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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's agenda (but projected to be there sooner or later), or underappreciated aspects of issues already on the policymaker's agenda. The long drafting and redrafting process, based on a series of interactive consultations with outside experts, guarantees quality control.

The first, and possibly most significant indicator of success is that the Report is being read. Issue 00 (December 1995) had a print run of 2000 copies, in what seemed an optimistic projection at the time. Since then, 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 ENEA and the US Council of Strategic and International Studies.

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

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

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

Preface

The last "Universal Exposition" of the Century is to be opened this month, in Lisbon. It should highlight the importance of oceans as a key actor for maintaining the natural balance of the Earth's biosphere: covering over two thirds of the Earth's surface, the oceans contain about 97% of the world's water; interaction between the atmosphere and the oceans and seas has a large influence on climate and weather patterns; plant life in the oceans is an important part of the 'lungs' of the planet, and photosynthesis in the seas and oceans is responsible for the removal of a large amount of carbon dioxide from the atmosphere. Thus, the seas and oceans represent the new frontier of knowledge and human activity.

The European Commission (EC) pays a special attention to the issue to which it contributes by its own research programme as well as close participation in international research schemes. One of the four pillars under the Fourth RTD Framework Programme (1994-1998) of the European Commission has focused on action in the area of the environment. It encompasses a Task Force on Maritime Systems of the Future and the RTD Programme Marine Sciences and Technologies (MAST), and aims to develop the scientific and technological bases for sustainable exploitation of marine systems and to understand their precise role in global change. Its research falls under four main headings, as follows:

"MARINE SCIENCE" in order to understand the fundamental processes governing marine systems, including extreme marine environments (deep sea floors, ice-covered seas, etc.) and specific European areas (Baltic, Mediterranean, etc.);

"STRATEGIC MARINE RESEARCH" to ensure compatibility between the exploitation and protection of marine resources. Hazards and adverse impacts liable to affect the marine environment will be identified;

"MARINE TECHNOLOGY" the aim of which is to develop generic technologies for monitoring, using and protecting the marine environment (oceanographic observation, underwater communication and viewing, analysis of natural substances, development of measurement instruments, remote-controlled vehicles and benthic laboratories for deep-sea and Arctic exploration);

"SUPPORTING INITIATIVES" in order to improve coordination and develop European cooperation (training, SMEs, access to advanced experimental facilities, etc.).

In order to contribute to world research on global environment, Community activities are carried out within the framework of the European Network for Research into Global Change (ENRICH). Community RTD is also directed in such a way as to support the objectives of the International Geosphere-Biosphere Programme (IGBP), the World Climate Research Programme (WCRP) and the Human Dimensions of Global Environmental Change Programme (HDP). In addition, account is taken of the scientific requirements expressed in the setting-up of the Global Ocean Observing System (GOOS) with its European component called EuroGOOS. Within this programme, measures are included to establish interdisciplinary regional research networks to address the distinctive problems of particular European regions. There is a close collaboration with corresponding activities of the EC Joint Research Centre in particular in relation with the Institute for Space Applications and the Environment Institute.

Another subprogramme, called Land-Ocean Interactions in the Coastal Zone (LOICZ), is dealing with the question of how will changes in land-use, sea level and climate alter coastal ecosystems, and what are the wider consequences. The European contribution is constituted by the ELOISE programme (European Land-Ocean Interaction Studies).

Appropriate collaboration is taking place with other international bodies, such as the Intergovernmental Oceanographic Commission of UNESCO (ICO), the International Council for the Exploration of the Sea (ICES), the International Commission for the Scientific Exploration of the Mediterranean (ICSCM) and the NATO research centres.

The Fifth RTD Framework Programme will succeed the present Fourth RTD Framework Programme in 1999. This programme will set out the priorities for European Union RTD activities as we move into the next millennium. Marine science and technology will be related to many of the priority areas of the new Framework Programme strengthening interdisciplinary research, integrating activities and enhancing the knowledge on environmental systems and processes. Thus, the ultimate objective will continue to be the improvement of the quality of life world-wide.

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EDITORIAL

Defining sustainable development

Dimitris Kyriakou

Sustainability is a term that is used so often that its users do not bother to define it. Or maybe they attempt to, realise that there is a vast spectrum of definitions, then decide to skip it. Daunting as it may seem, the task of toiling over the gamut of various definitions to extract the common essence is not insurmountable.

The sustainability criteria espoused by sustainable development (SD) models can be broadly classified along a **weak-strong** axis, according to the quantity/entity they would opt to preserve (e.g. total capital stock, natural capital stock, individual forms of natural capital, etc.) and their belief in **substitutability across various forms of capital**. Underpinning this focus, differentiation is a varying degree of belief in the ability of technical progress to allow substitution across different forms of natural and man-made capital.

The weak version is epitomised by the Hartwick-Solow (HS) rule calling for investing a part (the 'scarcity rent') of the revenue received from the extraction and exploitation of depletable resources, in order to build up capital to a level that would balance the natural resource depletion, and would thus guarantee non-declining consumption over time. Although a seminal result, its robustness can be questioned, as small departures from its underlying assumptions undermine its validity. In any case, the success of the rule hinges on the capacity of man-made capital to substitute for natural capital.

Substitutability will improve with technical progress. The latter can be seen as a form of human capital in which society invests. In a virtuous circle pattern, *technical progress not only enhances substitutability across forms of capital, it also promotes economic growth, which in turn, allows high investment in human capital formation.* The picture becomes less rosy when we are near catastrophe thresholds, or, perforce, when there is uncertainty about what such thresholds are. The inability of price signals to reflect the imminence of catastrophe threshold crossing is at the heart of the problem. It is due to limited (though improving) scientific knowledge but also to economic/legal issues (e.g. property rights allocation, public good characteristics). Uncertainty about the stability aspects of the biosphere renders problematic the application of standard rational agent rules (i.e. forming rational expectations, weighing expected costs and benefits, etc.). A useful rule-of-thumb seems to be to keep the option set as intact as possible for as long as possible while science improves our understanding of what is at stake.

A **synthetic/eclectic approach** drawing on all shades of the weak-strong spectrum results in:
a) assigning a **finite** *(possibly very high)* cost to resource depletion, when substitutability obtains;
b) treating resource preservation as a rigid constraint whose violation carries an **infinite** cost, when faced with **irreversibility**;
c) postponing critical decisions for as long as possible, when severely constrained by **information scarcity** (e.g. on the proximity of thresholds) - thus preserving the option set until scientific/technical progress reduces uncertainty;
d) *promoting scientific and technical progress,* not only as a means to *resolve uncertainty* and *enhance substitutability* but also as an *engine of economic growth that will finance substitution across forms of capital, where technically feasible.*

The **dual role of technical progress**, both for enhancing substitutability and for sparking growth, can not be emphasised strongly enough. Preserving the natural capital restoration option for future generations may prove irrelevant if the technical and economic ability to afford restoration/recovery is not available. In this light, **growth and sustainability will either flourish in unison or stagnate in discord**.

6 Functional Food

European Perspectives on Functional Foods

Gérard Pascal, ***CNERNA***, Christina Collet-Ribbing, ***CNERNA***

Issue: Modern techniques in epidemiological, nutrition and biomolecular research make it possible to establish relationships between eating habits/lifestyle and various increasingly prevalent diseases and mortality in Western countries. A beneficial preventive effect could be expected by changing diet or eating healthier foods (functional foods) accordingly.

Relevance: The use of functional or health claims for food is not yet authorized by European Union regulations, but procedures for their use are under discussion in many instances, such as Codex Alimentarius Commission, the Codex Committee on Food Labelling, the European Union and at the national level of its Member States. These procedures will enable industry to use functional claims, before health claims can be justified, and thus encourage important and necessary research in human nutrition. However claims must be built on solid scientific bases and on a consensus on their justification and substantiation.

Evolution in concepts of nutrition during this century

During the first half of this century, it was essentially vitamins that received most of the attention from the nutrition research community. "The period from 1910 to 1950 has been referred to as the first golden age of nutrition as it was characterized by the discovery of 13 essential vitamins" (Hasler 1996).

During this period, the primary concern with *food* was that it should be abundant, not contaminated or adulterated, but *wholesome and nutritious* in order to reduce prevalence of deficiency diseases (Glinsmann 1996).

During the next period, up to the 1980s, dietary habits that increased the risk of certain degenerative and other diseases (principally cardiovascular diseases, cancer and obesity, due to overconsumption of foods high in total and saturated fat) became a leading public health concern. Thus during this period, scientific research on relationships between food and health concentrated on the *negative* effects on health or triggering *effects of foods on disease*, such as the comprehensive review of the causes of cancer by Doll and Peto (Doll et al., 1981), which estimated that up to 70 % of certain cancers are attributable to diet (these estimations are, however, very controversial). However, the possibility of *preventive health effect of dietary modification* was established.

Over the last few years, this scientific approach has considerably changed. Euragri (an informal group of European Union agronomic research organizations and universities) proposes in "Agriculture and human health", 1994, (EURAGRI), possibilities for modifying the composition of agricultural products, not only by reducing undesirable substances but also by enriching them with desirable substances. This changing approach underlining protective effects is also clearly perceived in three US publications: "Opportunities in the Nutrition and Food Sciences", (US Institute of Medicine, 1994), "Carcinogens and Anticarcinogens in the Human Diet", (US National Research Council, 1996) and "Food, Nutrition and the Prevention of Cancer: a Global Perspective, (World Cancer Research Fund: American Institute for Cancer Research). In France, CNERNA published an extensive review of scientific evidence of the relationships between cancer and nutrition, with the identification of protective components in diet (Riboli et al. 1996).

The opinion of consumers has also changed: in France 87 % of consumers consider a balanced diet as a priority for maintaining health (CREDOC).

What is a functional food?

Even if there is not yet world-wide agreement on what functional foods are, a European acceptance of the term could be the definition proposed by Professor M. Roberfroid, Université Catholique de Louvain: "a food is functional if it contains a food component, (whether a nutrient or not) that affects one or a limited number of functions in the body in a targeted way, so as to have positive effects that may justify functional (physiological) or even health claims. A *functional claim* refers to the positive consequences of the interactions between a food component and specific genomic, biochemical, cellular or physiological functions without direct reference to any health effect or disease prevention... *Health claims* refers to the prevention of a pathology or a disease by consuming a specific food component or food ingredient. A true health claim will require, in most cases, additional studies involving large populations and long term trials" (Roberfroid, 1996).

The U.S. National Academy of Sciences has defined *functional foods* as foods that "encompass potentially healthful products" which include "any modified food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains" (Thomas et al. 1994).

Nutraceuticals is another notion and refers to any substance that may be considered a food or part of a food and provides medical or health benefits, including prevention and treatment of disease (Foundation for Innovation in Medicine). However, there seems to be a fairly good international agreement that any *claims about treatment of diseases (medicinal claims)* with a specific food *should not be allowed.*

Strategy for the development of functional foods

This includes scientific substantiation of the functional claims by:

- identification and understanding of mechanisms by fundamental research on interactions between food, food ingredient or component and human genomic, biochemical or physiological functions,
- demonstration of effects in human nutrition and the positive consequences of these effects. This might involve development of biomarkers or models,

Developments in the concerns of the nutrition research community began to focus on the preventive health effect of dietary modification at the outset of the 1980s

Today's scientific focus has moved towards possibilities for modifying the composition of agricultural products

A food is functional if it contains a food component, that affects one or a limited number of functions in the body in a targeted way, so as to have positive effects that may justify functional (physiological) or even health claims

Claims regarding foods can either be functional claims or health claims, however, there seems to be a fairly good international agreement that any claims about treatment of diseases (medicinal claims) with a specific food should not be allowed

Interest in functional foods from consumers, industry and regulatory authorities will increase concomitantly with the body of scientific evidence substantiating their health benefits

The difficulty lies in providing scientific evidence to prove the protective effects of a specific food or a food component isolated from the food

- proofs that the functional effect leads to benefits for human health through appropriate human studies.

As the weight of scientific evidence supporting the physiological effects or health benefits and the safety of functional foods increases, there is a corresponding increase in the interest shown in these foods by consumers, industry and regulatory authorities.

What kinds of functional foods can be expected?

Box 1 provides a fairly complete description of physiological fields currently explored in functional food science. The foods acting on these functions might be functional.

In some cases, the relationship between a food component (for example calcium) and its preventive effect on a pathologic state (in this example, osteoporosis) is quite clear. In other cases it is the relationship between the total dietary model (for example the Mediterranean diet or a diet rich in fruits and vegetables) which has been shown to be preventive of disease states (cardiovascular disease or cancer). However, for a specific food, and a *fortiori*, for a food component isolated from the food, it is much harder to obtain a consensus on the protective effects.

Three examples are given here to illustrate this: non-nutritious phytochemicals in fruit and vegetables, betacarotene and probiotics.

Phytochemicals in fruit and vegetables

These substances may explain, to a large extent, the overwhelming evidence linking the increased consumption of fruits and vegetables with reduced cancer risk. An extensive review of these substances and the scientific evidence of their activity was given by M. Suschetet in "Alimentation et Cancer" (1996). He concludes: "... there are no studies on the relationship between the consumption of particular phytochemicals and cancer incidence. The knowledge of the content of these compounds is very partial, tissue and serum levels are completely unknown.[...] Some of them are anticarcinogens in certain circumstances, procarcinogens in others, [...] two or several constituents could act in synergy, by identical or different mechanisms at doses that individually are exempt of effect [...] different constituents of the same phytochemical family do not have the same effects..."

Thus "in the current state of knowledge it is not possible to make specific recommendations for particular components, or for foods containing these components", but only "to encourage *a high consumption of fruits and vegetables*".

Results vs. expectations: the case of betacarotene

Three extensive intervention studies were conducted with a supplementation of β-carotene in order to prevent cancer and cardiovascular disease.

A rise in the frequency of lung cancer and in global mortality in smokers, in parallel with no protective effect in non smokers, put a stop to some of these studies before they were concluded.

This knowledge makes European nutritionists cautious about articles such as the one in the American news in Business Week, Nov. 10, 1997: "Eat your superveggies-researchers push to develop nutrient-enhanced food. Loaded carrots:

the maroon Betasweet variety with double dose of beta carotene may help ward off cancer and heart disease". Tomatoes, pepper, corn, broccoli, cabbage, Brussel sprouts are also implicated, with beta carotene, vitamins A, C and E - nevermind that some of them are toxic in sufficiently high doses!!

According to Steinmetz and Potter (1991): "There is a diet to which humans are adapted; this diet includes regular exposure to substances on which the human metabolism is dependent, only some of which to date have been labelled as essential nutrients. Vegetables and fruit contain the *anti-carcinogenic cocktail* to which we are adapted. *We abandon it at our peril*".

It is interesting that populations from different parts of earth for centuries spontaneously chose healthy combinations of cereals and pulses at their disposal, which gave them optimal aminoacid intake, for example wheat semolina and chickpeas, or corn and red beans, and this without any nutritional education or sophisticated chemical analysis. If the composition of all food products changes, then consumers no longer have the chance to use their inborn or acquired landmarks.

However the possibilities of enhancement (or reduction) of specific well-defined components in the diet of populations with established undesired intake levels of these components do open most interesting perspectives in public health. Genetic modification of food plants could contribute valuably to these changes.

Probiotics, prebiotics

A probiotic is a live microbial feed supplement that beneficially affects the host by improving its intestinal microbial balance. A *prebiotic* is a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon. Frequently, the prebiotic is a mixture of short and medium chain non-digestible carbohydrates with bifidogenic effects. Chicory fructo-oligosaccharides has been accepted in some European countries with functional claims as a soluble dietary fiber and a bifidogenic factor.

According to M. Roberfroid (1996) "more human studies are needed to demonstrate the health benefits of having a colonic flora in which bifidobacteria predominate". Without these results, health claims cannot be justified.

However, Y. Lee and S. Saliminen (1996) wrote "it is possible to verify that certain bacterial clones are probiotic from well argumented examples of their capacity to maintain or enhance health in the host".

So even in this area scientific opinions diverge! Despite these contrasting views, this is certainly one of the most promising areas to date: a considerable amount of research has already been done (Conference of Functional foods: Designer foods for the future, Sept. 30 Oct. 2, 1997, Cork, Ireland) and most nutritionists seem to think bifidus is good for you.

Claims

Claims lie at the heart of the problem of regulation of functional foods. Functional or health claims are not yet authorized by the regulations of the European Union. However, discussions within both the Codex Alimentarius Commission and the Codex Committee on Food Labelling, as well as within the European Union (EU) and at the national level of its Member States, have emphasized different approaches between countries.

Evidence linking increased consumption of fruit and vegetables with reduced heart disease cannot lead to specific recommendations for particular components or foods containing these components

An interesting health perspective is opened by the possibilities of enhancement or reduction of specific dietary components

Functional and health claims for functional foods have not yet been authorized by EU regulations, one difficulty being the different approaches of Member States

The most sensitive question that remains unanswered concerns the nature of claims that may be used and the type of proof to be put forward to assess their truthfulness

International co-operation on nutrition could serve to agree general principles regarding claims, to be specified subsequently by national authorities

One of the benefits of functional food science could be a reduction in health costs generated by inappropriate diet

To summarize, several common points are found at international level:

- Functional foods are foods (i.e., differentiated from dietary supplements).
- Functional foods should be safe.
  These products can be foods or traditional constituents that long experience has shown to be harmless. Functional foods can also be novel foods or can contain novel ingredients. It may also be considered as a novel food if the content of one of its usual components or ingredients changes significantly, or if its consumption level in a population changes, with risks of nutritional imbalances. In this case, their toxicological and nutritional safety must be evaluated according to rules established for that new category of foods.
- Medicinal claims cannot be accepted.
- Any authorized claim must not be false or misleading.
- Claims should be for a generally recognized and accepted action or effect of a nutrient or a food component.
- Only guidelines can be subject to international agreement within the scientific community. The wording of claims that depend on the cultural and sanitary context of a particular country should remain the responsibility of the competent national authorities.

The most sensitive question that remains unanswered concerns the nature of claims that may be used and the type of proof to be put forward to assess their truthfulness. The following general scheme can be envisaged:

- Draw up an open and positive list of *generic claims*.
  The list should be set up according to a series of concepts identifying the functions that can be modulated by a diet or a food component and according to a group of markers proving the modulation of the function. Using these claims would only assume that a dossier would be submitted before marketing and that the actual control would be carried out afterward.
- Possible use of *new claims* with very strong scientific arguments and control before marketing. The nature of the scientific dossier should be established by the competent national authorities after international discussions to reach an agreement on general principles.

Because of the difficulty of demonstrating that a food component, food, or diet can contribute to the long-term maintenance of good health, it would be pragmatic to accept two types of claims: *functional claims*, whose truthfulness is easier to prove, and *health claims*, which are more difficult to justify. This general scheme would encourage industry to support research in human nutrition because it would enable the use of functional claims as a first step before health claims could be justified (Pascal 1996).

European Commission support towards scientific work on functional foods

International research in functional food science has assumed considerable dimensions, especially in the United States and in Japan, because of the perceived interest of consumers in maintaining good health through healthy eating. In the ageing populations of developed countries, an adequate diet preventing degenerative diseases could participate in a reduction of health costs: 5% of total health expenditure is considered to be due to inappropriate diet (Kohlmeier et al. 1993).

Numerous workshops and conferences are organized on this subject in order to compare experiences and to draw up inventories of possibilities.

Box 1

1 The gastro-intestinal system

a) intestinal microflora;
b) intestinal mucosal function;
c) human gut-associated lymphoid tissue;
d) dietary risk factors for colorectal carcinogenesis;
e) physiological and health benefits of probiotics and prebiotics to humans.

2 Defence against reactive oxidative species

a) oxidative damage, antioxidant defence and the role of pro-oxidants in disease;
b) available methodologies for evaluation and quantifying damage to DNA, lipids and proteins by pro-oxidants *in vivo*;
c) nutritional options modulating oxidative damage and antioxidant defence system;
d) safety aspects of antioxidants;
e) technological aspects related to the production of anti-oxidant rich food products.

3 The cardiovascular system

a) major risk factors;
b) cellular functions in the cardiovascular system, with special attention to immuno-mediated processes;
c) arterial thrombosis, platelets (and white blood cells) and endothelial cell function, blood coagulation and fibrinolysis;
d) hypertension and the heart function;
e) dietary components and serum lipoproteins.

4 Substrate metabolism

a) health issues usually referred to as syndrome X, including obesity, insulin resistance syndrome and diabetes; with the metabolic conditions related to these diseases including body weight control, insulin resistance, blood glucose and triglyceride control;
b) nutritional factors to prevent malnutrition and osteoporosis;
c) functional foods for athletes.

5 Development, growth and differentiation

a) specific aspects of growth and development;
b) nutrient gene interaction and genetic regulation;
c) investigations into functional foods and their effects on the immune response;
d) nutrient effects on gastrointestinal maturation, apoptosis, bone growth and mineralisation;
e) early nutrition and neural and cognitive development;
f) modulation of intrauterine development and differentiation, and effect of lactation.

6 Behavioural and psychological functions

a) functional effects on activation, sedation and mood state;
b) influence of food and food constituents on behaviour and psychological function;
c) foods on cognitive performance.

Functional food has a potentially important role to play in terms of health, as well as for the food and agriculture industry, but progress must be based on solid scientific evidence and an understanding of cultural differences

In this context of a growing world market, the European Agro-food industry needs to improve its competitiveness, on the basis of a large consensus on concepts in functional food science, with the possibility to claim the improvements obtained.

This is the reason why ILSI Europe has elaborated a project called "Functional food science in Europe" (FUFOSE) approved for an European Commission concerted action within the FAIR RTD programme. In this project, the Steering Committee, comprising members from both industry, academia and research institutions, identified six priority areas in human physiology, studied in Individual Team Groups (see Box 1). A total of 54 scientists from 10 countries are involved in this work. Each team group critically assesses the science base required to provide evidence that specific nutrients positively affect functions and identify areas where further research is required.

Theme papers are reviewed by plenary meetings for identification of scientific criteria to recognize relationships between food components and functions, for which sound hypotheses can be postulated and biomarkers of beneficial effects approved.

The consensus document on "Concept of Functional Food Science and Options for their Application" is planned to be published in 1998.

Conclusion

On the threshold of the third millennium, with its growing and ageing populations, functional food will constitute a tremendous challenge for Europe's food and agricultural industry.

However, this progress must be cautious and built on solid scientific bases. The consensus on functional claims must be carefully evaluated and adapted to each culture so as to be adopted by the conscious European consumers. Otherwise their reaction could be summarised as "as long as I stay healthy, I will avoid eating substances with a physiological effect. As long as it is good, I prefer not to interfere with my physiology" (Astier-Dumas, 1997)!

About the authors
Christina Collet-Ribbing has been a Research Engineer at CNERNA/CNRS since 1971. She is a graduate physician having worked in biomolecular research. Her current responsibilities are to follow the safety evaluation of novel foods, food consumption and health, etc.

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functional food, human nutrition, functional claims

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Driving the Research on Alternative Technologies to Methyl Bromide

Miguel Vega, *IPTS*, Antonio Llobell, *CSIC* and Laurent Bontoux, *IPTS*

Issue: Methyl bromide, a phytosanitary product widely used in agriculture, has a high ozone destruction potential. As a consequence, the Montreal Protocol calls for a gradual reduction of its use to reach a total phase-out by 2005 in developed countries and by 2015 in developing countries. However, current alternative technologies are so far unable to provide the same performance per unit cost as this product.

Relevance: Recently, there has been a push in the European Union for a total phase-out of methyl bromide ahead of the 2005 deadline. The latest proposal is to follow the US calendar and reach complete phase-out by 2001. However, in Southern EU countries, this early phase-out may have a strongly negative impact for certain crops (e.g. tomato, green pepper, strawberry), making a satisfactory technical solution, and research towards it, a high priority.

Introduction

Due to its ozone-depletion effects, there has been a call for the total phase-out of methyl bromide world-wide by 2015, with an earlier schedule of 2005 in developed countries

The Montreal Protocol is an international treaty developed to protect the earth from the detrimental effects of ozone-depleting substances. This protocol was established in the late 1980's and was signed by 160 countries, including the Member States of the European Union. This treaty aims to control the production and trade of ozone- depleting substances on a global basis. On September 17, 1997 at the Ninth Meeting of the Parties to the Montreal Protocol, a timetable for methyl bromide phase-out was established, calling for total elimination by the year 2005 for developed countries and 2015 for developing countries.

The uses of methyl bromide

The agricultural uses of methyl bromide are two-fold: for preparatory fumigation of soil and post-harvest use

Methyl bromide, now essential for the intensive Mediterranean agriculture, is a gas with potent phytosanitary properties acting simultaneously as nematicide, herbicide, insecticide, rodenticide and fungicide, and in certain cases bactericide, while leaving no toxic traces in the crops and in the soils. Its agricultural uses are two-fold:

- For **preparatory fumigation of soil** to control weeds, insects and soil-borne diseases, including nematode, fungi and bacteria wilt diseases.
- For **commodity use**, which includes post-harvest treatment of non perishables and perishables and for quarantine purposes.

When used as a soil fumigant, methyl bromide is injected into the soil at a depth of 30 to 60 cm before a crop is planted. Since Me Br is heavier than air, this practice effectively sterilizes the soil to depths of up to 1 m. Immediately after injection, the soil is covered with plastic tarps, to increase methyl bromide contact time in the soil

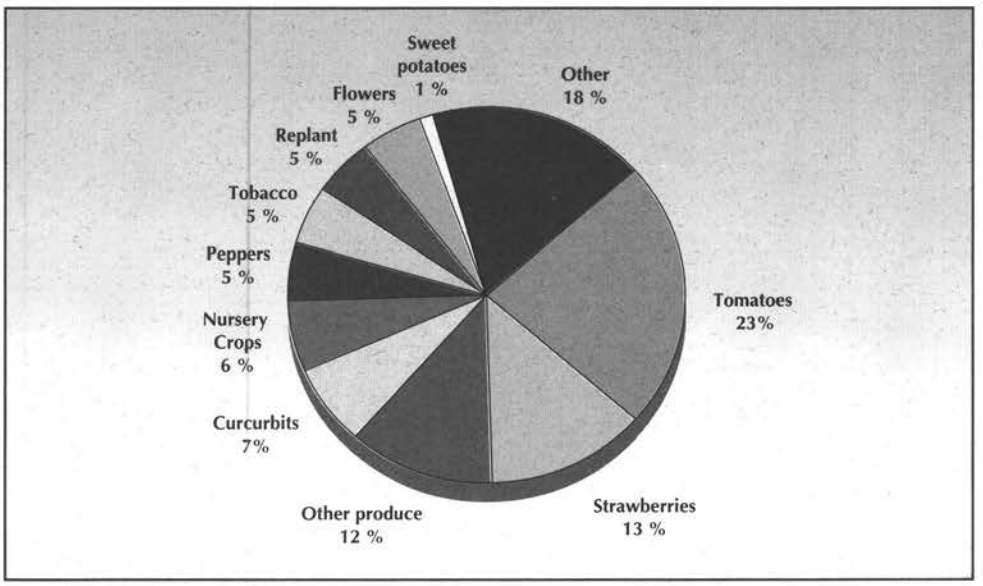
(from 24 h up to 120 days, depending on crops). 50 to 95% of the methyl bromide is released to the atmosphere at the end of the fumigation. This significant variability comes largely from soil conditions such as pH, moisture contents, organic content and biological activity. Recent data indicate that, after soil treatment, approximately 87% is lost to the atmosphere within 7 days. In Europe and world-wide, the largest uses of the fumigant by crop are for tomatoes, strawberries, cut flowers, peppers, cucumbers, squash, eggplant, ornamentals and nurseries, tobacco, grapes, watermelon and melon (see Figure 1).

When used as part of post-harvest pest-control regimes, methyl bromide is injected into a chamber or under a tarp containing the harvested crop. At the end of the required contact time, the methyl bromide is vented and about 80 to 95% eventually enters the atmosphere.

On reaching the stratosphere, methyl bromide undergoes photo-oxidation releasing bromine atoms that enter the ozone depletion cycle. Today, 30 to 40% of total ozone depletion is attributed to bromide radicals, which are ozone depleters 30 to 60 times more potent than chlorine radicals.

In its use both as a soil fumigant and in post-harvest treatments, between 80 and 95% of total methyl bromide used eventually enters the atmosphere

Figure 1. Global methyl bromide use by crop (US EPA, 1996)



Between 30 and 40% of total ozone depletion is attributed to bromide radicals

Alternatives to methyl bromide

So far, no single alternative exists for all of the uses of methyl bromide. Research on alternatives will probably result in a wide range of options, depending on the pest, crop and application.

Chemical alternatives for fumigation

It seems that chemicals are just a short-term solution as substitutes for methyl bromide since most are under restrictions because of the toxicity of their residues. However, they are seen as the best solution to avoid large economic impacts of the ban in the coming years.

Chemical alternatives to methyl bromide are seen as a short-term solution due to the toxicity of their residues

Studies on strawberries, tomatoes and other crops are currently in progress in the USA (California and Florida) and, to a lesser extent in Europe, (e.g. Spain, Italy and Greece). Several chemicals are being tested on different crops and the available results are:

- *Methyl Bromide/Chloropicrin.* The mixture of methyl bromide with other control substances

The use of virtually impermeable plastic films, and mixtures of methyl bromide with other control substances are highly promising alternatives

Methyl iodide has yielded encouraging results as an alternative in field and lab tests but toxicity issues remain to be evaluated

such as chloropicrin is the best alternative to accomplish the gradual reduction imposed by the Parties of the Montreal Protocol. Available studies in the USA and Spain have concluded that the combination of these substances (67/33%) and the use of virtually impermeable plastic films can achieve reductions of methyl bromide use in strawberry fields by up to 80%. So far, field tests already conducted in strawberry fields have demonstrated that yields are highest with the methyl bromide/chloropicrin mixture when compared to other mixtures.

- *1,3 Dichloropropene/Chloropicrin.* This mixture, commercialized under the name of Telone, Pebulate or Tillam, is often used to control nematodes, weeds and a variety of diseases. The control level seems to be comparable to that achieved with methyl bromide and chloropicrin combinations.
- *Metam Sodium.* This chemical is mainly used in fruit and vegetable production (carrots, tomatoes, strawberries and on orchard replant sites) for weed, nematode and plant disease control. The use of metam sodium to control pests currently treated with methyl bromide will require some low-cost modifications of cropping systems, since metam sodium acts in the water phase while methyl bromide acts in the air phase. To date, there is not enough data to compare its efficiency with methyl bromide.
- *Methyl Iodide.* Research by agricultural scientists in both California and Florida on the use of methyl iodide as a soil pest treatment appears to be very encouraging. In lab and field tests, methyl iodide was equal to or better than methyl bromide in controlling plant pathogens and weeds. It has also been carefully evaluated with regard to ozone depletion, with findings indicating that it will not cause problems. Methyl iodide undergoes atmospheric photolysis and its breakdown products are rapidly removed from the lower atmosphere (average atmospheric residence time estimated at 4 to 8 days, compared with 2 years for methyl bromide). The US EPA is now in the process of evaluating the toxicity issues.
- *Dazomet,* commercialised under the name of Basamid, is a chemical specifically indicated for forest tree and tobacco nurseries. It is already widely used for these purposes, however data currently indicate a lower performance than methyl bromide to control soil-borne diseases in strawberry and tomato production.

Physical alternatives for fumigation

- *Virtually impermeable films* (VIF) have been developed and tested in Israel, the US- and Europe. This alternative allows a significant reduction in methyl bromide consumption (50% or more) because it keeps it longer in the soil, thereby increasing treatment efficiency. However, this solution has not been properly taken into account either by the Parties of the Montreal Protocol or by US authorities. On the one hand, the Parties to the Montreal Protocol failed to realize that through the application of this method, agriculture would no longer to be the main methyl bromide emission source. On the other hand, the US authorities were reluctant to consider it because *"VIF tarps are currently made only in Europe in sizes incompatible with US application equipment, and European production capacity is not great enough to supply the US market if these tarps were to be required at this time."* (US EPA, Methyl bromide phase-out web site, 1998). Research is continuing and further analysis on mass balance of methyl bromide emitted after fumigation under VIF tarps is needed.
- *Soil solarization,* a thermal heating of moistened soil by sunlight under plastic mulch to temperatures that are lethal to a broad spectrum of pathogens, insects and weeds. This practice may be suitable for Mediterranean countries, due to the fact that

the high temperatures needed to apply this method are reached in the summer period. However, the disadvantage of this method is the need to immobilize the agricultural surface during a long period, from 4 to 8 weeks. This is not a self-sufficient method and combination with other chemical or biological technologies could improve the potential of this alternative.

Other physical methods may range from hydroponics and soil-less culture on artificial substrates, to the use of steam in nursery crops, a common practice in north European countries.

Physical alternatives for fumigation include virtually impermeable films and soil solarization

Biological alternatives for fumigation

- *Disease suppressive compost* (biofumigation). Addition of organic matter to the soil in combination with solarization could effectively control a wide range of soil-borne pathogens. As an alternative, the use of biofumigation prior to methyl bromide application may substantially reduce emissions of the chemical to the atmosphere. Both approaches are under research in the EU and US.
- *Cultivars resistant to major pathogens.* Strawberry and tomato varieties grown commercially have no resistance to major pathogens because most of the breeding efforts have focused on developing high-yielding varieties with good shipping qualities and other desirable agronomic traits. Further research is needed to develop resistant cultivars adapted to different growing conditions. In addition to plant breeding programmes, plant genetic engineering is an important tool to produce new crop varieties with better resistance to pests and pathogens.
- Biological control. There are three main biological control strategies:

a) Use and improvement of natural control, taking advantage of the natural suppressive activity of soils on pathogens/pests.

b) Modification of ambient conditions to enhance natural antagonistic effects. This can be done by crop rotation, a traditional method avoiding the increase of pathogen populations, by growing mixed crops, or by incorporating organic manure, water or other products into the soil.

c) Release of biological control agents (antagonists). A wide range of organisms can be used to control plant pathogens such as fungi, bacteria, nematodes and insects. The high degree of specificity and selectivity of antagonists used as biological control agents offers many advantages in environmental and consumer safety compared to chemical control. Because of this high specificity, effective biological control needs to include a large number of antagonistic agents to control different diseases in different conditions. However, rather than being used alone, biological control will probably soon be a part of integrated pest management (IPM) systems and will be used in low-input sustainable agriculture (LISA). IPM strategies will have a wider range of action than biological control alone, due to the combination of low chemical doses with antagonistic organisms.

d) Production of new low-risk biocides for pest management with post-harvest effects. Biocides are toxins or toxic proteins produced by micro-organisms that may have been genetically modified to control pests and diseases.

- The planting of pathogen-free plants, identified by molecular diagnosis methods may become another biological method in the future.

Biological alternatives for fumigation include the use of disease suppressive compost, cultivars resistant to major pathogens and biological control strategies

Combined approaches

It is clear from the research conducted to date that a single alternative to methyl bromide is unlikely to be found. Therefore, the best alternative, both from an economic and environmental point of view, may be a combination of the methods presented above

The best alternative may be a combination of biological alternatives, cultural practices and low doses of low-risk chemicals

Alternatives for post-harvest use include controlled atmosphere, low-risk biocides, irradiation, refrigeration and heating

In many cases, methyl bromide remains the only solution to achieve full eradication of pests and pathogens in 24 hours

Although research is underway on an EU level, some Member States are complementing this with national programmes but with little international co-operation

(biological alternatives, cultural practices, and low doses of low-risk chemicals) under Integrated Pest/Pathogen Management.

Alternatives for post-harvest use

- *Controlled atmosphere.* Recently, shipping containers able to maintain modified and controlled atmospheres have been developed. They are used by commercial exporters to extend the shelf-life of crops and to kill insects and other pests. Transporters are now able to maintain extremely low oxygen and ethylene concentrations resulting in both decreased decay rates and better control of pests.
- *Low-risk biocides.* Several patents have been filed in the US in the past five years concerning antifungal proteins that can be used in citric and strawberry post-harvest periods. Similar approaches are currently being developed in the EU by different research teams.
- *Irradiation.* A broad spectrum of national and international studies conclude that food irradiation can control contamination, inhibit sprouting in crops, destroy insects and parasites, delay the ripening and spoilage of fresh fruits and vegetables and eliminate disease-causing micro-organisms in food. However bacterial and fungal spores and viruses are not affected by the most common dose levels. Further research is still needed. A common position for a future European directive on food irradiation has been adopted by the Council in October 1997 but the list of foods considered does not include fresh fruit and vegetables. In contrast, the US FDA has approved the use of irradiation for strawberries and white potatoes.
- *Refrigeration and heating.* Refrigeration is already widely used to control diseases and ripening in fruits and vegetables, especially during transport. On the other hand, heat treatment consisting in very short-time exposure to temperatures in the range of 60° C is currently under research.

However, in many cases, methyl bromide remains the only solution to achieve full eradication of all pests and pathogens in 24 hours.

Policy issues

There is a now lively debate about the substitution of methyl bromide in the European Union. Being aware of this situation, the European Commission took measures in 1996 and amended the FAIR research programme to include a specific line of support for research on alternatives to methyl bromide. However, this measure seems to be insufficient. Various interested Member States have developed their own national research programmes, apparently without any international co-operation. The European Commission expressed the wish for improved co-ordination in order to make the best possible use of most needed resources.

The methyl bromide ban may hit very hard several agricultural regions of the European Union, especially in Greece, Italy and Spain. Strawberry production is particularly vulnerable. For example the strawberry production from the province of Huelva, in Spain, exceeded 250,000 tonnes in 1997 and reached a value of 357 million ECUs.

So far, no cost-benefit analysis of the elimination of methyl bromide in the EU has been performed. Such an analysis would be invaluable to determine the economic implications of this ban. The US Environmental Protection Agency has already performed such a study for the US which shows an estimated 25% decrease in the production of the crops at stake.

On the European side, there is disagreement among the Member States as to whether or not to meet the Montreal Protocol or the US deadline. Southern European countries favour a phase-out by 2005, while northern European countries

prefer to follow the US calendar (2001). One must bear in mind at this point that most northern European countries no longer use methyl bromide due to their weather and soil conditions, which allow the use of alternatives. In particular, The Netherlands phased out the use of methyl bromide for soil fumigation in 1992 because of groundwater concerns and Denmark banned all agricultural uses of methyl bromide in 1998. Sweden is expected to follow shortly. Table 1 gives the timetable agreed by the Montreal Protocol. Exemptions for "critical" uses may be granted in exceptional cases, but cannot be relied upon for the long-term.

Conclusions

Between the year of total phase-out of methyl bromide in the EU (2005 or 2001) and 2015, European growers will be in direct competition with others that have continued access to methyl bromide (e.g. from Morocco). This is likely to create trade tensions and socio-economic strain. It is therefore necessary that the shift to this new situation be properly prepared by the European Union. Means to attenuate the economic impact of this transition can be given by co-ordinating and/or financing at European level of the various national research efforts to develop reliable alternatives.

The economic implications of the ban are not yet known, although somesouthern European regions are likely to be hit extremely hard by its impact

Table 1. Timetable of the methyl bromide phase-out agreed by the parties to the Montreal Protocol (Montreal Protocol, 1997)

For developed countries: (based on 1991 consumption levels)	
Level of reduction	**Deadline**
25%	1999
50%	2001
75%	2003
100%	2005
For developing countries: (based on average 1995-96 consumption levels)	
Level of reduction	**Deadline**
25%	2005
100%	2015

So far, the best short-term solution to substitute methyl bromide appears to be either chemical or physical alternatives, or a combination of both. The best long-term solutions will probably be biological alternatives, combined with judicious use of low-risk agro-chemicals (IPM strategies).

The best short-term solution appears to be use of physical or chemical alternatives, whereas in the long-term, it appears to be of biological ones

US firms and laboratories are currently leading the research on alternatives to methyl bromide, and are already positioning themselves to be market leaders on the methyl bromide alternatives that European farmers will need to use, a situation that can be found in other areas of application of biotechnology. Developing methyl bromide alternatives is important not only for agriculture, but also in terms of the potentially large markets for such alternatives.

Developing methyl bromide alternatives is important not only for agriculture, but also in terms of the potentially large markets for such alternatives

Keywords

agricultural biotechnology, methyl bromide, alternatives, integrated pest management, agro-chemicals

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Research Joint Ventures: the Use of Databases

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Issue: Inter-firm co-operation has become increasingly important for the competitive strategies of firms in most high-technology industries. Research joint ventures have been acclaimed for their alleged ability to open up new technological options to participants, pool R&D resources to achieve a critical minimum mass, exploit synergies in R&D, maintain continuity of effort, pool risk, and reduce research duplication.

Relevance: The incentives of firms to collaborate, the nature of the research they pursue collectively vis-à-vis the research undertaken in-house, the impact of co-operation on profitability, and the effect on industry concentration are core policy concerns. Yet, even though both the European Union and the United States have more or less actively promoted co-operative industrial research, we know relatively little about the impacts of the policy. More can be known through recent efforts to build databases and analyze impacts in the US, with a possible translation of the methodology in Europe.

Introduction

The same year that the European Union was initiating the first Framework Programme for research and technological development activities (1984), the Congress of the United States was ratifying the National Cooperative Research Act (NCRA). The two policy initiatives shared the concern of policy-makers on both sides of the Atlantic over the shrinkage of the technological gap between the two regions and the rest of the world and the gradual loss of market share by western firms in high-technology industries. In the wake of the much publicized VLSI research programme and the grandiose initiation of Fifth Generation Computer programme in Japan, it was widely perceived in many Western countries that industrial collaboration in R&D had a significant role to play in raising the technological prowess and competitiveness of companies in high technology industries.

Industrial collaboration in R&D in the mid 1980s was perceived as a means of improving the technological development and competitivity of high-tech companies in the US and EU

The Framework Programme and NCRA aimed to promote generic interest (pre-competitive research). The basic rationale rested on classic market failure arguments emphasizing insufficient incentives of individual firms to undertake highly risky and imperfectly appropriable generic research at socially optimal levels. However, the two initiatives differed significantly in terms of actual implementation and the incentives they provided to the private sector for collaboration. The Framework Programme encompassed a number of specific programmes, such as ESPRIT, BRITE and EURAM, offering cost-sharing

Policy initiatives aimed to promote pre-competitive research by offering concessions to research joint ventures (RJVs)

These initiatives can provide useful information to policy-makers, policy advisors and other researchers and form the basis for a comparative analysis between the two approaches

Companies included in the database have been classified as research joint ventures according to a single official definition

opportunities to research joint ventures (RJVs). NCRA simply offered a way for RJV participants to avoid the acute penalties emanating from a very stringent antitrust regulation system in the US should the venture be contested in court on anti-competitive grounds[1].

Both the American and European initiatives have, by now, left a trail of incredibly rich sources of information regarding inter-firm collaboration in R&D. If collected and analyzed consistently, this information can be of great value to policy-makers, policy advisors and other researchers. The use of a similar analytical methodology and, thus, similar data collection routines is important for comparative analysis. The results of comparative analysis will be of great value to policy-makers and researchers given the differences between the European and American approaches to industrial, competition and S&T policy which may have affected the incentives for, character of and returns from collaboration.

Such a process has begun in a major study of US-based RJVs currently underway at the George Washington University[2]. This study has created a very extensive database of all RJVs registered under NCRA, developed a detailed empirical methodology, and is already producing valuable results to inform policy-makers and facilitate the improvement of future policy measures targeted to inter-firm collaboration in R&D. Significant value will be added at a later stage from a sister research project that will cover EU-based RJVs.

US-based RJVs

The NCRA-RJV database

The parties of an RJV seeking to benefit from the provisions of NCRA were required to file notifications with the US Department of Justice (Attorney General) and the Federal Trade Commission, disclosing the principal research content and member composition of the intended subsequent changes in either the research content or membership of the RJV.

The filings, which are published in the Federal Register, constitute the basis of the NCRA-RJV database.

The unique features of this database are:

- The database covers organizations which have been classified as research joint ventures under a single official definition (Merger Guidelines of the US Department of Justice). This is an advantage for three reasons. First, it avoids some precarious definitional problems underlying existing databases on inter-firm strategic alliances. Second, it allows concentration on these specific organizational forms that have aroused significant attention among policy-decision makers in the European Union and the United States during approximately the last fifteen years. Third, there is significant economic literature on joint ventures to substantiate the analytical methodology, which is still lacking in the case of the more generally defined strategic alliances.
- The database combines the information on joint venture characteristics: initiation date, a statement of purpose, technological area(s) of research, the list of participants, and dates of entry and exit of individual participants, with information on the characteristics of all business participants, product differentiation (primary and secondary lines of business at the 4-digit SIC level), sales, R&D investment, capital investment, employment, assets and profits.
- The database has been designed to support both qualitative and quantitative research on the subject. It currently covers all registered RJVs from January 1, 1985 (when registration began) to December 31, 1995. It will be updated in each of the next three years at least.

Aggregate descriptive statistics and research focus[3]

Five hundred and seventy five RJVs had registered with the Department of Justice during the first eleven years. As of the end of 1995, there were close to 8,000 completely identified memberships to these RJVs corresponding to approximately 3,400 entities, including business firms, universities and government agencies. The vast majority of entities are business firms. For example, business firms account for 86% percent of American entities participating in these RJVs. More than half of these are privately owned firms, almost 40% are public firms, 1% are joint ventures and less than 0.5% are partnerships.

The number of new RJV registrations has increased steadily throughout this time period, with the exception of two years (Figure 1). The abrupt drop of new RJV announcements in 1986 can be easily explained. Many firms considering co-operative ventures, but hesitating to proceed before 1984, filed en masse in 1985 when the NCRA went into effect. The smaller drop in RJV announcements ten years later possibly reflects the extension of NCRA in 1993 to allow co-operation in activities beyond generic research, which may have sent prospective collaborators back to the drawing table, thus producing a delay in registration. The huge leap of new RJV announcements in 1995 (approximately 83% above the previous year) corrected that delay.

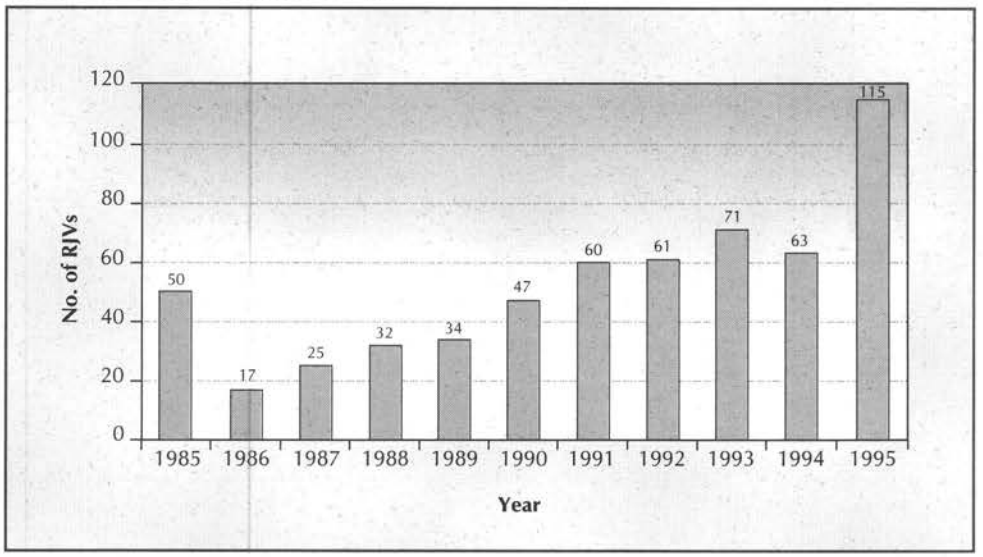
Co-operation has involved high technology activities. Telecommunications RJVs outnumbered RJVs in any other technical area. Other technical areas with significant activity have included environment, advanced materials, energy, transportation, software, and chemicals (each accounting for 5-10% of the total recorded co-operative activity). Subassemblies and components (which include semiconductors), manufacturing equipment, factory automation, photonics, test and measurement, and computer hardware, each accounted for 2-5% of the total. **During the last two years, very high rates of increase in RJV announcements were recorded in software, advanced materials, photonics, environment, manufacturing equipment, and the test and measurement areas. Much less activity has been recorded in technical areas with well enforced intellectual property rights, such as biotechnology, medical equipment and pharmaceuticals.**

The database fields are extensive, designed to enable both qualitative and quantitative research into RJVs

86% of the approximate 3,400 registered RJV participating entities are US business firms

The main sectors represented include telecommunications, the environment, advanced materials, energy, transportation, software and chemicals

Figure 1. New RJV Announcements



Membership has fluctuated during the lifetime of many RJVs (Figure 2). The number of initial (founding) members reached a peak in 1991, fell precipitously during 1992-1994 and recovered only in 1995. The number of add-on members increased steadily until 1993, when it seemingly reached a plateau. On the other hand, exits (terminated memberships) which kept increasing moderately until 1991, as expected given the increasing stock of registered RJVs, rose sharply in 1994 and landed in 1995. **The combination of these trends in aggregate membership makes the hypothesis that the policy amendments of 1993 had an important impact on firm incentives to collaborate in R&D quite plausible.**

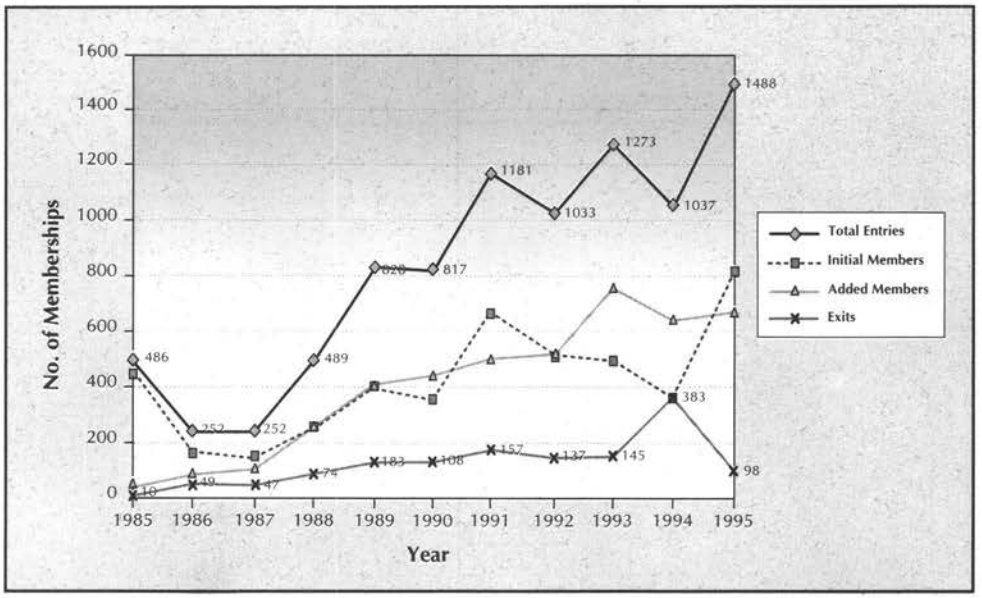
More than two thirds of all identified entities have participated in only one RJV (Table 3). A full 92% of all identified entities participated in less than five RJVs. Nevertheless, a significant level of concentration in RJV participation is indicated by the fact that almost half (47%) of all identified memberships were accounted for by approximately 8% of the identified entities (entities with five or more memberships). By and large, the very active organizations correspond to firms on the top 100 list of large multinational corporations.

While, as expected, US organizations have dominated NCRA RJVs, a significant number of the identified participants are foreign-based (Figure 4). The United Kingdom, Japan, Canada and Germany have had more than one hundred participants each. France, Italy, Australia, Sweden, The Netherlands, and Switzerland have had more than thirty participants each. Organizations from many other countries, including developing countries, have also made their presence felt.

The NCRA-RJV database is currently being used to address a number of empirical questions with obvious policy relevance[4].

- Incentives. What factors influence the incentives of firms to cooperage in R&D?

Figure 2. RJV Membership Changes



* Total Entries = Initial Members + Added Members.
Added Members are the new members of existing RJVs.
Initial Members are the members when RJVs are launched.
Exits are the terminated Memberships.

Table 3. Cooperative Activity of All Identified Entities

No. of Memberships	Memberships	Entities	% (entities)
1	2396	2396	70.0
2	1028	514	15.0
3	510	170	5.0
4	292	73	2.1
5	265	53	1.5
6 to 10	871	116	3.4
11 to 20	924	65	1.9
21 to 50	870	28	0.8
more than 50	797	10	0.3
Total Identified Memberships	**7953**		
Total Memberships	**9136**		
Total Identified Entities		**3425**	100.0

- Impact of RJVs on R&D. What is the effect of RJV formation on the overall R&D expenditures of member firms?
- Impact of RJVs on Profitability. What is the effect of RJV formation on member firm profits?
- RJVs and Industrial Concentration. Do RJVs provide a vehicle for increasing industrial concentration and, thus, market power?
- Complementarity. Do RJVs complement (pursue research that is complementary to) the research undertaken in-house by member firms? Or do they substitute for it?
- Diversification. Do RJVs create "virtual" combinations of complementary strengths, by linking diverse business firms, which are necessary for carrying out the specific R&D but which are not typically met in stand-alone firms?
- Pairs of firms. Is it possible to distinguish "pairs" of firms that tend to join forces frequently in RJVs on the basis of their characteristics?

Questions being addressed to the database include important policy issues relating to R&D: co-operation, impact on expenditure and profits, complementarity and diversification, among others

EU-based RJVs

A follow-up to the research project on US-based RJVs would appraise similar organizations in the European Union. The first step will involve the assembly of an extensive database covering the RJVs with private sector participation which have been sponsored by various Framework Programmes. This database will be methodologically similar to the NCRA-RJV database[5]. The second step of the project involves a full scale appraisal of the European RJVs to answer questions similar to those listed in the previous section relating to the purpose of the joint ventures, their profiles, technologies pursued, member incentives to participate, the impacts of RJVs on aggregate R&D expenditures and profitability, and the ways these impacts materialize. The ultimate goal is to link the results of the American and European studies in order to draw conclusions on the effectiveness of different sets of policies on the rate of formation, type and effects of RJVs.

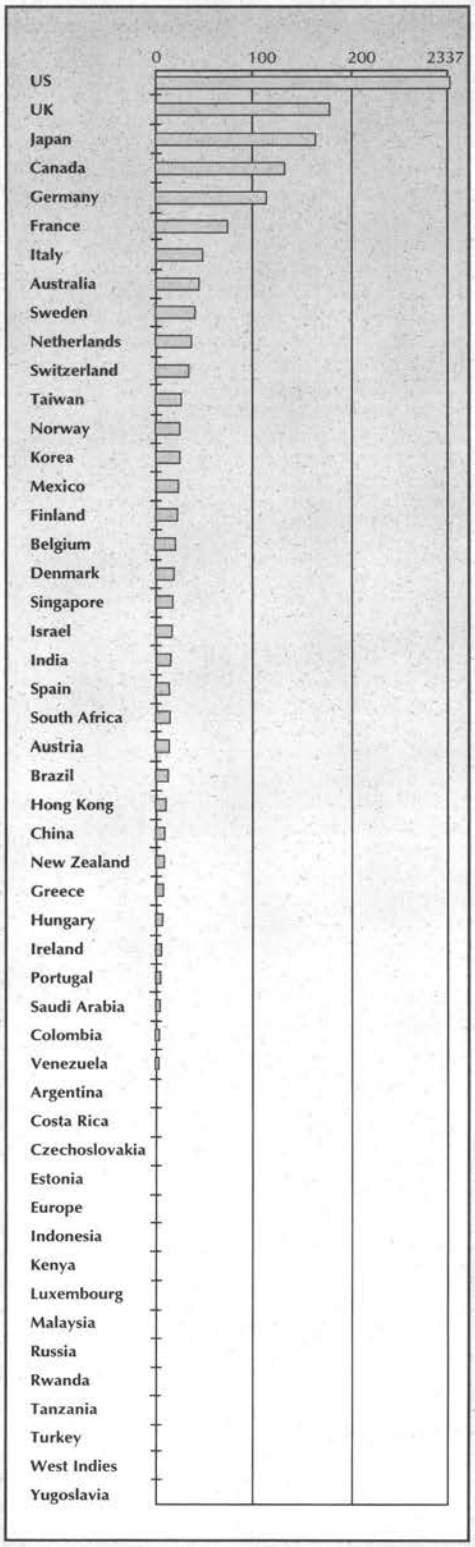
The most important expected benefit from such an endeavour is to provide the necessary "intelligence" for improving decision-making in a very significant policy area. On the one hand, policy makers will have available two very rich, "standardized" sources of information: one for the European Union and one for the United States,

A sister database for RVJs in the EU would link the results of the two studies and providing standardized data to improve decision-making

Results will also provide a tool for testing economic, business and policy hypotheses proposed in literature on inter-firm collaboration in R&D

Figure 4. RJV participation by country

Country	No. of Entities	%
US	2337	68.2
UK	175	5.1
Japan	161	4.7
Canada	132	3.8
Germany	115	3.4
France	78	2.3
Italy	48	1.4
Australia	46	1.3
Sweden	40	1.2
Netherlands	34	1.0
Switzerland	32	0.9
Taiwan	20	0.6
Norway	19	0.6
Korea	18	0.5
Mexico	18	0.5
Finland	14	0.4
Belgium	13	0.4
Denmark	13	0.4
Singapore	13	0.4
Israel	11	0.3
India	10	0.3
Spain	9	0.3
South Africa	7	0.2
Austria	6	0.2
Brazil	6	0.2
Hong Kong	6	0.2
China	5	0.1
New Zealand	5	0.1
Greece	4	0.1
Hungary	4	0.1
Ireland	4	0.1
Portugal	4	0.1
Saudi Arabia	3	0.1
Colombia	2	0.1
Venezuela	2	0.1
Argentina	1	0.0
Costa Rica	1	0.0
Czechoslovakia	1	0.0
Estonia	1	0.0
Europe	1	0.0
Indonesia	1	0.0
Kenya	1	0.0
Luxembourg	1	0.0
Malaysia	1	0.0
Russia	1	0.0
Rwanda	1	0.0
Tanzania	1	0.0
Turkey	1	0.0
West Indies	1	0.0
Yugoslavia	1	0.0
		0.0
Total Entities	3429	100.0



which can be annotated at regular time intervals, at a marginal and extremely low cost. On the other hand, an analytical methodology will be supplied that can be used repeatedly to appraise new information as it comes in and, if desired, compare the results between the two regions.

In addition, the research community will greatly benefit from the creation of a versatile research tool which can be used to test various hypotheses suggested in the exploding economics, business, and policy literature on inter-firm collaboration in R&D. Let us consider an example from the study on US-based RJVs currently in progress. One notices that about one third of the publicly traded American firms participating in these RJVs declare their primary line of business to be in an industry classified by NSF as "non-manufacturing" (NSB, 1996). Almost all of them are in a service sector. Given the popular perception of many service sectors as non-R&D intensive[6], the question naturally arises: what accounts for the strong service sector showing if these firms are not very active in producing technological innovations?

A possible explanation is that RJVs play a significant role in facilitating supplier-customer linkages. High capital investment in many service sectors indicates firms that use new technologies intensively (embodied in the capital goods they purchase). They may participate in RJVs to influence the outcome of the research so that the final products better fit their specific needs. Similarly, suppliers of capital equipment may use these RJVs as a vehicle for getting important customers on board early in the R&D process. While strong channels of communication between suppliers and customers have been argued to be very important for efficient technological innovation (von Hippel, 1988), a potential role of RJVs as organizations fostering close supplier-customer linkages has not been adequately explored[7].

Results will also provide a tool for testing economic, business and policy hypotheses proposed in literature on inter-firm collaboration in R&D

Research is still required as to the role of RJVs in promoting supplier-customer linkages

Keywords

Research joint ventures, co-operation, research and development, technological advance, National Cooperative Research Act, Framework Programme, US policy, EU policy

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Notes

1- The US emulated the approach adopted in Europe subsequently with the establishment of the Advanced Technology Program at the National Institute of Standards and Technology in 1990. Importantly, however, ATP funded research projects proposed by individual firms in addition to those by RJVs.

2- This study is funded by the US National Science Foundation, grant SRS-9510909.

3- See Vonortas (1996) for a more detailed description of the contents of the NCRA-RJV database.

4- All these issues have been raised in the relevant economics and business literature. See, for example, D'Aspremont and Jacquemin (1988), Hagedoorn (1993, 1995), Katz and Ordover (1990), Joshi and Vonortas (1996), Link and Bauer (1989), Scott (1993) and Vonortas (1991). Different econometric models are used for testing hypotheses on each question.

5- Researchers at various European Universities have compiled a number of databases of inter-firm strategic alliances (e.g., Colombo and Garrone, 1994; Doz, 1992; Hagedoorn and Schakenraad, 1990). Strategic alliances include various types of co-operative agreements: from ephemeral non-equity agreements and joint ventures to majority equity investments, and various types of activities: from marketing, second sourcing, ,licensing and production to co-operative research. An alliance often involves more than one type of agreement and more than one activity. These data compilations are extremely useful for appraising strategic business behaviour as it relates to inter-firm co-operation. They are seemingly less useful for addressing some of the typical policy concerns with respect to inter-firm co-operation in R&D as exposed in the previous section.

6- Interestingly, this perception has been fuelled by data on R&D which may have been partly misleading. NSF recently revised the numbers on industrial R&D expenditure in the US, raising the share of non-manufacturing firms considerably.

7- Such an explanation would bode very well with recent findings by the OECD concerning the direction and importance of embodied technology diffusion in an economy (OECD, 1996; Papaconstantinou et al., 1996).

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European Electric Power Industry Liberalization and Technology Diffusion

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Issue: Liberalization of the European electric power market, as a prerequisite for construction of the Internal Energy Market, is a key issue to be analyzed due to its implications for power generation technologies dynamics and European energy technology policy. At the same time, the diffusion of environmental-friendly new power technologies specifically related to the European environment protection commitment, recently reaffirmed in Kyoto, may provide a valuable option.

Relevance: When studying liberalization of the electric power industry, little attention appears to have been paid to its potential impact on the generation technologies relative market shares. Exploring the conditions that are necessary for the liberalization to lead to an environment-friendly energy scheme, as well as the intervention possibilities of the future market regulators would be essential.

Introduction

Liberalization appears to have important effects on technological dynamics, such as the decentralization of electric power production and the possibility of investing in the less capital-intensive and divisible technologies now available. The decentralization process could specifically provide some "niche" markets through which renewables could enter the electricity grid on a competitive basis.

The issues concerning the possible liberalized industry structures (relating to generation, distribution etc.) condition the analysis of the liberalization effect on technology diffusion. Examination of the possible sources of economies of scale may help in addressing future technology dynamics.

Liberalization is a general term, referring to the introduction of competition in a market which was traditionally a natural monopoly, viewed as a natural monopoly or one that enjoyed, justifiably or not, protection from market forces.

Regulation refers specifically to the setting of rules and prices by a regulator in a non-competitive market in order to make it more competitive. Passing from a public ownership to a private one may only constitute a possible first step in the liberalization process and is neither a sufficient nor a necessary condition in some cases. Indeed, the question of ownership is only a minor (although important) part in the overall electric power restructuring: the key questions concern freedom of entry, market contestability and the actual market mechanisms (who are the sellers and the

Two key elements requiring analysis in liberalization of the European electric power industry are environmental protection and the role of future market regulators

Liberalization refers to the introduction of competition in a market that was traditionally a natural monopoly or one that enjoyed, justifiably or not, protection from market forces

The main issues in restructuring the electric power market include an analysis of current mechanisms and future conditions of accessibility and contestability

buyers, what are the rules for wholesale supply and how the transmission channels are priced and managed).

Natural monopolies are mainly due to the presence of economies of scale along the entire range of the cost curve, resulting from large fixed costs.

On the supply side, new technologies are providing the opportunity to decentralize power production (i.e. at low scale of production), without any significant losses in scale economies or efficiency compared to the centralized system, and to invest in less capital-intensive technologies. Therefore, the possibility of a small-scale power production scheme gives the opportunity to introduce more competition. Nevertheless, the economies of scale associated with traditional, large, baseload power generation technologies are not yet exhausted, and, considered separately, some of them will continue to operate in the decreasing cost curve branch. The growth of independent power generators in some of the markets that have been already liberalized, shows that, thanks to the diffusion of these new technologies, the absence of scale economies loss in decentralized production may no longer justify the view of this activity as a natural monopoly. The entry costs may become also lower, favoring a diversity of operation firms.

Changes in demand and supply explain and justify current liberalization, that is, more competition within the electric power industry as a means to achieving optimal resources allocation, a reduction in costs and prices and, finally, an increase in global welfare to the society.

The competition market structures are classified in Table 1 according to the degree of scale economies opportunities, as well as to the degree of production centralization.

Departing from a situation of natural monopoly (i.e. of large-scale economies exploited through a centralized production scheme), the objective is to reach a competitive market environment, where, *in order to be effective*, production must take place in an industry with a diversity of suppliers employing energy technologies with few scale economies opportunities.

The justification for liberalization is to achieve optimal resources allocation, a reduction in costs and prices and, therefore, an increase in the overall welfare of society

An insufficient exploitation of scale economies would, therefore, be a source of inefficiency in the liberalization process.

Table 1. Modes of competition

	High Fixed Costs	Low Fixed Costs
Centralized Production - Monopoly	Natural Monopoly (Nuclear, Coal)	Politically Supported Monopoly
Decentralized Production - Diversity of Suppliers	Yardstick Competition (insufficient exploitation of scale economies)	Competitive Markets (perfect competition, perfect contestable market); (gas turbines)

Possible market structures

The electric power market opening, programmed at the latest for February 19, 1999, is designed by the European Parliament and the Council Directive of December 19, 1996. Achieving the competitive electric power market is an important step towards construction of the Internal Energy Market. The general principles of the Directive are *public service obligation* and *open access to the grid.* Concerning the former, member states can implement long-term planning in order to guarantee security of supply, and consumer and environment protection. Moreover, member states can impose on the utilities public service obligation in respect of the service's quality and price requirements, as well as environment protection. It is stressed that the competitive market alone can not guarantee these outcomes.

Member states will be required to open their national markets according to the following: during the first three years of application of the Directive, eligible final customers are those consuming at least 40 GWh per year. Three years after application of the Directive, all customers consuming more than 20 GWh per year will be allowed to enter the liberalized market. Finally, after 6 years, all customers with a consumption in excess of 9 GWh per year will be able to choose their suppliers. Customers will have progressively greater choice in their electricity supply, resulting from competition in electricity generation.

Electric power may be considered as a product from the generator's viewpoint, but its transmission through the network is a service provided by grid managers. Four generic potential market structures are distinguished according to "how much" competition is introduced into the marketplace.

- The first structure is the current one in most EU countries, that is, a *legally established monopoly* within a fully vertical-integrated industry: regional monopolies provide the power supply service to all customers according to their public service obligation. There is no accounting separation between generation, transmission and retail distribution. This market structure is precisely the one which should disappear.
- The second structure foresees *competition in generation.* A single purchasing company has the monopoly on transmission networks, and acts as a monopolistic seller to final consumers. However, this firm buys under a monopsonistic (single-buyer) scheme from a number of different generators, according to an appropriate bidding scheme to encourage competition. Competition in generation gives the utilities and independent power producers access to the transmission lines. However, electricity price negotiations are taking place between the producers and single-buyer as opposed to between producers and final consumers. Moreover, there is accounting separation between generation, transmission and retail distribution (unbundling).
- The third possible structure supposes *competition in generation and in wholesale supply*. Under this scheme, distribution companies buy electricity directly from the generators and supply it to final consumers over a transmission network. Open access to the transmission grid is allowed, although local retail companies still retain a monopoly over final consumers.
- The fourth potential structure assumes full retail competition and direct access to the grid. Within this model, there is full *competition in power generation, distribution and retail sale.* Customers can choose their suppliers who have open access to the wires. These customers are typically the large ones at the

Two principles of the future Internal Electricity Market structure are the public service obligation and open access to the grid

beginning of the liberalization process, progressively extended to the smallest ones. This is typically the California model.

The possible industrial organization schemes may be summarized in Figure 2.

When considering these models in succession, the choice among electricity providers moves increasingly closer to the final consumer. For them to work properly, the structure of contractual arrangements between market actors has to be of a different nature. It must be emphasized that the issue of the economies of scale is fundamental, since the hypothetical perpetuation of economies of scale in generation would lead to maintaining a monopoly market structure.

New regulation of the electric power industry may include two main components. An initial regulation task concerns the fixing of electricity and transmission prices, if and when desirable. On the other hand, an independent system operator may take charge of the grid management and be required to optimize dispatching flows. This is a *system operation planning* task, aimed at respecting the grid's physical limits and helping the effective match of supply and demand.

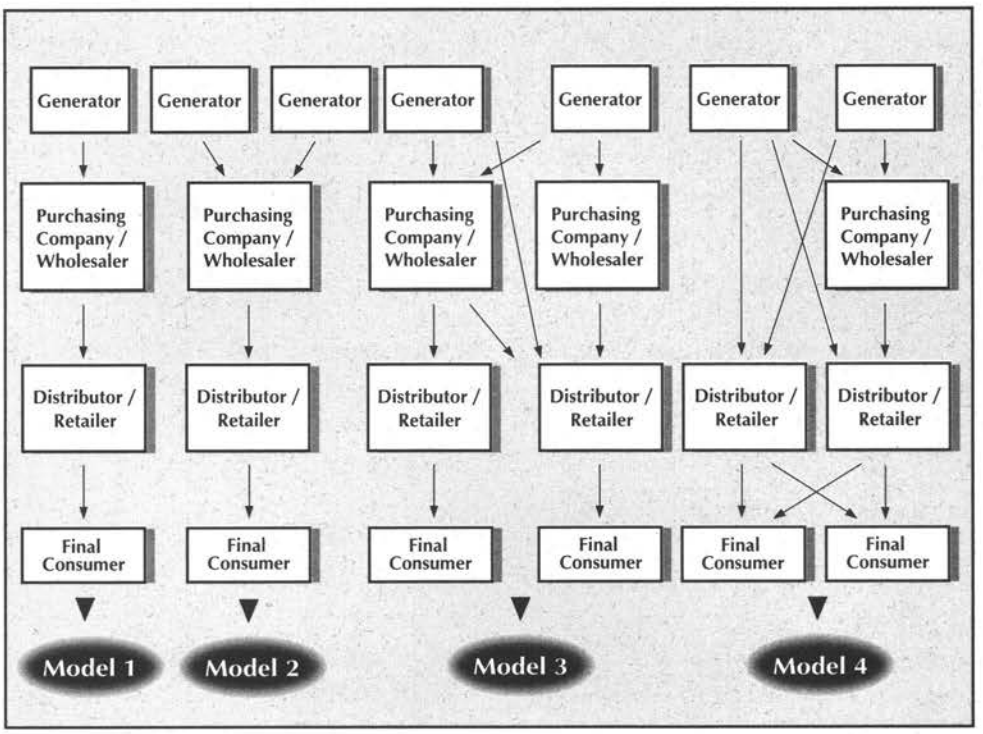
The four potential market structures are classified according to differing levels of competition: a legally established monopoly, competition in generation, in generation and wholesale supply, in generation, distribution and retail sale

Electricity and grid access prices regulation

The price-formation rules for electricity and of transmission services are fundamental issues facing the future regulation of the power industry. An in-depth review of most of the theoretical frameworks aiming at the regulation of natural monopolies is given in Train, 1991. Taking advantage of recent research in this field by Baumol and Sidak, 1995, the following remarks seem pertinent.

A potential theoretical framework for regulating prices of electricity and grid access is that of the perfectly contestable market, incorporating a price floor and ceiling managed by a regulator

Figure 2. Market Competition Structures



This figure is based on Hunt and Shuttleworth, 1996.

It seems that taking some of the *perfect competition model*'s corollaries literally may lead to difficulties, (e.g. marginal cost pricing may lead many old utilities to bankruptcy). The *perfectly contestable market* is a competition model specifically allowing for the possibility of economies of scale, of scope and not requiring a multiplicity of firms, which may help to address regulation issues in oligopolistic markets. The main characteristic is that entry and exit from the marketplace are assumed to be free, just like in the standard model above, but the actual presence of many competitors is not necessary to keep prices low; the mere threat of entry is enough.

A *regulated price-segment*, including a floor and ceiling may be determined by the regulator. The floor limit is designed to *prevent predatory pricing* and cross-subsidy from firms having a potentially dominant position, whereas the ceiling limit is designed to *prevent monopoly profits* as well as to promote innovation and productivity growth.

Within this scheme, firms must be innovative in order to achieve temporary above-competitive level earnings.

The pricing of transmission services should also preserve effective generation competition. The task is to design a pricing rule preventing the utility supplying the grid access from charging its rivals more or less than it implicitly charges itself. An efficient pricing rule may oblige the service provider to charge a price equal to its average incremental cost, including the incremental opportunity costs always priced in competitive markets.

Managing the grid

The post-liberalization power distribution system will probably be much harder to control and manage than it is under the classical, vertically-integrated utility concept. In a competitive energy market, market clearing and grid reliability would ultimately be guaranteed only by the flexible and rational response from customers to price signals, without the need for an administratively-determined installed reserve.

Two main contract types may emerge for the electricity business: the first is based on bilateral contracts between generators and consumers. These contracts are on a long-term basis and will include interruptibility, risk-sharing and operating penalties. Needless to say, this is a system in which the installed capacities of generating companies play a fundamental and strategic role. The second approach comprises the creation of a genuine electricity spot market, where price is determined according to instantaneous market conditions, for example at 15-minute intervals.

An independent company, referred to either as pool company (on the spot market basis), or as independent system operator (ISO), may take charge of grid and overall system management.

The new technology-diffusion dynamics

Concerning the effect of liberalization on the technological mix in electric power markets, several features may be highlighted. This issue is essential since the technology mix is of crucial importance in respecting CO_2 targets.

The interdependence between market structures and technology diffusion should be underlined. Indeed, liberalization, permitted by the suitability of new information and control technologies, in turn induces an evolution of the electric power technological mix.

Grid management and control on the liberalized market will be more difficult and may be required to be implemented by an independent company

The technological mix emerging from liberalization may lead to the promotion of renewable energy technologies

Grid ownership and transmission regulation are likely to become other key factors that could help or hinder renewable energy technologies to penetrate the market

Public intervention based on policy-driven measures to protect the environment and reduce CO_2 emissions can find space among regulatory provisions

The downsizing of generation activities permitted by the new technologies now available, and above all by the latest gas turbines generation, may enhance the diffusion of less centralized electricity generation schemes. Renewable energy technologies diffusion may be promoted by this evolution, since they are well-suited to technology hybrid devices (combining an intermittent energy source with, generally, natural gas electric power technology). On the other hand, it is widely acknowledged that liberalized electricity markets, at least in generation, will lead investors to choose lower capital-cost technologies, allowing for greater flexibility, lower construction time and, therefore, increased efficiency. Natural gas-based power technologies are then the best-placed candidates, since the energy carrier is versatile, clean, available and relatively cheap. Moreover, the operating flexibility of these technologies may permit them to provide electric power and to compete with traditional technologies on peak as well as on base loads.

This foreseen predominance of natural gas may boost fuel cells diffusion for decentralized electricity production, as well as decentralized hydrogen-based co-generation to satisfy heat demand. The related technologies in the transport sector (hydrogen-based fuel cells through gas reforming and compressed natural gas) may also benefit from this evolution. In turn, the diffusion of hydrogen-based technologies may induce a more widespread use of renewable-based water electrolysis.

However, technology-induced decentralization may not be strong enough to bring about dramatic changes in the distribution system. As a result, the electric power market may become characterized by three features: the persistence of traditional centralized baseload electricity technologies (mainly nuclear, coal and gas-based), while co-generation and renewable energy technologies diffuse in their respective market niches. The heat market may be boosted by the availability of natural gas-based new technologies and increase end-use efficiency significantly. Simultaneously, since the new gas turbines are highly flexible (accommodating peakloads and baseloads), the importance of demand side technologies may be reduced, and affected, moreover, by the new proximity between supply and demand. Large voltage and long-distance electric lines may be substituted in part by local low-voltage grids, locally operated, and by appropriate gas pipes networks. This tendency may facilitate competition between independent power producers and a diversification in generation technologies.

The resulting technological mix may also be greatly influenced by contracts and joint-ventures established today by the old utilities with other ones in Europe and the US, in order to prepare and prevent the competitive pressure which will arise in the forthcoming years. Re-monopolization of the industry could preclude the introduction of superior new technologies competing with the ones currently used and prevent technological progress to some extent.

Grid ownership and transmission regulation are likely to become other key factors that could lead to a position in which renewable energy technologies penetrate the market. Specifically, if a marginal price rule for transmission services is applied, less flexible generation technologies may be penalized. This would not only affect large, centralized nuclear or coal power stations but also, possibly, renewables, although these are usually more divisible. However, the importance of total network costs prevents the application of this rule, which may be adjusted in order to give price-premium to "green" electricity-producing technologies. Indeed, new power technologies,

and especially renewables, need to gain economic and technical confidence and overcome the current pricing patterns, which do not fully reflect environmental externalities. Such price-premiums appear essential to achieve prices that reflect full social costs and reconcile private companies' and policy-makers' views on technology costs estimation.

Finally, modeling and simulating the effects of the competitive electricity market on the substitution dynamics of electric power generation technologies appears essential in order to provide a quantitative estimation of the proposed policy options.

A changing role for future national regulators

Government policies and regulation remain of primary importance in reaching the desired reasonable degree of competition and preventing distorted competition. Since the power industry transition is departing in many countries from a monopoly position of one power generation utility, much will have to be achieved in this respect. In addition, European governments have committed themselves to preventing environment degradation and, particularly, to reducing CO_2 emissions. The measures permitting fulfilment of these targets are expected to be, and remain, mainly *policy-driven* and have immediate effects on the choices made within the power sector. The technology option is clearly of primary importance. There is therefore room for public intervention in the future competitive power market, which has to be carefully assessed by the regulatory authority.

In addition to the role of addressing externalities, that is, the formation of *correct price signals*, the regulator may then have to integrate long-term strategic views in order to shape the capacity planning which will be decided by producers, mainly on the basis of short-term total production costs. Achieving an environmentally sustainable and competitive power generation industry should include the long-term issues relating to the depletion of European and world-wide reserves (oil, coal and gas), to CO_2 targets and to security of supply.

Based on past experience in the UK and Norway, the regulator's functions have been adjusted and reinforced. Indeed, past regulatory elements in terms of controlling the natural monopoly, investments, prices and consumer protection require redefinition. Long-term planning, as well as the public service obligation are no longer the regulator's exclusive responsibility: competitive rules should give all competitors incentives for long-term views and respect for environmental constraints.

The UK and Norwegian markets also show that patterns of market structures and ownership within the industry, after a massive restructuring, are far from being definitive. This simply reflects the fact that incentives to form vertically-aggregated electric power monopolies have not completely disappeared. Remonopolization would annul the liberalization effort and may undermine the necessary technology renewal. **Amongst the regulator's new tasks, a permanent monitoring of the market status and capital movements amongst players will be of crucial importance, in order to avoid the formation of trusts that could have a price-making power.**

A further important issue is the future trends and direction of R&D expenditure which will be generated by the market liberalization. According to recent studies on the power generation sector privatization in the UK in 1991 (J.A. Walker, 1996), it appears that R&D data indicates a general increase in customer-oriented

Long-term factors also require consideration, such as depletion of European and world-wide reserves and security of supply

Of crucial importance among the regulator's new tasks will be a permanent monitoring of the market status and capital movements amongst players, in order to avoid the formation of trusts that could have a price-making power

The regulator could be crucial in providing incentives for long-term efficient planning and for fostering the adoption of environmental-friendly technologies

expenditure. Indeed, it seems that R&D expenditure relating to generation and environmental protection is decreasing to the benefit of that for distribution, utilization and commerce, when externalities are not addressed (internalized) through policy measures. Short-term R&D planning, therefore, may reveal drawbacks, in neglecting long-term issues such as global warming or the development of new production technologies, presenting an area in which economic incentives and technological policy could play an important role.

A co-ordinated EU-wide energy R&D policy may present significant advantages, such as R&D economies of scale exploitation and more exhaustive exploration by preventing research duplication, promotion of technology diffusion and exploitation of economies of scope. Basic lines of energy research to be supported by public policies at EU level can be catalogued on a time scale basis. In the mid-term, the continued prevalence of fossil-fuel based technologies (oil, coal and gas) may imply a specific effort in development the clean use of fossil fuels, reducing the risks of climate change effects accordingly. On the other hand, the analysis focusing on the energy/economy/environment relationships may permit a better understanding of how to gear the technology shift towards a more carbon-free system, and of the damaging process of carbon emissions. The development of clean fossil-fuelled technologies may have twin objectives: enhancement of the competitiveness of the European technological industry, as well as environmental protection through judicious technology transfer mechanisms and adoption incentives, especially to countries which will experience double-digit electricity demand growth rates (China, India...).

In the long-term, the EU energy R&D policy may focus on minimizing the fossil fuels-based technologies wave and foster the emergence of a sustainable cluster of technologies: renewable energy technologies development, and support, when near-competitive, is therefore a priority.

Conclusion

The new role of future national regulators may particularly include the setting of competitive price formation rules for electricity and grid access, and control of the concentration in the marketplace. In addition, the regulator could be crucial in providing incentives for long-term efficient planning and for fostering the adoption of environmental-friendly technologies. To date, many uncertainties still remain around the precise institutional form regulation will take. However, it is of utmost importance to design the regulator's capabilities correctly so that the aforementioned two-fold function is fulfilled.

Keywords
liberalization, technology diffusion, electric power market, optimal regulation

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Implications of Electric Vehicles on Consumers, Congestion and Traffic Patterns in Europe

Anette Schmitt, *VDI-TZ*

Issue: Although electric vehicles have virtually no significant presence on the roads, they are beginning to play an increasingly interesting role in discussions on the future of private traffic within the metropolitan areas of industrialised countries. An important parameter to take into account is that electric vehicles cause the user to alter his/her driving behaviour and mobility needs.

Relevance: The use of electric vehicles may create learning effects which could make the driver more sensitive to problems of road traffic, congestion, energy conservation, and the more careful use of the (often still existing) conventional second car. Whereas Japan and several US States support the introduction of electric vehicles, European countries have various strategies, partly due to different assessments of the ecological balance and efficiency of electric vehicles.

The case of California

Motivated by the increase in traffic-induced air-pollution and endeavours to support the use of alternative energies, in order to become independent from mineral oil and to create new jobs on the high-tech industrial field, US authorities in the mid 1960s (mid 1970s in Europe) started a "renaissance" of the electric-driven automobile. The consequence was an intensification of R&D into electric vehicles. An important milestone, an essential current and future factor concerning the development of electric vehicles, is the 1990-ratified US California Zero Emission Mandate and its update (the Memorandum of Agreement) of March, 1996. In the US, the implementation of electric vehicles depends very much on the Californian development in this field. In 1990, the California Air Resources Board (CARB) authorities obliged the leading US and Japanese manufacturers on the Californian automobile market to start the sale of electric vehicles in California in 1998. This Californian push has been taken over by other US States and resulted in a broader recognition of pollution problems. However, the automobile industry did not accept this measure and, in 1996, obtained the reintroduction of the CARB regulations, at the price of far-reaching concessions, formulated in the "Memorandum of Agreement" (MOA) in March, 1996. This CARB "two steps forward, one step back" policy produced several joint, contractually-protected and very strict - mandatory concessions from the automobile industry. Formalized in a letter of intent, the controversial positions of the Californian

environment authorities and the automobile industry turned into a common strategic proceeding, accompanied by the definition of specific standards for effective testing. This collaboration signifies that California is going to maintain its leadership role.

The European Situation

The situation in Europe is very different. The introduction of electric vehicles in France is based on a centralist approach. Under increasing environmental pressure, a contractual declaration from the automobile industry, the state and the monopoly company Electricité de France (EDF) proclaimed intensive support for the promotion of the electric car. The production and sale of electric vehicles started, followed by fleet-tests in several French cities, for instance La Rochelle. The state offered attractive depreciation rates and supported the purchase of electric vehicles with FF. 5.000; EDF added FF. 10.000. Even though co-operation has been arranged between regional/local institutions and authorities to install more charging stations, to inform and to train interested drivers and to reduce premiums for electric vehicles, the enthusiasm of private users proved moderate.

The German federal transport and environmental authorities refused to recognise the electric vehicle as a major environmental improvement, because it is claimed that unless electric vehicles reduce individual motorized traffic, public money could be more effectively invested in an extension of the public traffic system infrastructure. The German automobile industry, the battery industry and the Association of German Electric Power Plants explained in 1994 that the electric vehicle is only a very long-term alternative to fossil fuel. Nevertheless, two of the biggest German companies, Deutsche Post, AG and Deutsche Telekom, AG, declare the electric car to be a prospective alternative for low-emission road traffic.

In Norway, the air pollution caused by automobile exhaust fumes and strategic reflections on introducing alternative automobiles, in order to reduce reliance on diesel and gasoline, have played a very insignificant role in the public discussion for a long time. The Norwegian government, meanwhile, promotes the use of electric vehicles by a vehicle tax exemption. Environment protection organisations accentuated the need for better public transport systems rather than the implementation of alternative vehicles. The Norwegian electricity company "Oslo Energi" (powering the pressure group NORSTART), the municipal government of Oslo, some individual initiatives (University of Trondheim, Kolega Bil) and the company PIVCO, promote the use of electric vehicles. In collaboration with several companies and institutions from Norway and abroad, PIVCO is successfully producing the CITY BEE for external use in the Norwegian and the Californian market.

Since the early 1970s, the introduction of electric vehicle technology in Switzerland has gained acceptance. There is an important boom in the sector of so-called Light Electric Mobiles (LEM), where Switzerland achieved the leading position in Europe. With a budget of 1,5 million SFr per year until 2001, the 'Mendrisio' project is heavily subsidised by the Swiss federal government. Due to strong political support and the commitment of several distribution companies, the Swiss population is extremely well-informed about alternative electric vehicles.

In the US, California is the leading state in the implementation of regulations regarding electric vehicles

The situation of electric vehicles in Europe varies substantially according to Member State

Government support varies according to the estimated environmental benefits of electronic vehicles in terms of pollution reduction and energy resources savings

Switzerland appears as the leading European country in awareness of electric vehicle technology

EV limitations include restricted range, recharging requirements, low speed and high cost

An important potential of the EV lies in its possibility of affecting driving habits and raising global awareness of mobility and traffic

The European Consumer

Public acceptance is particularly influenced by the vehicle range, refuelling infrastructure requirements and capital cost. Major constraints include the limited range of the vehicle (no more than 100 km), the long period required for recharging (at least six hours), the low maximum speed (less than 100 km/h) and the high price.

In 1994, users of electric vehicles and their mobility patterns were analysed in detailed studies undertaken in Switzerland, Austria and Germany. In France results were obtained from the "La Rochelle project" and Norway completed a survey in 1993.

Results of these reports indicate that the electric vehicle user-profile is as follows:

- individuals, male, about 40 years old,
- well-educated, employed,
- earning a net-income of over ECU 2.500 per month,
- interested in environmental protection topics,
- respecting environment protection requirements in their daily lives,
- participating in other environmental protection projects,
- having a positive opinion towards technology.

This does not correspond to the "typical" population composition in any of the examined countries. Only the Swiss partners have determined that the electric vehicle user collective represents 8% to 51 % (depending on specific criteria) of the total Swiss population.

Users declare themselves to be content with their electric vehicles. This applies, in particular, to the limitations of use that are frequently anticipated (shorter range, slower speeds, limited seats).

A source of annoyance are technical malfunctions: the unsatisfactory quality of the electric vehicles (processing, reliability, functionality), battery handling has the reputation of being susceptible to trouble, the variable range of the cars (particularly in regard to the summer/winter-comparison) and the often non-existent or unsatisfactory service. The proposition "the technology is available" is not in evidence. The majority of today's electric vehicles offer a great margin for optimisation in respect of quality enhancement.

Other results include:

i) electric vehicles are rarely used as toys, fun cars or leisure time occupation: they serve for everyday traffic (to work, supply trips);

ii) electric vehicles are driven in a predominantly defensive and far-sighted way: this driving style raises traffic safety standards;

iii) the use of electric vehicles might produce learning consequences: these are related to a higher sensitivity to general traffic problems and energy usage;

iv) the emergence of a more attentive, more careful, more far-sighted and more defensive driving style;

v) changes in mobility behaviour: leading to an increasing interest in new co-operative traffic systems.

The aforementioned learning effects and technological limitations of EVs (limited range, limited speed) could lead to a well-planned, economic and effective use of the individual car and lend support to a more holistic view of mobility and traffic.

The substantial increase in pollution in urban areas may lead to situations in which the use of electric vehicles is favoured by locally-stimulated needs and competition, in city areas striving for higher air quality standards. In these

circumstances, the creation of cleaner cities is perceived more as a business opportunity than a necessity. The introduction of electric vehicles could form part of an overall package alongside the construction of cleaner cities, with the use of zero-emission vehicles providing a benefit and service to the local community. The trend towards individualism and the intrinsic weakness of public authorities in creating and enforcing rules limit the scope for establishing both the necessary electric vehicles infrastructure (for re-charging and maintenance), and related non-technical facilities (e.g. reserved parking, free circulation in restricted areas, etc.).

A systemic approach to pollution, noise and congestion in urban areas requires the balanced integration of urban planning, traffic management, public transport and cleaner technology vehicles. Electric vehicles can provide environmentally friendly urban transport with energy benefits. More specifically, they are free of emissions at the point of use. Nevertheless, perceptions of the ecological balance of the use of electric vehicles is controversial. The results depend on various factors. The current technological emission balances are based on assessments of respective power plant structures (which vary from country to country and from region to region) and the energy consumption of the vehicles.

They cannot take into account possible secondary effects caused by the physical configurations of the car: far-sighted and defensive use of electric vehicles, in order to save energy reserves; critical position on the problems of ICE-traffic; including additional transport systems (for goods transport or long distance trips) in personal mobility-mix (intensifying the effect of integration of different transport means). Even though electric vehicles are relatively well-positioned with respect to other technologies, their use is mainly motivated by collective rather than individual needs.

Conclusions

Particularly in metropolitan areas, the ecological damage caused by the automobile will reach a stage which necessitates their increasing ban from highly vulnerable inner-city areas. But a decision vis-à-vis electric vehicles has still not been taken in European markets. The German position is dominated by the German Federal Environment Protection Agency. Interesting market introduction experiments are being conducted in France, Norway and Switzerland. The implementation of electric vehicles is not a self-maintained movement, it requires an intelligent publicly and privately organised strategy, which, in the future, will increasingly consider the argumentation for and the empirical assessment of electric vehicles[1].

The Californian example illustrates that it is possible to support and oblige the introduction of electric vehicles. This cannot be achieved through legal obligation alone, but in co-operation with the automobile industry. California reached an agreement with the industry and developed a common understanding, which is accompanied by the definition of specific standards for effective testing.

The technological deficiencies of today's electric vehicles are still serious. Overcoming them is one of the most important tasks for the near future. One of the main elements, therefore, is to improve battery technology. In spite of the problems, however, the current technological state-of-the-art of electric vehicles (e.g. French

The use of EVs is motivated primarily by collective rather than individual needs

One of the main challenges facing EVs is finding solutions to the technological limitations, in order to increase acceptance and overcome consumer resistance

cars) is sufficient for them to be released from the laboratory stage to field tests. The problems of acceptance, frequently not unjustified, can be bridged in the process. Only through practical use can the strengths and the weaknesses of electric vehicles be recognised. The automobile industry needs to use its existing potential and offer reliable technology, 'even if it is limited'. The large US, Asian and European automobile manufacturers have sufficient capacity to meet this demand. The European car industry has to take care not to let its US and Japanese counterparts consolidate or lead. The main important characteristic, therefore, is the conscious and careful use of the individual passenger transport car. Learning effects and technological limitations (regarding range and speed) suggest that electric vehicles will lead to a well-planned, economic and effective use of the individual car.

The major limitations for the introduction of electric vehicles European markets are not only related to technological aspects, but also to the resistance of consumers to modify their transport habits, leading to a restriction to a few market niches where personal standpoints are not important.

There are also issues relating to the restructuring of the manufacturing industry, as traditional suppliers of raw materials and fuels are replaced by new players. The current equilibrium and established market characteristics could be substantially affected in many regions of Europe. In addition, non-technical measures and initiatives undertaken by governments to improve acceptability by and involvement of the general public in new transport policy might be difficult to introduce, with particular challenges relating to converting interest into real participation and changing people's mobility habits.

Electric vehicles have the potential of enabling learning processes that could lead to changing mobility patterns. Adequate support, ideally in the form of a European strategy for EVs, could help strengthen this potential. All computations being made for the ecological costs and benefits of EVs should take these dynamics into account, as well as the dynamics that will come into play when EVs are more widely used in society.

Keywords
mobility, traffic, congestion, electric vehicles

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Note

1- The article only refers to pure battery-powered electric vehicles in an isolated manner. However, there are other technological options and issues strongly interconnected with this. For instance hybrid electric vehicles, fuel cell electric vehicles and related developments regarding infrastructure and cost issues. This means that policy-makers (public and private) have very complex decisions to make.

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

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