be:

- the creation of a united European front for the imports of fruit, vegetables and flowers irrigated with reused wastewater from third countries
- the elimination of potential health scares within Europe because of poor wastewater reuse practices
- better protection for tourists visiting European facilities irrigated with reused wastewater such as golf courses, hotel lawns, parks, etc.
- the development of wastewater reuse as an environmental protection measure, regardless of the local need for additional water resources.

The water unit of DG XI (environment) of the European Commission has already expressed its interest in the matter. With the help of the IPTS, it is planning to organize a forum of experts in order to provide a European rationale on the re-use of municipal wastewater. The specific objectives of the project are:

- To identify a common European rationale for wastewater re-use
- Define 'good wastewater re-use practices'
- Identify data gaps and research needs.

No legislation is foreseen at this stage, but this work will be highly relevant for European water policy. Considering the status municipal wastewater reuse is achieving in the world, the work of this forum is expected to have a world-wide impact. Besides, a rigorous public health debate at European level on the issue of wastewater reuse would be useful for another important emerging issue: the use of sludge from municipal wastewater treatment in agriculture.

Keywords

Wastewater reuse, public health protection, environmental protection, European guidelines

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US-driven trends in combinatorial chemistry

Chris Tils

Issue: Combinatorial Chemistry is set to become a core technology for pharmaceutical and chemical companies. In combination with technologies such as High Throughput Screening (HTS), robotics, advanced software and genetics, it has the ability to shorten the time to market for new drugs and make drug discovery a less costly process. Combinatorial chemistry is now also moving into new fields of application like agrochemicals and advanced materials.

Relevance: European chemical and pharmaceutical companies have acquired the technology through joint ventures, consortia or take-overs of small firms, which are mostly located in the USA, and almost none in Europe. This is possibly due to the fact that Combinatorial Chemistry partly has its origin in dedicated biotechnology firms, which are much more abundant in the USA than in Europe. This underlines once again the importance of small high-tech firms as source of new technological developments and points to the need for an examination of policy implications.

Analysis

The last few years we have observed a peak in the attention given to combinatorial chemistry. Articles in scientific journals suggest that these developments will lead to a revolution in drug discovery processes and in several other areas of application. From a European perspective it may be interesting to note that the technology seems to be almost exclusively developed in the USA.

In this article, we explain what combinatorial chemistry is and what future technological trends and spin-offs can be expected. We will also discuss the relationship between biotechnology and combinatorial chemistry and will argue that it is most probable that the USA is leading in combinatorial chemistry, because it is stronger in biotechnology than Europe is. To continue, we discuss Europe's response to these developments. The article ends by signalling certain policy implications.

What is combinatorial chemistry?

Pharmaceutical companies face considerable pressure to develop new drugs in a less costly and time consuming way. Powerful health care organizations demand cheaper drugs. At the same time scientific research, for example through the Human Genome Project, is revealing more and more possible targets for tackling diseases. Moreover, a number of resistant pathogens and new diseases like AIDS require new drugs quickly. Combinatorial chemistry provides a tool to meet these demands for cuts in costs and time. Traditionally, chemists in the pharmaceuticals business had to synthesize possible drug candidates one by one before they could screen the activity of the candidate. The basic idea of combinatorial chemistry is to synthesize rapidly large amounts of different compounds at the same time, using a process that is supported by computation and automation. Combinatorial techniques enable chemists to combine several chemical building blocks in many different ways, resulting in large numbers of different compounds. The collection of compounds is called a combinatorial library. Box 1 explains in more detail how combinatorial chemistry works. The philosophy of the approach is clear: the more compounds we can screen for activity as a drug, the more chances we have for quickly finding a possible drug candidate, or in jargon: a lead. Experts expect that a lot can be saved in terms of money and time. Identifying a lead in a traditional drug discovery process typically takes approx. 3-4 years. It is expected that this step will only take 2 years using combinatorial libraries. The costs incurred in generating compounds are expected to drop by a factor of 10.

Advanced software plays a key role in combinatorial chemistry. In the first place, software is used to steer the automated synthesis and analysis of compounds. Secondly, but more importantly, there is a clear trend towards smaller and smarter libraries. It is easy to imagine that the larger a random library is, the lower the chances are of an individual compound representing a suitable drug candidate. Ways to focus a library to a specific target (disease), could lead to a higher probability of finding a suitable drug. Advanced software is developed for this purpose. Computational chemistry can 'draw a picture' of the chemical structure a drug has to tackle. Moreover, it can then 'advice' which chemical building blocks are most likely to be able to establish a 'hit' towards that structure. In jargon: software can advice on structure-activity relationships. In this way, the use of libraries gets 'smarter' and more focused.

All in all, combinatorial chemistry seems to be a promising technique. However, we should emphasize that the technology also has its limits, the most important one being that the chemical building blocks used still determine what novel leads can be discovered. It is likely that, for example, natural products will remain an important source of novel chemical building blocks for subsequent use in combinatorial chemistry technology.

The state-of-the-art and future applications

At present most pharmaceutical companies have capabilities in combinatorial chemistry. The total number of companies that list combinatorial chemistry as part of their technology base now stands at around 200. If we take an overview of the combinatorial scene we can see that a new industry has emerged comprising firms based exclusively on combinatorial chemistry. The amounts of money invested in this industry are considerable: in the USA the capital raised by combinatorial chemistry companies was around 600 million dollars in 1996 (By way of comparison between July 94- June 95, US biotechnology firms were capable of raising roughly 3.5 times as this amount). Considering the fact that combinatorial chemistry is a very recent development, the amount of capital invested in it is remarkable. Whether the investments pay off will depend on the amount of new products and applications combinatorial chemistry creates and when they appear. At this stage it is not possible to predict what the importance of the technology will be from a financial point of view. However, the expectations are high, certainly considering the degree to which the technology already shows promising results.

Pharmaceutical companies already have the first drugs designed by combinatorial chemistry in the clinical trials phase. These are products

Combinatorial chemistry allows the generation and testing of a large number of related compounds simultaneously, thus reducing development costs and lead times in the pharmaceuticals industry

The outcome still depends upon the building blocks used, and these continue to be largely drawn from nature

Large amounts of capital are being invested in combinatorial chemistry, reflecting the perception of its economic potential

Other sectors outside pharmaceuticals, such as agrochemicals, super-conductor research, etc. are beginning to take an interest in this technology

In the US the combinatorial chemistry industry appears to have grown up in the context of a thriving biotechnology sector

intended to combat the pain of cancer, migraine and arteriosclerosis. The trials suggest that the promise of shortening the time to market seems likely to be fulfilled. Market approval of drugs developed by combinatorial chemistry seems to be a question of time. Though combinatorial chemistry has so far mostly been applied in the pharmaceuticals sector, other industrial sectors are also affected by the technology. Recently, the agro-chemicals sector started to use combinatorial chemistry techniques to look for new leads, for example for insecticides and fungicides. It makes sense for this sector to follow the pharmaceuticals sector in taking up combinatorial chemistry. In both sectors it is important to be able to rapidly screen large amounts of compounds for biological activity.

The interesting point is that applications of combinatorial chemistry techniques are diffusing into others arenas than just those where some kind of biological activity or effect is sought. The technology is now also being applied in the search for new materials. Recently, US investigators were able to use combinatorial chemistry successfully in their search for high-temperature super-conducting materials. The investigators composed a library of materials based on elements that were screened for their superconductivity. The technology has also been used to trace thin-film batteries, new liquid crystals for flat screens or new catalysts. The crucial feature of combinatorial chemistry today appears to be the ability to combine an almost endless range of substances and to screen them for whatever feature, instead of just biological activity.

In conclusion, combinatorial chemistry currently plays and will continue to play, a role in pharmaceuticals, agro-chemicals and new materials. However, we should point out that these are not the only fruits of combinatorial chemistry. Specialized robotics and software should also be considered as important spin-off applications of the technology.

USA biotechnology and combinatorial chemistry

In the USA there is a close connection between the industrial structure of biotechnology and combinatorial chemistry. In recent years it is even common for a good deal of biotechnology firms not only to hire bio(techno)logists, but also combinatorial chemists. There are good reasons for this: also from a technological point of view, there are connections, which we describe below.

Firstly, biotechnology serves combinatorial chemistry as a provider of new targets. Over the last two decades, pharmaceutical and biotechnology companies have been working towards a clarification of the biological mechanisms which underlie disease. The Human Genome project has played a key role in this venture. This research brought information concerning new biological targets that could possibly be targeted by new drugs. We have already mentioned that this availability of new targets was one of the triggers for the development of combinatorial chemistry. The fact that combinatorial chemistry companies are established exclusively for research aimed at specific genetic targets (for example involved in cancer), clearly underlines the connection between biotechnology and combinatorial chemistry.

The second connection between biotechnology and combinatorial chemistry is more important for the argument we want to make later-on in this article. Combinatorial chemistry has actually grown out of the success of one the basic technologies of biotechnology, namely molecular biology. Combinatorial chemistry only came about after molecular biology became a discipline in its own right about 25 years ago. In fact, the first generation of combinatorial libraries focused largely on peptides and oligonucleotides, because of the existence of automated, nucleid acid and peptide synthesisers/analysers. Biotechnological research was an important driver for the development of this equipment. Since then, the focus in combinatorial chemistry has shifted towards organic materials for drug design, peptides are far from ideal as an oral drug due to availability considerations.

Why is it important to point out that combinatorial chemistry has grown out of biotechnological techniques? Recent publications reveal that by far the majority of combinatorial chemistry companies are located in the USA (40-45 companies) as compared to Europe (1-2 companies) This fact can certainly not be explained by the weakness of European chemical industry, as it is traditionally very strong. Though there is no scientific research on this issue yet, the connection mentioned above between biotechnology and combinatorial chemistry suggests another explanation. The leading position of the USA in biotechnology and the far greater number of small biotechnology firms might have been the decisive factor also giving the USA the lead in combinatorial chemistry. We might observe here a 'second generation effect' for Europe's widely acknowledged weak position in biotechnology. This is all the more severe, since combinatorial chemistry can very well grow out to a new important high-tech sector. Certainly if we take into account that other advanced technologies as software and robotics are closely connected to it and that it is moving into several fields of application.

Europe's answer to USA driven trends

If combinatorial chemistry is a future core technology for pharmaceutical companies then European companies cannot afford to lag behind. The European private sector has responded accordingly. Besides starting its own activities, European companies have been active in acquiring USA based combinatorial chemistry firms. To date the take-over of Affymax, a leader in combinatorial chemistry, by pharmaceutical company Glaxo for $533 million is the largest of these acquisitions. In the agrochemicals fields forms of co-operation are being established between small combinatorial firms and large corporations, in the form of either acquisitions or target driven deals.

A few European companies and institutions are involved in the formation of largely USA based consortia which share critical resources among the partners for the efficient development of new products. These developments again shows the connection with biotechnology because the formation of consortia is a development which was already going on for quite some time in biotechnology. In fact, consortia in biotechnology and in combinatorial chemistry are sometimes closely related or even overlapping. The formation of consortia is a particularly interesting phenomenon from the point of view of the future development of combinatorial chemistry. In the innovation literature it is widely acknowledged that the formation of networks is an important factor in shaping technology and innovation.

Europe's slowness to enter the biotechnology field has limited its ability to be in at the start of combinatorial chemistry

European companies have got into the field by buying existing US firms

Box 1. Combinatorial Techniques

Combinatorial Chemistry uses different approaches to synthesize large amounts of compounds, that can subsequently be screened by rapid screening techniques. One of the most important ways of synthesising a combinatorial library (collection of compounds) is the split and mix synthesis, which we explain in more detail following the figure.

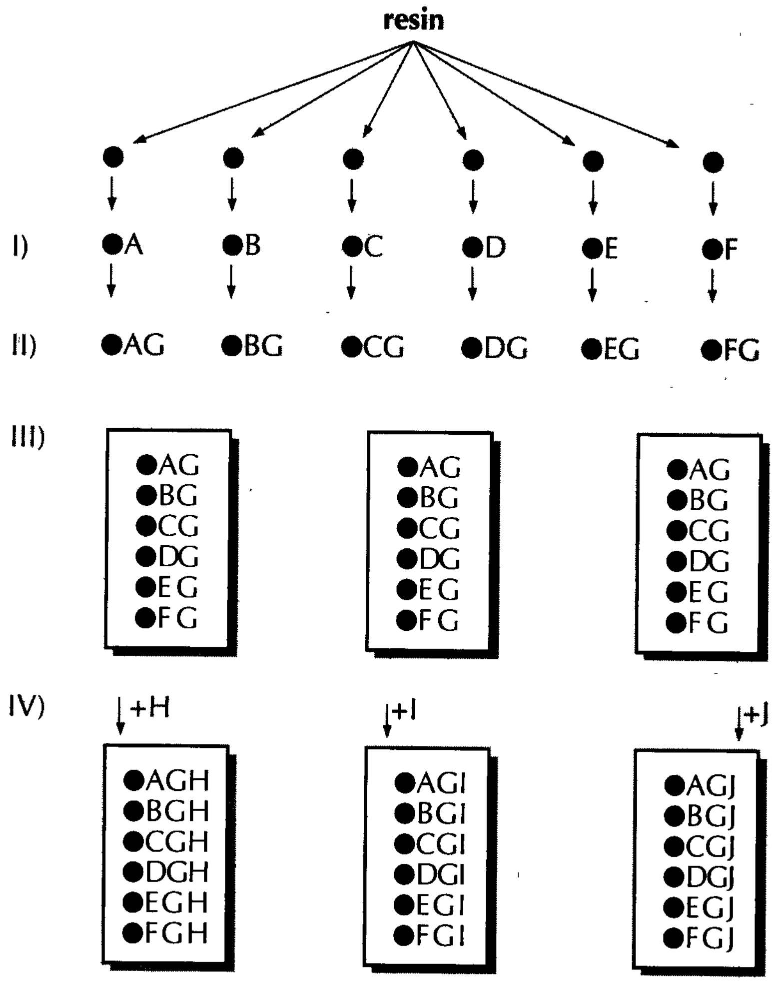

FIGURE 1. FIGURE SPLIT AND MIX COMBINATORIAL SYNTHESIS

I. In an array of separate reaction vessels, a carrier material ('resin') is present. On each carrier material, a different chemical building block is attached (in the figure: A, B, C, etc.
II. The second building block is added, G
III. The resulting compounds of step B are mixed and then split into three separate reaction vessels.
IV. Three different building blocks are added: H, I, J. The result is 18 different compounds.

It is important to note that in general, chemists do not set out from just any type of molecule fragments. If they seek a novel lea d, they will start with a broad selection of interesting building blocks to combine them to a broad library. If, however, the purpose is to optimize a lead already there, they will create a more focused library, composed of building blocks closely related to the a lready established lead. Both approaches, lead creation and optimization, are feasible with combinatorial chemistry.

Huge amounts of potential drug candidates requires also techniques that facilitate rapid activity-screening of the compounds. Techn iques such as High Throughput Screening make it possible to screen the activity of compounds in a limited amount of time. With combinatorial chemistry and HTS, a number of automation and computation techniques have co-evolved, that facilitate the handlin g of large amounts of (data about) substances. For example in analytical chemistry, changes were needed to be able to assess the pos sible activity of compounds on a much larger scale than before. For this goal, from a cost perspective it was not possible just to m ultiply the use of established analytical procedures. So for this purpose, robots are developed which can automatically synthesize h uge amounts of compounds as well as test them for specific activity. But automation of established procedures is not the only change in analytical technique that combinatorial chemistry has spawned. Recent developments show more advanced analytical techniques such as using a combination of microchips and chemical substances to measure activity of drug candidates.

The fact that at present networks are formed with USA companies at the core, will certainly influence the future landscape of combinatorial chemistry.

Policy Implications

What does this all mean for policy from a European point of view? It is widely acknowledged that small ('dedicated') biotechnology firms were and are of great importance in the development of biotechnology. Europe lacks the large number of dedicated biotechnology firms as they exist in the USA. If our hypothesis about the role of biotechnology firms in the development of combinatorial chemistry is right, then the existence of dedicated biotechnology firms seems to have a double importance: not only for the development of biotechnology, but also for their technological spin-off, in this case in the form of combinatorial chemistry technology.

We should draw two lessons from this: first it underlines again very clearly the importance of a policy aimed at stimulating the emergence of dedicated biotechnology firms. However, it might not be too easy to catch up in the field of combinatorial chemistry by stimulating the emergence of dedicated biotechnology firms, because the combinatorial technology is a 'second generation technology', i.e. a spin-off from an already established sector. The second lesson comes along with this point. Historically, biotechnology policy in Europe was understandably heavily influenced by the public debate on biotechnology and its ethical issues. Since of course the public's opinion has to be taken into account, these circumstances urged European policy makers to proceed in the field of biotechnology slowly and with caution. This might be one of the factors which contribute to Europe's present weak position in this technology. This article describes one of the possible backlashes of Europe's position on biotechnology, namely being outside of the core of developments which are a spin-off of biotechnology. This poses a difficult dilemma for the policy maker: slowing down the pace of development of one technology might mean that you cannot get in on a technology that emerges in the future, as one technology can be a spin-off of another. This can be particularly irksome if this spin-off technology is able to produce new drugs that are usually greatly appreciated by the public. There's no definite answer to solve this dilemma. However the least we can say is that the idea of investing to ensure a minimum technology base in a sector that is not widely supported by the public has at least one argument in its favour, i.e. that of keeping open the possibility of exploiting possible spin-off technologies in the future.

One lesson to be learned is that getting off the technology train because you think it's going too fast might mean you can't get back on later

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Keywords

combinatorial chemistry, biotechnology, technology policy

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Collaboration in Research and Development in Food Safety in the EU

Erik Millstone

Issue: The problems created by the epidemic of bovine spongiform encephalopathy (BSE) have been the most serious, but not the only, problems related to food safety in recent years in Europe. The incidence of bacterial food poisoning has also been rising in many, although not all, Member States, and the European Commission has identified a need to reorganize food policy-making in the EU. Improvements in food science and technology could also contribute to ensuring a safer food supply.

Relevance: The evidence suggests that there is considerable scope for improving co-operation between Member States in their research and development on food safety. New conditions are being created under which food safety research policy can and should be refocused both at the EU level and within the Member States.

Analysis

Introduction

In all EU Member States there are problems of food safety, both acute and chronic. (Federal Institute for Health Protection of Consumers and Veterinary Medicine, 1995; Fisher, 1997) While the governments of all the countries involved are investing in scientific and technological research and development (R&D) to help solve these problems, individual countries are acting more or less in isolation and are ignorant of each other's efforts. Many of the problems are, however, common across Europe and so there may be scope for greater collaboration in R&D. The problems which confront policy-makers in both the public and private sectors seeking to diminish or even to eliminate the hazards posed by food-borne pathogens are aggravated in part by the uncertain and inconclusive state of scientific knowledge, as well as by serious shortcomings in some of the technology currently available.

Scientific uncertainties

Serious uncertainties afflict numerous aspects of the science of food safety at the level of both acute and chronic problems. While we know, for example, that the incidence of E.Coli 0157 is far higher in some regions than others, we do not know why this is so. (Pennington et. al., 1997) Fortunately, with E.Coli, it is relatively easy to eliminate the hazard as long as contaminated meat is always properly cooked. The same cannot, however, be said for all food-borne pathogens, especially transmissible spongiform encephalopathies. We know that if and when cattle below the age of 30 months carry the BSE pathogen, the levels in their tissues are considerably

Although all EU Member States are to some extent affected by food safety problems they continue to work in isolation

Effective policy-making is hampered by incomplete scientific knowledge about the behaviour of certain food-borne diseases

Classical microbial tests are reliable but slow, moreover they are less well suited to modern flow process techniques than former batch production

lower than in those older animals that have already exhibited the characteristic symptoms of the disease, but we do not know whether or not all asymptomatic animals below the age of 30 months are entirely pathogen-free. If we had a quick and reliable method for measuring levels of pathogenic prions, and if we knew whether or not there was some threshold of exposure below which the risks were non-existent or insignificant, policy-making would be far less challenging or controversial.

It is very probable that BSE arose from the incorporation of meat and bonemeal rendered from carcasses of diseased animals into agricultural feeds, but this has not yet been conclusively established because some of the experiments which could provide confirmatory evidence remain to be conducted. It is probable that new variant Creutzfeldt-Jakob Disease (CJD) has arisen as a consequence of humans consuming BSE-contaminated meat, but that would also be very hard to demonstrate conclusively.

Technological opportunities

Such scientific uncertainties are linked to, and compounded by, the absence of rapid and reliable technological methods with which to establish the presence or absence of pathogens in particular samples of food (and if they are present, to obtain an accurate indication of the levels at which occur). Advances in food science and technology should however enable the food industry more effectively to provide consumers with healthier diets, and should facilitate public policy-making by reducing the uncertainties with which policy-makers have to grapple.

Classical microbiological techniques are reliable, for many bacteria and viruses at any rate, but they are slow and consequently expensive. It is relatively straightforward to take a sample of material from, say, milk, meat or fish, or products containing them, and to introduce it into a growing medium in a glass dish, and then to incubate it for many hours or even for a few days. If bacteria were present in the initial sample, this will be evident because they will multiply in the interim, and will have formed a conspicuous colony in the host medium. This would provide evidence that the initial sample may have been unfit for human or animal consumption, but the method, although reliable, is hardly prompt. If you are operating a food processing factory, you would like to be able to certify the safety of your output as it comes off the production line, and not several hours or days later, least of all after it has left your premises. Technological improvements at the point of production would drastically reduce the incidence of food poisoning from processed products.

With increasing quantities of food now being handled by flow, rather than batch, processes, technologies are needed that will provide reliable, continuous, real-time data on the microbiological status of food ingredients as they enter and flow through the manufacturing process. The urgency is compounded by the growing integration of the single European market for food products. The scale of production facilities is growing, and the distribution networks are becoming larger and more complex. A localized problem of contamination could therefore be spread over a long product run, and be distributed across a very wide area. In this regard, a particularly area of innovation is provided by the development of what have come to be known as biosensors. (Hobson et al, 1996) Progress has been made in recent years in particular to provide real-time, accurate and sensitive methods for microbial detection, and the use of immobilized enzymes appear to offer particularly promising techniques. (Oh, 1993)

The delays in obtaining results from tests for BSE are substantially greater than those for bacteria. The only remotely reliable test which we have, other than exposing cattle to a test material and waiting for anything between 7 and 10 years, involves using experimental mice. This test is performed most effectively using a relatively rare and expensive strain of inbred mice that require a high standard of care because they are especially vulnerable to infections. Following their exposure to pathogenic material, the mice do not start to exhibit overt symptoms of spongiform encephalopathies until they are geriatric, that is to say not before they are 18 months old. The lack of a rapid test has not only caused great difficulties for the farming and meat industries but also for the scientists seeking to conduct research into BSE and diseases of the same type.

It has been widely recognised, at least since the publication of the Southwood Committee report in 1989, that research to develop a rapid and reliable test for the presence and/or absence of the BSE pathogen must be given high priority. (Southwood et. al., 1989) This fact has been repeatedly acknowledged, most recently by the EU Commission in its call for research proposals on BSE. (Commission of the European Union, 1997) As soon as it becomes technically and commercially viable reliably to certify live animals and/or carcass meat as BSE-free, the entire crisis will become substantially simpler to manage.

Investments in R&D

In recent years there has been considerable technological progress, and that technological progress has arisen as a consequence of a sustained programme of investment in research and development (R&D) by both the public and private sectors. Some progress is evident to the extent that the time taken to obtain reliable bacteriological results has diminished in some cases from several days to several hours but, as Patel has explained, '..commercial on-line techniques...are a long way off..' (Patel, 1993) As far as a test for BSE in live animals or carcass meat is concerned, it would appear to remain a remote prospect. The potential impact of the development of such a test could be massive. The period since the announcement, on 20 March 1996, that evidence had emerged indicating that the consumption of BSE-contaminated meat had most probably been responsible for the emergence of several cases of so-called new variant CJD, has seen rapid growth in the investment of public resources in pursuit of such a test, with an ever more rapid increase in investment by the private sector. Prior to this, the private sector had shown only a faint interest in developing such a test. If a reliable test had been available at any time in the preceding 10 years, the crisis of March 1996 would almost certainly not have occurred. The above discussion indicates that both public authorities and private firms in the food and the scientific instruments industries have incentives to invest in scientific and technological research and development to help produce, process, distribute, store and sell food products more safely. Scientific and technological progress should also be invaluable in simplifying the policy-making process.

Testing for BSE can take months or years and a more rapid test still looks to be a long way off

Identifying current research policies and programmes

R&D projects are underway in all EU Member States, but no-one can provide us with an overall picture of the work which is, and is not, being done, let alone that which is being planned. The governments of all Member States are investing in such R&D activities, and the work is being conducted in a wide range of different kinds of institutions, from government laboratories to independent universities and research institutions, as well as in the corporate sector.

Effective tests would prevent diseases like BSE from reaching crisis proportions

There are good commercial reasons why many companies may be relatively secretive about some of their R&D, but the same considerations do not, It is quite possible that there is some wasteful duplication of effort in the current context of uncoordinated research

Particularly expensive and long-term research might best be pursued in coordinated multi-national programmes

and should not, apply to public authorities. Senior food scientists representing the governments of the EU Member States meet on a regular annual basis, but not even they have established an arrangement under which they would share with each other a description of the R&D programmes and projects they are each funding separately. There is, therefore, an opportunity and a need to establish precisely what R&D activities are in progress or being planned. It would then be possible to explore the scope for collaborations and for co-ordination in the future.

EU-wide Co-ordination

There could be a number of potential benefits from improved bilateral and multilateral co-operation in food safety research. It is quite possible that there is some wasteful duplication of effort. Particularly as while the scientific literature is quite good for distributing information about achievements, it is less effective at warning colleagues about lines of investigation which have not been fruitful. There are, moreover, important lines of research that would benefit all countries but which would be so expensive that no Member State on its own is prepared to fund them.

For example, policy-making and product formulation would be far simpler if we knew how reliable rodent toxicology studies are at providing indicators of the effects of compounds on humans. There is plenty of scientific scope for a comparison of the results of animal toxicological studies with the evidence which has been accumulated, and which could be obtained, from epidemiological studies in occupational settings where workers are per force exposed to higher levels than average consumers, and for longer and more consistent periods. Research along those lines would substantially reduce the uncertainties which complicate decision-making, but it would be an expensive and long-term project, and so might be pursued more effectively in a co-ordinated multi-national programme.

The case for further R&D and collaboration is not confined to toxicological issues, and similar considerations apply to many microbiological topics. OECD-wide collaboration would obviously be desirable, but evidence that an EU-wide collaborative programme was productive would attract other participants. There is, in short, plenty of scope for obtaining some international economies of scale in food safety R&D. Relevant expertise is not always uniquely located in domestic, public or private sector laboratories.

Summary and conclusion

The discussion has indicated that improvements in food safety science and technology would benefit consumers, producers and policy makers. There are substantial benefits which could be obtained firstly by sharing information and subsequently by achieving some degree of co-ordination, benefits which would be fostered by initiatives taken by the research community, by official representatives of the governments of Member States or by the European Commission.

Keywords

Food safety research policy, Research co-ordination in the EU

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Joint Implementation from a European Perspective

C. Hendriks, A. Zwick, A. Soria, F. Peeters

Issue: The concept of Joint Implementation involves a bilateral or multilateral deal in which countries facing high pollution abatement costs invest in abatement in countries with lower costs, and receive credit for the resulting reduction in greenhouse gas emissions. In 1995 the Conference of the Parties decided to establish a pilot phase, during which Framework Convention on Climate Change signatories can participate in Joint Implementation projects on a voluntary basis, without accruing credits for achieved greenhouse gas reductions.

Relevance: As soon as the Parties come to binding commitments on the reduction of Greenhouse Gases next December in Kyoto, the countries have to translate this into their national policy. The principle question will be how to attain the reduction objectives. Among the options under discussion is Joint Implementation, whose advantages and disadvantages need to be carefully evaluated in order to achieve its successful application.

A wide variety of instruments have been put forward as part of the implementation of green-house gas emission reductions, among them so-called 'Joint Implementation'

Analysis

1. Introduction

Preparations are currently underway for the Conference of Parties (CoP-3) at binding emission reduction targets of greenhouse gases (GHG) will be negotiated. Once agreement is reached, a variety of different policies and measures will be required to meet reduction targets. These range from "no-regret" policies to active, precautionary measures. Reducing GHG (greenhouse gas) emissions in production processes can be achieved by (further) energy efficiency improvement, by CO_2 removal and by larger-scale replacement of fossil fuels with alternative energy sources. Market-based instruments have been identified as useful tools for the introduction of GHG emission reduction measures. These include voluntary agreements, carbon/energy tax, tradable emission permits, deposit refund systems, subsidized product bans, and joint implementation. This latter approach has been adopted in article 4.2 (a) of the 'UN-Framework Convention on Climate Change'. The first stage of its implementation includes only Annex I countries, but provisions have been made for non-Annex I[1] countries to be included at a later stage.

The idea of environmental policy instruments, conceptually comparable to JI (joint implementation), is becoming wide spread and provisions for it have already been made in international agreements such as 'The Montreal Protocol', 'The Second Sulphur Protocol' and 'The Rhine Salts Treaty'.

This article looks at two questions. Firstly, whether or not JI implementation is feasible, and secondly, whether or not JI will accelerate the implementation of GHG reduction measures and to what extent it will affect the necessary development of environmentally sound technologies in the investing countries. We also review the current position of some important actors on the JI scene and more specifically discuss the position of the EU.

2. Joint Implementation: The Benefits

The driving force behind JI is obvious: it allows measures to reduce GHG emissions to be taken where they are least costly, on a world-wide level. This fits in with the nature of greenhouse gases, whose impact on global climate is the same regardless of where they are emitted. JI may induce significant capital flows from private investors in the OECD countries to their counterparts in developing countries, in addition to already existing or forthcoming official capital flows between governments. A condition for encouraging the involvement of the private sector may be an exemption from taxes or the application of a quota system.

Joint Implementation allows broad participation, and this may avoid 'leakage' of reduction potential that may occur under certain tax regimes (taxed activities may shift to other countries, outside of the agreement, where the GHG emissions will consequently rise). Emission targets could, thus, be even more ambitious than obligations under any agreement.

For the host country, the acceptance of JI projects will primarily depend on the demonstrated economic value from both capital and technology transfer points of view. Additionally, a reduction in SOx, NOx and dust emissions by technology improvement or reduced erosion in the case of reafforestation, will cause a secondary environmental benefit. This and spin-off effects of innovative technology in the country could provide important incentives for developing countries to participate. The diffusion of new technologies could be in some cases even more crucial than the expansion of existing technologies (Box 1).

JI may also make time to develop integrated environmentally sound technologies, which usually take longer to develop and introduce than the so-called end-of-pipe technologies. This farsighted application of Joint Implementation might create a pathway for more 'sustainable' solutions.

JI is considered feasible, for instance, for projects in the forestry sector, energy production and energy efficiency or demand-side

Joint Implementation makes it possible to reduce emissions where it is cheapest to do so and create flows of capital and technology to developing nations

One criticism is that JI shifts emissions reduction away from polluter nations and perhaps reduces incentives for the future development of cleaner technologies

Box 1. Rural Electrification in Indonesia

A forthcoming article by Císcar Martínez (IPTS Report: to be published) on the electrification of remote rural areas by Solar Home Systems in Indonesia illustrates the potential of Joint Implementation. Assessment of the expansion of the grid to these areas and the attendant maintenance envisaged its total costs being greater than that of solar power. Renewables would be more favourable than the simple option of diesel-powered engines in each household to which they would certainly switch to meet their energy demands in the near future. The financing of renewables in this area through a JI project could avoid expected emissions and disseminate renewables in the market. Both parties' interests could thus be met, achieving both cheaper emission reduction in a developing country and the desired electrification to improve the living standards in certain areas.

Another drawback is that certain countries currently outside the JI agreement framework look likely to account for the largest increases in emissions

For Joint Implementation to be fair, baseline emissions need to be defined accurately. This is often difficult to do at country level

Joint Implementation projects are divided into two main groups: technology-based JI and environmentally-based JI. Technology-based JI perhaps offers greater long-term advantages

management, services and maintenance of pipeline networks, renewables, agriculture, waste and modern traffic systems.

3. Joint Implementation: The Concerns

First and most importantly, JI gives rise to an **ethical question**. Given that the aim of the Climate Convention is to mitigate climate change by reducing greenhouse gas emissions, it may seem counterintuitive that nations do not reduce emissions within their own territory, but try to offset them elsewhere. In this context, it can be questioned whether - contrary to the sustainable pathway mentioned above - JI would promote reliance on current fossil fuel technologies in the investing country and would reduce incentives for major breakthroughs in terms of future alternative technologies.

Another main question concerns the **involvement of non-Annex I countries**. A preferred target for JI are the East European Annex I countries. However, the International Energy Outlook 1997 projects that in 2015, annual global emissions will be 9.7 billion metric tons of carbon (GtC), with about 45% of these emissions coming from the developing world (EIA, 1997). These figures are based on projected increases in world energy demand from EIA's 'reference case' scenario, which indicates that the developing world, particularly Asia and China, will account for more than sixty percent of emissions growth between 1995 and 2015. This calls for a greater level of introduction of cleaner energy sources in non-Annex I countries: it would be wise to respond in time to their future energy demand in an environmentally and economically sound way. In this light, JI could also provide a way of technology transfer. It should be noted that in the case of JI between an committed investing country and a host country without commitment, as foreseen for the initial phase of JI, emission accounting can only be done at a project level. A cross-checking of the emission reduction results achieved on a national level would not be possible.

This is not the only accounting/definition problem to be kept in mind when considering both JI and other emission reduction efforts. Another problem for the implementation of JI involves the **baseline definition**, i.e. what is the amount of GHG emissions that would otherwise have been emitted. Emissions reduction under JI should be 'genuine', i.e. countries should not be rewarded for emission reduction that would have taken place anyway. For this reason, some argue that JI may only be established between Annex-I countries, with well-defined emissions, base years and emission targets. For developing countries this is normally not the case, so others have argued that the question of the baseline can only be tackled on a micro (project) level.

The question of **equity** also needs to be looked at: how can the system guarantee that the net benefits will be equitably shared between investing and host country? (This highlights a problem intrinsic to the "commitment" mechanism, not JI per se). The situation differs according to whether the agreement is with another Annex 1 country or with a non-Annex 1 country (without commitment), since the latter is not interested in obtaining emission reduction based on national commitments. In the latter case the total reduced amount could be credited to the investing country. As soon as the country without commitment enters the group of countries with commitment its emissions will already be lower than it would have been without JI, which brings us back to the baseline definition issue mentioned earlier. In any case the host country will negotiate to get the most out of this "deal".

In general, Joint Implementation projects can be grouped around two major lines, namely technologically based JI and environmentally based JI. Forestry, for instance, can be grouped under the environmentally-based activities, which have been given preference in the pilot phase of jointly-implemented activities[2]. A principle difference from technology-based activities is that once a forest is mature, little or no additional amount of CO_2 will be sequestered, and the possibility remains of the sequestered CO_2 being returned to the atmosphere in the event of the forest's being felled. Technology-based activities, such as energy efficiency improvement or development of renewables, are not easily reversible because the emissions avoided are not stored and can thus not be re-emitted later on. Additionally, once an improved technology is adopted, it is unlikely that the old technology will return. The technological progress is a rather critical issue. There are voices that are sceptical of afforestation in the JI context, as this could delay necessary sustainable development, given that the investment is siphoned away from the technological innovation process of the investing country. Apart from the general concerns mentioned above, JI may also be subject to some specific issues which affect both host and investing countries. Table 1 gives an overview of (assumed) advantages and disadvantages for the investing and host countries.

4. Joint Implementation: The Institutional Implications

The issues discussed above make it clear that JI projects need prior endorsement and assessment before credits can be accrued to the parties involved. These two JI specific tasks have to be performed in any case by independent and authorized institutions and call for the creation of a structure, and the definition of criteria, evaluation procedures as well as the necessary technical expertise. **One of the main issues to be solved is the baseline issue.** Defining the baseline requires a well-founded state-of-the-art review that can be used as a reference point, taking future planning into account. If the company or country already planned to install more energy efficient technology, the baseline evaluation has to take this into consideration. The energy conversion efficiency of coal-fired power plants serves as an example. This amounts to about 36% in OECD

Table 1. Overview of advantages and disadvantages for the investing and host countries

	Pros	Cons
Investing country	• Cost efficient • Avoid or reduces non-voluntary policy instruments • Creates business opportunities	• Loss of local investments • May reduce short-term incentives for technological developments
Host	• Improved transfer of know-how and technology • Additional resources and employment opportunities • Local environmental benefits (elimination of local pollutants such as NO_x, SO_2, etc.)	• A possible mismatch between available infrastructure and rapid technological development • Limited incentive for local technological developments and for enhancing future potential

The baseline issue needs to be resolved if 'free-riding' is to be avoided, in which projects which were due to be implemented anyway are included in JI accounting

An international clearing house could provide the formal ratification of projects, whilst national institutes could serve as a focus and promoter for JI projects

countries, but to only 20-22%. in some developing countries. In the case where a new high-efficiency power station was already planned less credit should be given for the emission reduction achieved. Otherwise, free riding may occur in which activities which would have been implemented in any case are funded. Under such circumstances emission reduction would be inappropriately accounted by the investing country. Such free riding can only be reduced if criteria are defined clearly by an international institution in which as many countries as possible participate.

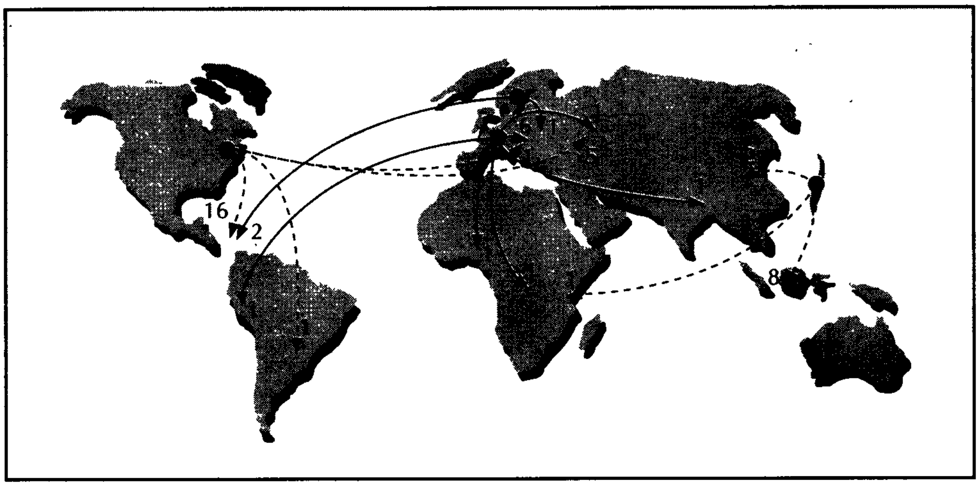
In order to gather information and gain experience with JI,,AIJ (Activities Implemented Jointly) programmes have been set up in about 20 countries world-wide (JIQ, 1997). Some of those already have a national organization for JI and gained relevant experience with the system. The FCCC secretariat in Bonn is currently active in solving technical issues on JI. In Box 2, the current JI status is described for the USA, Japan and Europe, while Figure 1 presents an overview of ongoing AIJ projects, indicating investing and host countries.

Based upon the experience gained the following structure (Fig. 2) may be an appropriate starting point. On an international level a clearing-house could be established. This institute would deal with the formal ratification of projects, based on proposals from the national institutes.

National institutes should deal with the credibility of a JI project and serve as national focus point for the identification of projects as well as provide information on financial aspects. They should also set up a kind of bulletin board on which potential JI projects can easily be identified. Thus, the interests of developing countries are preserved, ensuring national equity on this issue. Furthermore, they may have to interfere with private sector activities as targets have to be reached (eg. set levels of GHG emissions reduction), which may be of lesser concern to the private sector.

Another aspect that certainly needs to be clarified is the financing of JI projects. The financial additionality criteria (CoP-1) requires JI projects to provide financial engagements apart from official development assistance of the parties, including

Figure 1. Projects under development or ongoing AIJ projects around the world, indicating the investing countries and host regions together with the number of projects (JIQ, 1997)



Box 2. International experience with Joint Implementation

USA

The USA established the US Initiative on Joint Implementation (USIJI), which started working in autumn 1994 and is currently the most developed and experienced JI programme world-wide. The structure of the USIJI is such that the responsibility for policy and project criteria, ultimate project approval and daily working is separately observed by the Interagency Working Group, the Evaluation Panel and the Secretariat respectively. According to the CoP-1 decision 5/CP.1, the USIJI established nine criteria for project approval. The USIJI not only monitors and verifies the achieved emissions reductions of accepted projects, it also provides technical assistance to initially refused, but potentially worthwhile JI projects. Besides supplying support, the USIJI performs a number of outreach activities, including: setting up bi-lateral and multilateral agreements with countries to facilitate cooperation on JI projects, organizing US and international workshops and providing information services. At this time 23 projects have been approved by the USIJI, ranging from reafforestation and renewables to district heating improvements and the capture of fugitive methane emissions from a pipeline. These have covered the following geographical regions: Eastern Europe, Asia, South Pacific, Russian Federation, Latin America and Africa. The USA recently announced the investment of a further 0.9 MECU for JI project development.

Japan

The 'Japan Programme for AIJ under the Pilot Phase' was established in November 1995, for which the Japanese Government created an Inter Ministerial Agency Coordination Committee for AIJ to facilitate communication among ministries concerned with JI (in Japan each ministry is responsible for approval of JI projects submitted to them). The criteria for JI project approval in Japan are basically those of CoP-1, in accordance with its decision 5/CP.1. Thus far, eleven projects have been selected as potential AIJ projects and are under further development now (these projects have not yet been officially reported to the FCCC and therefore not yet recognized), six of which are afforestation projects and five are in the field of energy efficiency and renewables. The projects are located in Asia and Africa. Japan recently decided to invest 1.4 MECU in development of JI projects.

Europe

At present the Netherlands, Denmark, Germany, Finland, Iceland, Norway and Sweden have AIJ programmes. More specifically, in April 1997, the Netherlands initiated a JI campaign directed at their industry, for which they made 40 million ECUs available to support AIJ projects. In the Dutch JI programme policy is established by an ad hoc Advisory Board and a Steering Committee, whilst the practical execution (project selection and approval) is carried out by the ministries of Environment (political responsible for JI), Economic Affairs, External Affairs and Development Cooperation. Here again, the criteria are basically those of CoP-1. Base line study, monitoring, evaluation and registration of the projects is done by the JI Registration Centre.

Constant monitoring of JI projects is also required to ensure the credibility of the scheme

Global Environment Facility (GEF) funding. Other resources will have to be found or created to stimulate private participants to be involved, especially during the AIJ pilot phase which offers little benefit for investors. This is particularly important because an achievement of JI's promise would depend heavily on the engagement of the private sector in developed countries taking into account today's era of shrinking government budgets. The national institutes should therefore provide an oversight of existing and new financing mechanisms for JI and eventually set up portfolios that could attract potential investors, who would otherwise not become involved.

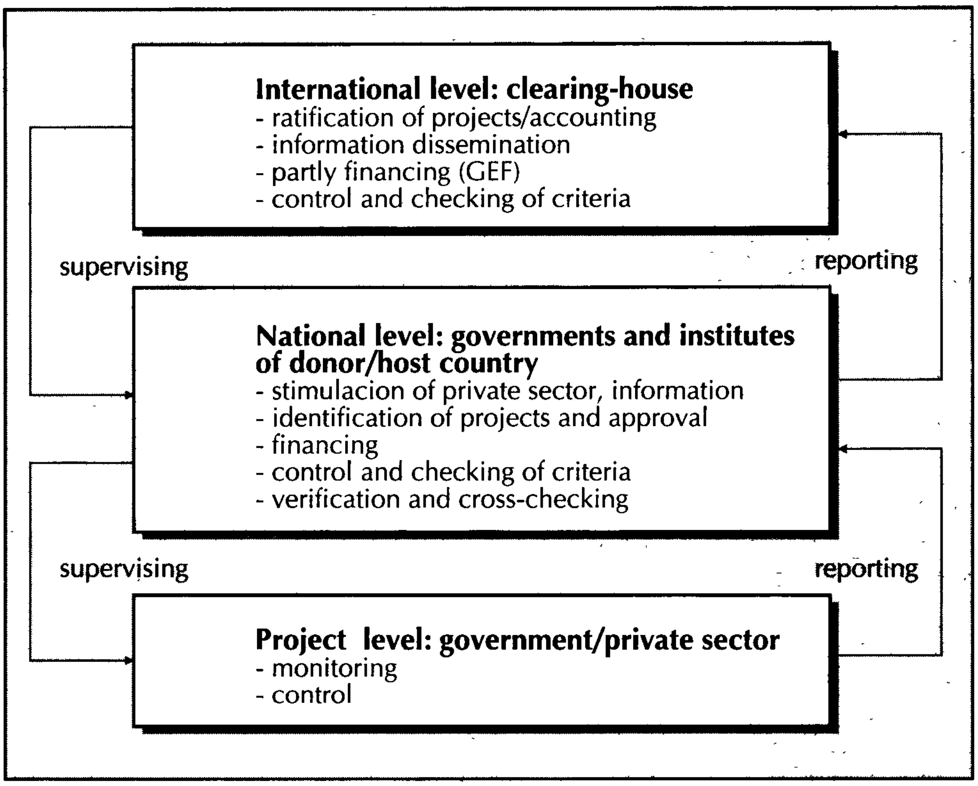
In order to guarantee the credibility of JI, each country involved in JI projects should monitor the emission reductions realized each year and this should continue throughout the life-time of a project. This assessment requires data acquisition and reconciliation, the development of methodologies and technical skills and would best be performed by highly specialized and independent technical experts from, for instance, research institutes, universities or NGOs, in the context of a **JI monitoring institute**. In addition international verification needs to be ensured.

5. Towards a European Approach

In the light of a common EU negotiation proposal in Kyoto for binding emission targets, it is natural that EU member states look for common or coordinated approaches to translating the binding targets into reality. As this implies, JI may bring both environmental and economic benefits. The

JI initiatives in Europe are currently fragmentary and concentrated in the northern countries

Figure 2. Possible structure of an institutional JI verification system based on theoretical considerations, available experience and international concerns (modified after Wuppertal Institut, 1996)



concerns and institutional implications have shown that a careful evaluation of the pilot phase is necessary. The verifiability and the efficiency of the current AIJ projects in terms of emission reduction has to be assessed by both individual member states and the European Union as supranational authority. JI needs more experience be gained from the AIJ pilot phase projects in order to set up a good working JI regime in the near future.

Until now there has been no common approach to JI by the EU. Initiatives on JI are being developed mainly by the Northern member states and not yet by the Southern EU countries. Current patterns suggest the evolution of many different JI initiatives, all developing at a different speed, implying different structures, rules and criteria, and each having restricted influence on the international forum. At this stage the EU could play an important role in the dissemination of JI by coordinating those tasks which would otherwise have to be done separately by each member state, such as establishing criteria and developing a unified assessment methodology. The EU could also provide and tune new funding during the pilot phase and regulate criteria for subsidies (JI funding could be on/over the edge of hidden export subsidy) in order to avoid conflict among the member countries. This emphasises the importance of a supranational clearing-house at EU level. A further important point is that a well defined political direction could provide a solid basis for industrial investment on environmentally-sound technologies, and in this way could be not only an important instrument for GHG emissions reductions but also increase the competitiveness of European firms in this area.

6. Conclusion

Europe is likely to agree to reduce its emissions of greenhouse gases. The question now is how to implement this objective. JI might be one route among many, but sufficient experience with the JI mechanism is not yet available to anticipate all the concerns and to make final decisions on an international level. The realization of JI concerns a delicate framing of criteria. Various institutional issues are not yet fully understood, although a certain common structure for JI and AIJ programmes (mainly based on the CoP-1 criteria) can be found in many countries already active in the field of JI. Therefore, the AIJ pilot phase constitutes a crucial moment for the identification of the right type of projects and a good legal basis, and should receive the necessary attention to create the right environment for a JI regime in the near future.

Incentives at national level should be created to stimulate the participation of private companies. Governments could encourage the business community by concluding covenants or issuing national credits, i.e. exemption from taxes or similar measures. Efforts should be made to disseminate JI information, to provide opportunities for research on JI and to encourage the discussion about JI on an international level. This could be achieved by a platform for information exchange on potential JI projects to lower administrative costs. A strong participation of all the countries is necessary to exclude free riding on a large scale and to create a common consensus about fairness in bilateral commitments.

JI can be initiated by the industrialized world, but to be effective it requires the developing countries being involved. The European Union could play a leading role by establishing a policy towards developing countries and help them to work out a JI policy that reflects their national priorities. A technologically-based JI would favour the dissemination of environmentally sound technologies.

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Keywords

Conference of Parties CoP, Joint Implementation, JI, AIJ, technology transfer, CO_2 reduction, sustainable development.

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Notes

1- Annex I Parties to the convention consist of 36 developed countries and economies in transition that agreed to stabilize their CO_2 emissions at 1990 levels by the year 2000.

2- Within the pilot phase of JI the activities are called Activities Implemented Jointly (AIJ).

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Facilitating Technology Uptake: The Case of Smart Structures and Materials

Celia Greaves

Issue: Smart structures and other applications of smart materials add value through their application, by reducing costs and increasing functionality. Applications include transport, civil engineering, medical hardware and manufacturing technology. Europe is currently lagging behind Japan and the US in terms of both uptake and awareness of smart materials.

Relevance: If Europe is to compete effectively in the area of smart structures, there is a need for policy frameworks which encourage innovation and facilitate commercial uptake. This requires an understanding amongst policy makers of the key challenges facing the sector and the identification of areas where policy intervention could make a significant contribution. Current evidence suggests that a major constraint to progress is not basic research, or the lack of it, but the absence of effective mechanisms to facilitate the translation of research outcomes to the marketplace.

Introduction

Smart structures are structures composed of, at least in part, intelligent or smart materials. Such materials generally exhibit the following characteristics (Scientific Generics Ltd, 1993):

- properties which are, in some way, unexpected or novel;
- the capability to respond physically to external stimuli without requiring external information processing;
- reversibility and recyclability, particularly in the case of systems; and
- general applicability to a variety of situations.

Users of smart materials perceive the 'smartness' as a feature of the application rather than an as latent characteristic of the technology. The greatest value arises not in the production of the materials, but in their application in systems and structures. By way of illustration, whilst shape memory materials are initially supplied in relatively simple forms, such as wires, rods and thin film, they have a diverse range of applications, as shown in Box1. This variety of uses clearly highlights the generic value of smart materials and the systems and structures into which they are incorporated.

Whilst many aspects of European policy have a broad applicability to smart materials, the focus of research and development is currently via the Brite-Euram Programme (Industrial and Materials Technologies - Brite-Euram III). The overall objective of this programme is to work

Box 1. Example materials and applications

Smart material	Application
Shape memory materials	• clothing inserts • medical implants • hydraulic couplings • bolt shearers
Electro-rheological fluids	• stimulation of shape change in actuators
Piezoelectric materials	• sensors in the aerospace industry • damping of engine mounts

towards sustainable development by preparing for the factory of the future. Research areas covered by the Programme include integration of new technologies into production systems and advanced materials, as an example of technologies for product information. Support mechanisms comprise shared cost research and technology development (RTD) projects, thematic networks, concerted actions and accompanying measures, including those targeted towards maximising spin-offs from the programme.

Technology challenges

Notwithstanding the generic appeal of smart materials and structures for utilization in a wide variety of commercial and technical markets, a number of remaining challenges need to be met if their commercial potential is to be realized across Europe. At the fundamental level, the history of smart materials has tended to be characterized by the development of technologies looking for a problem rather than novel solutions-based approaches. A key issue here is to differentiate between smart materials and the structures and systems which they are typically incorporated into.

The history of smart materials has tended to be characterized by the development of technologies looking for a problem rather than novel solutions-based approaches

Whilst access to the materials themselves is generally not limited, a number of factors constrain access to new applications. One of the most important of these is a lack of awareness, both in terms of knowledge/understanding of materials (and their applicability) and appreciation of the need for such materials to be tailored to suit specific structures and systems if they are to provide added value. For example, although electro-rheological fluids are well known, many technologists are unaware of the precise changes in viscosity and stiffness which can be achieved in use. There is also a tendency towards over-specialization, which results partly from sensationalization of impractical applications and partly from underestimating the value in more mundane applications.

An example of failure to understand the technology is the perception of low durability, which stems from a deficiency of technical knowledge and lack of appreciation of the production and manufacturing process. Thus, whilst it is possible to use base-stock to manufacture components which fail after five cycles or a million cycles, users are often unaware of this. Shape memory materials are a good example of a technology-push development. Awareness and commercialization have been aided by demonstrators, but there has been a tendency for progress to be concentrated in specific individual sectors, (eg. medical applications), with few trans-sector developments.

A particular challenge is to match technologies to individual applications, and to identify and resolve gaps. This requires co-operation between both providers and users of the technology to identify areas of synergy and linkage across applications. One area where such synergy is needed is shape memory polymers, which have, to date, experienced little commercial uptake because their cost/performance ratios have not been appropriate for the applications considered.

At present there is a diverse range of organizations involved in various aspects of smart materials and structures, including the University of Pisa (polymer gels), Siemens (piezoelectric), Scandinavian Memory Metals (shape memory), Strathclyde University (strain sensing rope) and Bosch (Electro-rheological Fluids). In the case of shape memory materials, applications are being developed through various routes, including the 'basket' strategies of specific specialist applications development companies, the technology-push strategies of manufacturers and the ad-hoc approaches of other companies. There is little co-ordination between the groups of organizations involved, and opportunities for cross-fertilization of ideas are few.

SMEs operating in the area of smart materials and structures face many of the challenges which they experience in other sectors. One aspect in which there are some differences is in the matching of technologies with applications. Whilst SMEs are unlikely to be able to compete in the initial development of the technology (which usually requires significant R&D investment), they can operate successfully in the development of applications. In contrast with areas such as biotechnology, the latter stages of the commercialization of smart materials require a range of design, engineering and manufacturing skills beyond the original scientific expertise.

The majority of European users have traditionally adopted a 'follower' stance and intend to monitor events until they judge that it is appropriate to move forward. This has been particularly true of the aerospace sector, where the US and Canada lead on new developments. Many users are relatively ignorant of the possibilities, or have distorted views of smart materials' capabilities. Only a few have been prepared to take a more proactive approach.

This phenomenon has tended to be reinforced by the lack of awareness highlighted above, which, in turn, acts as a brake on greater uptake amongst potentially pioneering users.

Approaches to smart materials and systems vary across the world. Whilst the US has tended to be rather structurally oriented, with a focus on end products rather than the underlying process, Japan has concentrated on the softer technologies, such as electronics, and has pursued these from the perspective of a basic understanding. The European approach has been closer to that adopted in the US than in Japan. The difference in approach can be illustrated by the aerospace sector, where the

There is a general lack of awareness of smart materials, partly as a result of sensationalization of impractical applications and partly from underestimating the value in more mundane applications

A wide range of organizations is involved in smart materials and structures, but their is little coordination between them and scant opportunity for cross-fertilization

Although the original research requires significant investments, applications often lie within the scope of SMEs' abilities

Improved awareness could be achieved, at least in part, through a pan-European awareness-raising campaign

Demonstrators provide a means of showing the practical use of a technology for a particular application or set of applications

Funding for smart materials and structures has often been hampered by the fact that they do not fall within the traditional scientific disciplines

US and Europe have, respectively, adopted contrasting 'make' and 'buy' approaches. Whilst Europe has kept broadly abreast of its competitors in terms of fundamental understanding, it has lagged behind in respect to awareness and commercial acceptance.

Policy aspects: current and future

The current status of materials technologies in Europe provides a number of opportunities for policy intervention to improve the overall competitive position and enhance the potential for long-term success. Current and possible future areas of activity are discussed below. In many cases, it is in the interests of all parties that progress be made. Thus, a particular challenge for policy makers is to ensure that appropriate mechanisms are in place to encourage collective action.

Targeting effort - There is a need for a selective approach to support for research and development, whether this builds on existing areas of strength or develops to take advantage of emerging opportunities. Possible priority areas include sensors and medical applications.

Improved awareness to promote understanding of the scope of smart materials and encourage holistic approaches to future design - Such awareness needs to be widespread throughout industry in order to break the current circle of unwillingness to take on new developments because of lack of understanding of the benefits which they can bring. It also needs to pervade the broad spectrum of manufacturing culture from engineering through to design. A focus on the need for holistic approaches would help to ensure that the scope for added value through application is optimised. For example, a greenhouse roof activator needs only a simple shape memory device, rather than an electronically controlled sensor activated battery system, to be effective. Improved awareness could be achieved, at least in part, through a pan-European education campaign. An important aspect would be to encourage a focus on finding the most appropriate solution to a problem, rather than on implementing specific technologies.

The policy makers' role in this could take the form of organization and implementation, support for an industry lead initiative, or some combination of the two. Specific mechanisms could include newsletters, workshops/seminars and conferences.

Support for demonstrators - Demonstrators provide a means of showing the practical use of a technology for a particular application or set of applications. They can play a key role in facilitating awareness and understanding (by overcoming mismatches between technological expectation and material capabilities) and are recognized as having the potential to kick-start new or emerging technologies and stimulate a 'snowball' effect, leading to the innovation of spin-off ideas. This type of approach can also help to reduce the technical and commercial risk to users associated with taking on smart technologies and, thus, increase the likelihood of uptake. Demonstrators can be useful in highlighting both the attributes of new technologies and the novel applications of existing technologies. This is particularly pertinent to smart materials and their incorporation into smart structures and systems. Outcomes could encompass direct copying by manufacturers in the same industry sector, direct copying and/or adaptation for the same function in new industry sectors, and innovation for alternative functions. This in turn could facilitate upgrading of reproducibility, durability and recyclability.

Standards - Modern industrial design requires accessible and meaningful data, embracing aspects such as basic characteristics, common specifications, nomenclature and test results. Any material which is not defined in these terms is likely to be at a severe disadvantage, particularly against the background of increasing computer aided design. Those materials for which there are no standards cannot be accurately modelled during new product development and are, therefore, likely to be passed over in favour of those which can. Policy makers could ensure that appropriate frameworks are in place by working with industry to develop standards. This type of activity will also help to promote awareness.

Greater collaboration - This would help to ensure technology appropriateness and that developments are sufficiently problem-driven to be of value to users. By ensuring that the technology is considered holistically rather than as a bolt-on, the potential for both cost and functionality benefits would be increased. Policy makers could facilitate greater collaboration by providing some form of brokering service or club aimed at bringing together potential customers and suppliers. There could also be a role in promoting holistic design as a long term goal. Consideration could be given to providing some form of regular fora for the exchange of views both between and across these groupings.

Ensuring that appropriate funding structures are available - Because smart materials and structures do not fall within the traditional scientific disciplines, with research requiring an interdisciplinary approach, it has been difficult to achieve an appropriate funding and administrative structure in the academic community. There have been a number of useful generic developments in this area in recent years, and there is a need to ensure that these continue. It is also important to ensure that, as communications improve (see above), there are mechanisms in place to allow productive collaboration between industry and academia.

Conclusions

Each new material development has the potential to give rise to a cascade of new applications. These essentially encompass:

- direct copying or adoption of existing best practice;
- the redesign of existing products to incorporate new materials which improve functionality or reduce cost; and
- innovative products.

The challenge for policy makers is to ensure that the appropriate conditions exist for that potential to be realised.

Standards also play an important role in uptake, as materials for which there are no standards cannot be accurately modelled during new product development and are, therefore, likely to be passed over in favour of those which can

Keywords

smart materials, smart structures, policy makers, awareness

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ABOUT THE IPTS

The **IPTS** is one of the seven institutes of the Joint Research Centre of the EU Commission. Its remit is the observation and follow-up of technological change in its broadest sense, in order to understand better its links with economic and social change. The Institute carries out and co-ordinates rsearch to imporve our understanding of the impact of new technologies, and their relationship to their socio-economic context.

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 between 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 free of charge in four languages: English, French, German and Spanish.

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- CEST - Centre for Exploitation of Science and Technology - UK
- COTEC - Fundación para la Innovación Tecnológica - E
- DTU - University of Denmark, Unit of Technology Assessment - DK
- ENEA - Directorate Studies and Strategies - I
- INETI - Instituto Nacional de Engenharia e Technologia Industrial - P
- ITAS - Institut für Technikfolgenabschätzung und Systemanalyse - D
- NUTEK - Department Science Policy Studies - S
- OST - Observatoire des Sciences et des Techniques - F
- SPRU - Science Policy Research Unit - UK
- TNO - Centre for Technology and Policy Studies - NL
- VDI-TZ - Technology Centre Future Technologies Division - D
- VITO - Flemish Institute for Technology Research - B
- VTT - Group of Technology Studies - FIN