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From irreversibility to participation: towards a participatory foresight for the governance of collective environmental risks☆

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Abstract

This paper presents a reflection on the introduction of methods and tools of "participative foresight" for scientific and technology policy as well as environmental policy fields. Future studies have recently made a comeback under the label of foresight. Future technology studies no longer claim to forecast the future, but are presented as a strategic tool for improving interaction between key actors and for anticipatory policy making. They can be defined as a "process by which one comes to a fuller understanding of the forces shaping the long term future which should be taken into account in policy formulation, planning and decision-making" [Foresight in Federal Government Policymaking, Futures Res. Quart. (1985) 29]. We discuss applications of this approach for perspectives on environmental policy and sustainable development. Foresight opens up the possibility of negotiating a new and more fruitful relationship or 'social contract' between science and technology, on the one hand, and society on the other. The focus has moved from merely scientific and industrial insights to social demand, thus emphasizing the importance of both the production and "supply" of innovation, and the "demand" as signaled in the views of citizens.

Keywords: Foresight; Prospective; Vigilance; Technological innovation; Environment; Sustainable development

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1. Introduction

In the 1990s, foresight studies have greatly contributed to activity in environmental policy and technological policy, the two fields being deeply linked by the elaboration of sustainable development policies. Given that technological innovation, one of the motors of competitiveness, is expected to continue at increasing speed into the next century [1]; one can also expect the creation of more and new situations of risk, notably on account of unwanted environmental effects. The irreversible nature of many environmental risks means that precaution is essential, and this calls for an increased vigilance in technological choice. A policy of post-event adaptation is no longer acceptable, and vigilance requires good foresight.

The 1990s have seen an acceleration in national efforts at foresight, but in a different perspective from what had been practiced in the past. The notion of (technological and environmental) foresight had been based, in the past, largely on opinions from scientific and industrial experts (researchers, industrialists). Yet today, those countries which have most exploited this type of tool all agree that much more accent must be put on the demands and inputs made by society at large.

In this new context, the old term "forecasting" has largely been abandoned. It is emphasized that foresight studies (*prospective* in French) do not claim to predict the future. Rather they must offer visions of the future, they must go beyond the horizons of specific scientific and technological policies, and must incite the "actors" of society to participate in the development of the future. They therefore constitute a means of improving, a priori, the strategic interaction between the key actors in the permanent process of policy implementation. The concept of foresight itself then becomes an instrument to facilitate the process of social participation.

This article analyses the introduction of methods and tools for "participative foresight"; on the one hand for the scientific and technological policies and, on the other, for environmental policy. In the first part, we outline the key concepts of "participative foresight" as applied in the environmental field. In the second part, we make a comparative study of foreign practices which are most representative in terms of environmental foresight. In the third part, we focus on the specific French situation.

2. Participative foresight in the environmental field

2.1. Technological foresight/social foresight

Two important philosophies currently co-exist in the domain of foresight, which we characterize as technological and social, respectively. The first of these, which we call technological foresight, is essentially preoccupied with identifying trends of technological innovation. This is explained by two quite distinct kinds of reasons:

- "Economic progress". Technological innovation is the motor of competitiveness. R&D activities should be favored in areas that provide the most added value, for example as measured by the number of patents. The environmental field offers good innovation prospects from this point of view (see [2]).

- "Social well-being". Technological innovation is supposed to answer to society's needs. Through foresight studies, governments seek to identify the fields of scientific and technological research that will bring social and environmental benefits (cf. [3,4]).

In both cases, a "technological" vision is prevalent. In the first case this is obvious, since society's needs are inseparable from economic competitiveness through technological innovation. In the second case, there is an underlying presumption that technology, if it is well chosen, will always be able to satisfy society's demands. Relying exclusively on foresight studies of this type to guide environmental policy seems, however, quite questionable. It is tantamount to supposing that R&D programming can assure technological innovations that responding to all the policy goals of reducing environmental pressures and risk management. This leads us back towards the "weak sustainability" perspective which makes the hypothesis of unlimited productivity gains while substituting away from dependence on natural capital (see [5]).

The second philosophy, by contrast, implies a social imperative. In social foresight studies, the priority is given to procedures for the definition of society's needs in economic, social or ecological terms. Then the means to satisfy them are considered. Amongst these may well be technological means, but attention is also given to possible disruptions and new problems which emerge (including those linked to technology). Priority no longer goes to technological innovation which becomes just one means amongst others of reaching a social goal. This "social foresight" perspective is increasingly influential in association with the idea of strong sustainability, in particular in the choice of policies of environmental improvement and health (and, more generally, the quality of life).

In our view, "technological foresight" and "social foresight" should not be seen as mutually exclusive. Social foresight frames technological foresight. If it is a question of adjusting policy with a view to improving the environment, then social foresight may be used to anticipate the emerging needs of the society in this way and to see what type of scientific and technical changes make this possible. Then, with regard to the innovation perspectives opened up, technological foresight can be used to explore and evaluate the R&D and technology policies which seem likely to offer substantial value-enhancing innovations and benefits.

2.2. Participative foresight: a new tie-up of futures studies and collective participation

The new trend of integrating scientific and technological expertise into wider processes of consultation and deliberation open to "social demand", can be described as the emergence of a participative foresight.

The Delphi surveys are based exclusively on the visions of experts (see Box 1) and, over the past 30 years, have been used to incorporate the main axes of science and technology into most of the foresight exercises. Presently, they are in the process either of total restructuring, as in Japan, or of being completely dropped, as in Germany and the United Kingdom. Alternatively, they are used in a complementary way to other methods which can absorb this new orientation as in the United States with the regular exercise of the World Future Society.

In the new foresight exercises, the particularity of the participative dimension is that it sets up the mechanisms for dialogue within the structures of collective research concerning

Box 1. The Delphi method

The Delphi method was developed in the 1950s by the Rand corporation; it is the method most frequently used in "technological foresights". It has been applied by Japan which has been carrying out regular Delphi surveys since the end of the 1960s. Most of the developed countries excluding the Netherlands which opted for other methods have used this type of exercise. In the days when the Japanese economic miracle seemed unstoppable, there was a fairly uncritical belief that these studies were a key to technological dominance and that, to catch up, United States and European countries would have to adopt something similar.

The method is based on the opinions of experts about the future developments and limits of technology in the 30 years to come and provides aggregate results. The aim of this method is to gather not only the raw opinions of experts on a certain number of questions concerning the future but also to make each expert react to the general opinions of his or her peers. To do this, a questionnaire is generally sent out in two successive mailings. The second mailing is adjusted according to the findings of the first one. The questionnaire and the experts differ according to the sector. The "participative" aspect is, however, not included in this method especially since it attempts to identify the convergences of opinion between experts by specifically erasing all potential source of discord or conflict.

any original (and sometimes unexpected) future developments. Moreover, it attempts to define either the area of acceptable choices, or (when this is possible) the choices which result from a consensus based on respect of differences of opinion and criteria and the need for co-existence. It is, furthermore, concerned with "transparency in the case of inherent conflicts of interest and highlighting those adjustments which were made to accommodate them" [6]. Thus, the actual process of constructing and setting up the foresight exercise becomes as important as the results. "The 'how' is as important as the 'what"' [7].

The effectiveness of any method of foresight depends very strongly on the participatory dimension in bringing together all the actors involved. This implies some use of participatory techniques. However, under the heading of participation can be found some extremely different mechanisms which imply very different concepts and levels of participation (see Box 2).

For example, public enquiries and public commentaries can imply flows of information in one direction only, from the public to the government, where the former does not really know what use the latter will make of the information. The degree of reciprocity between the two actors can be very low, and the "sense" of the communication can be monopolized by the private or public powers [8].

By comparison, citizens' juries and citizens' panels (including consensus meetings with an official status) constitute forms of participative techniques which permit the expression of knowledge and of underlying values in a manner which is both interactive and organized. These methods can be used both to examine and recommend decisions, and also to think up possible futures in conjunction with various foresight methods on a broad spectrum of environmental questions involving risk and conflict. For example, deliberative procedures such as mediation, citizens' juries and consensus meetings can be allied to computer-based

Box 2. Some current techniques used in participative processes

∗ *Public enquiries and public commentaries*: discussion groups on different subjects to gather citizens' opinions on particular problems.

∗ *Citizens' panels*: small groups selected to convey the representative opinions of the citizens to the decision-makers, usually at the local level, through moderate discussions on important problems.

∗ *Citizens' juries*: groups resembling citizens' panels, except that their deliberations must end in a "verdict" or a recommendation for specific planning on certain relevant questions.

∗ *Consensus meetings*: broader concertations which combine a panel of laymen and experts' evidence in an ad hoc public forum, typically to consider broader or more fundamental questions and who then produce a written report with recommendations.

∗ *Mediation*: the parties concerned in the debate or controversy try to identify their differences and find solutions through discussion with the help of a neutral third party.

All methods are open to bias. If the exclusion of "weak" or marginal interest groups does not correspond to the ideals of participation, attempts at broadening the processes can nonetheless permit well-organized or powerful actors to "capture" and dominate the proceedings.

technology using simulations (scenarios, simulation models, multi-actor games, etc.) which enable the construction and discussion of social, economic or ecological "futures". The assessment of these futures then turns into a process of articulation of values within the community and is a dynamic contribution to decision-making [9]. Such participative processes enable the assessment of the relevance of the information provided by the expertise and the examination of the questions relative to the underlying values which divide or unite the different communities of place or opinion.

2.3. A typology of the different methods of foresight

A simple typology of methods of foresight is presented in Table 1.

A wide participation of social interests seems to be indispensable to bring out shared and contrasting visions of futures which are possible and/or desirable for a society. Yet, expert evaluation and scientific quality are equally necessary to link possible futures to the technological challenges which exist and to the foreseeable scientific advances. Science and vision must be allied for the creativity necessary to challenge strong beliefs and interests [10]. It is then a question of evaluating the capacity of the various foresight methods to incorporate these different dimensions. We propose a typology of the foresight methods in the form of a triangle where the three poles represent respectively expert evaluation, participation and creativity.

The differences between foresight methods (and variations within the same foresight method) reflect the difficult balance that has to be struck between the expert opinions of scientists and users (industry, government, society) and the creativity of future visions. As can be seen with reference to Fig. 1, the character of the various foresight activities is highly dependent on the participation techniques that they employ. No one method can really find

Table 1
Recapitulation of the different foresight methods

Method	Approach	Advantages	Possibility of integrating participation	Limits
Delphi study	Analysis by a large group of experts	Synthetic view of a large number of experts' responses	No in reality, Yes in theory	Slow and costly method, difficulty of mobilizing a lot of experts, information loss due to quantity-based results
Method of scenarios	Construction of possible, alternative futures	Help in decision-making without giving forecast, explores uncertainty	Yes, according to the participative techniques used	Plausibility, necessitates time before establishing a definitive scenario, imagination of the "scenaristes"
Relevance Trees Method	Normative and systematic approach	Fixed objectives, display of possible choices	Yes, according to the actors and participative techniques used	Taking into account all the predefined factors; necessity of distinct levels of hierarchy; information loss between systems
Benchmarking method	Search for best ideas and methods to integrate them and then become the best	Fixing ever more efficient goals	No	Depends exclusively on opinions of highly specialized experts. No concertation possible. No creation possible
Critical technology exercises	Classification of technologies according to different criteria	Low cost and rapid results	No	Depends solely on experts' views. Low creativity
Multicriteria analysis	A set of criteria enable restriction of the number of possible results	Enables a simple classification of information	Yes according to the actors and participative techniques used	Can hamper creativity

the ideal balance. It seems preferable for a foresight exercise aiming at controlling environmental risks, to use several foresight methods simultaneously and in a complementary way and even to use several participation techniques within the same method.

2.4. From foresight to vigilance

The "weakness" of signals for environmental risks can have diverse origins:

- The "weakness" of the signals may be due to the scientific nature of the situation (for example, the threat bearing on a distant future, or a signal which is numerically weak or a signal which is hidden in an overloading of information and statistical "noise").

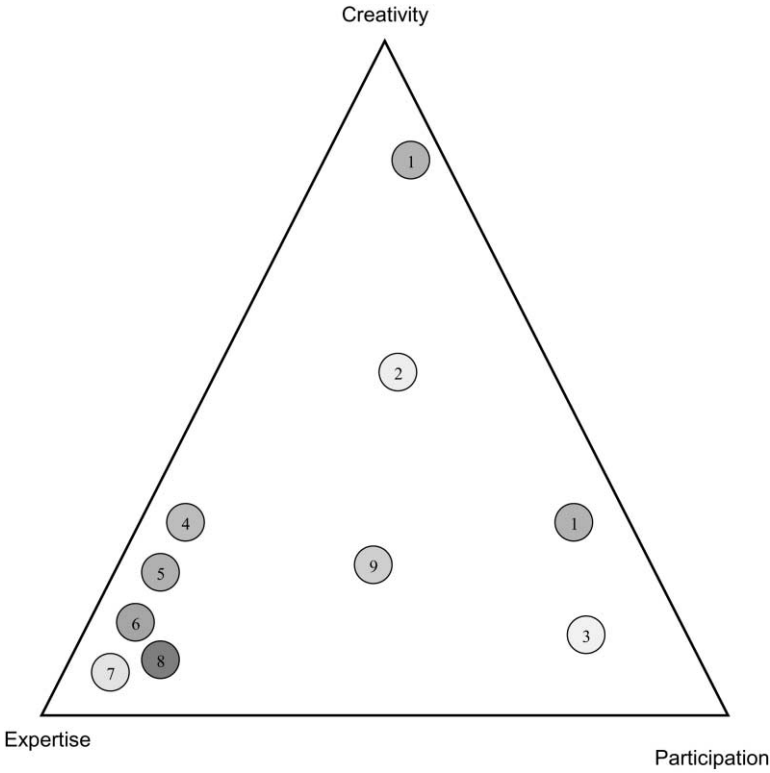

Fig. 1. Typology of foresight methods and participative techniques which they require: (1) scenarios based only on non-expert actors from society (two extremes may happen); (2) scenarios based on participative techniques linking experts and civil society; (3) multicriteria analysis and methods of Relevance Trees from participative techniques which exclude experts; (4) scenarios based on Experts' Panels; (5) traditional Delphi surveys; (6) Critical Technologies; (7) benchmarking; (8) multicriteria analysis and Relevance Trees Method based only on experts' opinions; (9) multicriteria analysis and Relevance Trees Method based on participative techniques linking experts and actors from society.

- The "weakness" can be due to institutional factors, for example, where the signal is weak because it is emitted by actors who have no legitimacy or because there is no institutional relaying system.
- There are "weak signals" for some known risks (for example, avalanches) and weak signals for latent problems (for example, mad cow disease).
- Certain "weak signals" can be emitted by experts and others can come from the civil society (easily assimilated to social demand).

We have been able to show elsewhere [11] on the basis of a certain number of returns on experiments (French and foreign) how the detection of precursory or weak signals constitutes a factor which, henceforth, must necessarily be included in all decision-making processes linked to environmental risks. The role of vigilance is to limit the blindness towards "weak signals".

The development of the environmental vigilance becomes crucial at the point where new principles develop inside legal systems (international, multinational and national) concerning environmental risks (extended responsibility of the producer, the precautionary principle in addition to the polluter-payer principle) [11]. This tendency progressively sensitizes the public and private decision-makers to the need to intervene earlier with a more careful management of environmental risk whence the closer and closer identification of the notions of vigilance and foresight. It is useful, in this regard, to make a distinction between the object and the goal of vigilance.

The object of environmental vigilance varies according to the origin of the "weak signals" it is concerned with. Thus, we speak of "scientific vigilance" when it is a question of ensuring the identification of weak signals of risks coming from the scientific community. We can also identify "vigilance concerning social demand" when we go about tracking weak signals coming from the civil society. We can also identify the changes in the areas of technological innovation and R&D linked to the environment on the national and international levels through what we could call "technological vigilance". Finally, if we choose to follow regulatory changes, we enter the area of "regulatory vigilance". These two last are fairly common place contrary to the two first which are little explored, particularly in environmental field.

Vigilance, whatever its object, may refer to at least three broad goals which must be distinguished from each other. First of all, it can serve the needs of information gathering and (perhaps) circulation and dissemination. A "documentary vigilance" is then set up. A vigilance system can be used for competitive purposes which is what we usually refer to when we use the term "economic or intelligence vigilance". In this case, it must refer not only to the significant changes in scientific environmental research but also to social demand movements or to technological trends and regulatory evolutions. Finally, a vigilance system can have a warning role for policy makers in charge of research on the one hand and the environment on the other, in order to avoid passing into a crisis situation (economic, social or ecological). In this case, we would speak of "strategic vigilance" to the extent that the transmission of the warning must be relayed directly to those in charge of decision-making, especially for reasons of responsibility. In fact, in this case, the receiver of the "weak signal" is the decision-maker. There is necessarily a continuum between the three possible goals which we have assigned to the vigilance system (Table 2).

The role of a foresight system is to provide questioning which enable the orientation and structuring of vigilance in order to avoid either process which is blind to weak signals or an accumulation of data with no interpretative framework or rejection criteria. Furthermore, the alerts towards which the strategic vigilance is turned can only emerge and be retained by the decision-makers if there is increasing reflection about the determining and possible upsets among the possible futures. In other words, strategic environmental vigilance must result (if not be part of) a system of foresight.

In these conditions, it appears that an environmental foresight should be undertaken before all environmental vigilance systems. This assertion is, moreover, confirmed by the lack of any strategic environmental vigilance in the present system, including those countries having developed the most sophisticated foresights. According to our investigation, most of them preferred, first, to concentrate on the development of their foresight exercise, only to worry about the setting-up of a vigilance system afterwards [12].

Table 2
Methods of vigilance according to the object and goals of the vigilance

Goal	Object		
	Documentary vigilance (gathering and dissemination of information)	Economic vigilance (competitiveness)	Strategic vigilance (alert)
Vigilance by social demand (identifying the weak signals from civil society)	Non-scientific press (international, national, regional, local), insertion in the national and international networks and forums of NGOs, trade unions, consumer associations	Market research	Social barometer poll focus group
Scientific vigilance (identification of weak signals through research)	Scientific press. Insertion in scientific, national and international, networks, participation in international seminars and conferences, followed by invitations to tender, web sites of the large research centers		Experts' advice inquiry with experts
Technological vigilance (identifying weak signals from technology)	Technical press, results from experiments, notes from embassy counselors	Technological data bases from patents	Benchmarking
Regulatory vigilance (identifying weak signals through violation of regulations or new regulations)	Miscellaneous and legal press, complaints to courts, experiment results	Regulatory data bases	

3. A comparative analysis at the international level of national foresight practices in the environmental area

3.1. The American experience: a generalized and fragmented culture of technological foresight for competitiveness motives

Towards the end of the 1980s, the growing worry about the industrial and technological competitiveness of the United States (in particular with respect to Japan) led to the realization of the need for a technological policy, whence the resurgence of interest in technological foresight [13].

In the United States, there are several exercises both private and public which are related to foresight exercises. However, we can identify no system of co-ordination between these different exercises, especially since the disappearance of the Office of Technology Assessment (OTA) in the 1990s.

We will now proceed to presenting three exercises of reasonable importance particularly in their application to the environment.

3.1.1. The Critical Technologies exercise

Since 1981 and at regular intervals, Congress has been financing a report from the Rand Corporation entitled "National Critical Technologies". This report consists in the preparation of a list of "Critical Technologies" in different sectors and mentions the position of the United States with regard to Europe and Japan.

The list is generated by discussion groups made up exclusively of technical experts and in the latest report [14] completed by individual directed meetings with these same experts who are often quite few in number (30 or so in the latest exercise). The selection of technologies is based on criteria such as their contribution to economic competitiveness, their relevance to national security and their potential application in the different industrial sectors [15].

This method, the cost of which is quite low compared to those exercises using Delphi methods or scenarios, aims at clearly identifying the investment priorities in science and technology likely to lead to substantial economic growth.

The environmental technologies involved are considered to have high priority alongside national defense, health and transport, to the extent that we consider that, after the year 2010, we will witness an explosion of radical technological innovations destined to reduce or avoid environmental impact and develop the use of renewable energies [16].

Beyond the fact that the participation aspect is totally left out of this exercise, it is, furthermore, conceived from a "technological foresight" viewpoint aiming at generalized competitiveness and not at all concerned with social or cultural criteria.

3.1.2. The "Road Maps" provided by the private sector

American industry has taken the initiative in a certain number of foresight activities, thanks to commercial associations. This has led to the development of technological Road Maps [17]. They are piloted by industrialists or commercial associations strongly motivated by economic survival. They concentrate on the success of businesses in a given sector. The common worry about the threat of competitiveness produces strong motivation to co-operate and develop networks. The Road Maps study competitiveness in the medium term (5–10 years). This approach does not take social demand into consideration, except, perhaps, in terms of solvable demand. Its preoccupations about the environment when they are declared, are only of an economic nature. The national objectives of improvement in the quality of life and prosperity are not explicit. In accordance with the "weak" approach to sustainable development, these objectives are supposed to result from technological innovation and competitiveness. Finally, these exercises depend on a restricted panel of experts since only the representatives of the sector and perhaps the federal government take part in the construction of the scenarios.

3.1.3. The original exercises of the World Future Society

The World Future Society created in 1996 is presently the most important US institution for work in the foresight area. It regularly carries out foresight exercises in partnership with George Washington University [18,19]. The approach is interesting for it relies on a variety of methods. The "scanning" is used to identify the emerging technologies. The

analysis of the tendencies guides the selection of the most important technologies to further develop the study. The Delphi method is then mobilized for an additional evaluation in order to arrive at a better scientific and technical credibility. The results are used as a basis for a scenarios contrasted work concerning the evolution of the social, economic and environmental conditions of the world. The final stage consists of the presentation of the technological innovations spread out per periods of time.

Among the main results of this exercise, it appears that many technological innovations will be concerned with the area of environment and sustainable development. The main innovations (like the others) will come from the two leaders in the technological revolution, namely information and genetic engineering.

Globally, if the exercise is focused on one single technological problematique, it appears to us that the method used is interesting. It easily enables (even if the exercise itself does not) using experts' opinions (through the Delphi survey) and comparing them with other actors' opinions in a participative approach during the scenario building stage.

In the United States, the various foresight exercises remain above all turned towards competitiveness and technological innovation and depend mainly on the opinion of experts. Social demand is explored very little insofar as it is supposed to adapt, afterwards, with the technological innovations.

3.2. The British experience: a resolutely technological foresight torn between competitive motives and social welfare

The foresight process in the United Kingdom has become the central mechanism in the conception and putting into practice of the scientific and technological policies of innovation and Higher Education. It has also been adopted by Australia and New Zealand who participated in its successive improvements.

The different stages of the British foresight are the following ones:

- In the first stage or pre-foresight, a certain number of focus conferences took place in different regions in order to explain to the scientific and industrial communities what a foresight is and the interest of doing one. This process was accompanied by a Delphi survey.
- The second stage is the main stage of foresight. The panels began by discussions to prepare the ground in their sector and to identify the strengths and weaknesses. They also organized broader consultations on the basis of regional, thematic workshops. Each panel produced a preliminary report at the end of 1994. In May 1995, the steering committee published its report entitled "Progress through partnership" [15].
- The third stage of the foresight program or post-foresight is the putting into place of a certain number of components including:
    1. the formulation of the new priorities of the government's R&D (Ministries, "Research Councils", the Founding Committee of Higher Education);
    2. the influence of companies' R&D strategies;
    3. the encouragement of partnerships between industry and research;
    4. the influence of broader government policy (regulation);
    5. the preparation of the next foresight program (scheduled for 1999/2000), the various advantages of the foresight process being already obvious at this time.

At the end of this exercise, the question of what should be done next was raised: should the exercise begin again at the risk of being repetitive? Should the focus be put on a small number of areas? These questions arise all the more so since in 1997 Labor won the General Election. Right from the beginning, the Labor party, even in opposition, supported technology foresight. The question is not so much, then, wondering whether the exercise will be pursued as how it will be implemented.

The new foresight was launched in 1999 [20]. It contains the four following modulations:

- It shows a better balance between the goals of competitiveness (wealth creation) and quality of life. This latter objective refers to social, environmental and equity objectives and more generally to what is outside the markets.
- It broadens the scope of the exercise, as much in the number of persons as in the variety of the actors and institutions involved.
- It leads to a serious reduction in the emphasis given to research and technology in the exercise. It shows a participative dimension in the sense that it is re-centered on social demand [21]. In this context, the new exercise has officially been renamed "foresight" and no longer "technology foresight".
- On the methodological level, the major initiative is the discarding of the Delphi method in favor of the reconstruction of scenarios based on recourse to various participative techniques and the setting up of a knowledge pool in a web-site. The functions of this new instrument are communication, interaction, the generation of hypotheses and reaction to these hypotheses especially aimed at young people. It is also informed by a series of workshops spread throughout the country and bringing together different categories of actors.

Globally, even if the British foresight in its new version constitutes, according to the founding fathers, a "new social contract" [22], it remains basically a "social contract" between science and technology on the one hand and society on the other. It is situated within the vision of a technological foresight of a participative nature.

It is admitted in this approach that competitiveness depends on technological innovation and that the latter must henceforth satisfy social demand. So, the improvement in the quality of life in which the environmental dimension is an essential component, is a priority in this case. This is the reason why the environment (and more broadly sustainable development) occupies an important place (without nevertheless being the center) within the new, British foresight program. However, we see here all the ambiguity of its position. If it is more open to the participative aspect and to social demand, its final outcome is nevertheless technological innovation and competitiveness. In these conditions, it cannot be considered as a social foresight.

3.3. The German experience in terms of technological foresight: from a competitive outcome to an ecological priority

The German foresight activities began in 1991, when the Federal German Minister for Research and Technology (BMFT) financed studies looking into long-term international developments in science and technology. Up to the present day, the German activity in this area includes a certain number of reports concerning the technological aspects of the future and three large technological foresights which use the Delphi method (see Box 3).

Box 3. The three German foresights

(i) Germany has deliberately followed the Japanese experience and directives (objectives, subjects, characters and methods) to carry out its first Delphi. The German study, done by Fraunhofer ISI, entirely reproduces the fifth Japanese Delphi of 1991. It was financed and the results published by the German Federal Ministry of Research and Technology. One of the objectives of this approach was to compare the Japanese and German approaches to analyze the possible differences and understand the cultural influences on the assessment of technology [23].

(ii) The second Delphi study is an exploratory study on a smaller scale undertaken along the same lines in both Germany and Japan following the Germano–Japanese conference held in Berlin in 1994. It was, in fact a Mini Delphi which was used to improve a new study [24].

(iii) The third Delphi exercise began in 1996, in the form of a traditional survey in line with the sixth Japanese exercise.

The environmental theme takes on such an importance in the third German foresight that a special, additional analysis was carried out. The latter consisted of a transversal study to catalogue the technologies which were efficient from an environmental point of view [25]. It calls for the objectives of putting a sustainable development in place and refers back to the so-called strong perspective of sustainability. The realization of sustainable development implies a limitation in the use of natural capital, in particular through stopping growth or even the reduction of input in terms of material and energy. This solution, described as "dematerialization of the economy", is strongly encouraged in many Northern European countries, including Germany. This perspective considers that, in the next decade, the products, the production processes and the services may become from 4 to 10 times less intensive from the "environmental" point of view (this refers to the famous *leitmotiv* factor 4 or 10). It is clear that the contribution of technological innovation will be fundamental even if changes in consumer habits are also to be taken into consideration.

Globally, it appears that from the point of view of the final outcome of the foresights in Germany, the environmental dimension has become at least as important as the competitive dimension. The German foresights are suggesting that a cleaner environment will be achieved through people giving this objective a high priority rather than through improvements in technology. Here, it really is a case of a double final outcome and not just a case of the former being submitted to the latter as we have seen in the United States. However, paradoxically, up until the present day, the German foresights have been of a technological and not social nature. Moreover, the foresight methods used remain based on the views of experts and do not make use of participation between the latter and the other social actors.

3.4. The experience of the Netherlands: a profusion of technological and social foresights in the area of the environment and sustainable development

The Netherlands probably possess the greatest experience in terms of foresight exercises, at the interface between environmental policies (and even sustainable development) and technological policies [26].

Box 4. The 5 main environmental foresights carried out in the Netherlands

∗ A study on the possible technological options for solving environmental problems. It is called Technological Options for Environmental Problems (TOEP-study) (1992, 1994).

∗ A long-term foresight carried out by the Committee for Research on Nature and the Environment (RMNO) (1992, 1996).

∗ A program attempting to set up a Sustainable Technological Development (DTO) (1997).

∗ An environmental foresight process by the Foresight Steering Committee (OCV) (1992).

∗ A foresight entitled "81 Technology Options for Sustainable Development" (TNO, 1997).

The concept of "environmental efficiency" is a key-concept in Dutch environmental policy. It refers to a sustainable development path where economic growth, competitiveness and employment go hand and hand with a reduction in environmental pressure and the use of non-reusable raw materials. Technological development is considered as one (but not the only one) of the main elements making environmental efficiency possible.

In the launching of the new National Environmental Plan, at least five foresight exercises relating to what we described as technological foresights, or social foresights, or as being at the crossroads between both, have been carried out (see Box 4).

The last foresight exercise, financed by the Ministry of Housing, Spatial Planning and the Environment, was carried out by a team from the TNO (Netherlands Organization for Applied Scientific Research) [27].

The notion of "*technological system*" has been introduced into the exercise with explicit reference to the works of Carlson and Stakiewicz [28] and more generally to those concerning evolutionary economics. It explicitly supposes that there are a great number of technological options which could be described as sustainable and that encouraging technological development without thorough analysis does not constitute a guarantee of environmental betterment. For example, a new technology can generate new forms of pollution. In other words, technology implies as many threats as opportunities. A technological policy aiming at putting into practice a sustainable development should enable the opportunities to be strengthened (where this is possible) and the threats to be reduced. In the same way, the obstacles of a social, economic, cultural or organizational nature encountered by these scientific and technological systems are highlighted. In other words, this exercise starts from the hypothesis according to which the new, technological developments must be promoted according to the needs of society and its willingness to accept them.

This foresight gives priority to the social demand aspect over the technological innovation aspect in its very concept. However, it relies mainly on the opinion of experts even if experts from the Social Sciences have been generously represented beside experts representing the technical and scientific aspects. The team responsible for this study, conscious of this limit, is going to increase the participative aspect between the different categories of actors in order to really offer a social foresight in the field of the environment and the sustainable development.

The different exercises of foresight applied to the environment in the Netherlands show a great variety of methodology: multicriteria analysis, scenarios, panels of experts including, in certain cases a wide variety of actors. The Dutch experience shows that to reach such a balance, it is fruitful to develop diverse exercises using diverse methods.

In Table 3, we propose a synthesis of the different international experiences in terms of environmental foresight that we have previously analyzed.

4. The French case: original experiences in the search of an institutional support

Foresight was conceived and developed in France thanks to several founding fathers like Gaston Berger, Jean Fourastié, Bertrand de Jouvenel and Michel Godet. Its development was institutional, as, since the beginning, the history of foresight and planning have been intimately linked. Yet, since the oil scares, the interest in planning and hence foresight has dropped considerably. We had to wait until the beginning of the 1990s to witness in France, as elsewhere, a renewal of foresight especially in the environmental field. Nevertheless, this renewal was only temporary as we show in this last section.

4.1. Two national technological foresights with an environmental opening up

4.1.1. A foresight exercise using the Delphi method

From 1993 to 1994, Germany and France successively carried out the same foresight exercise, deliberately using the questionnaires of the 5th Japanese Delphi with few modifications [23].

The environmental concerns are heavily stressed in this exercise and on account of its transversal nature, it deals with a great number of topics. The exercise, like most of those using the Delphi method depends exclusively on scientific and technological experts. Accordingly, all other actors representing society are excluded. It is therefore a matter of non-participative "technological foresight". This exercise nevertheless casts some light on scientific and technical supply which is very useful in national research programming, if we judge by the positive impact that the Delphi exercises have had in other countries including in the environmental area [24].

That is why it is regrettable that the report which resulted from this study was not put into circulation. The experiment did not get the support expected in its operational stage in terms of the publication of results, the circulation of a layman public-orientated version, consideration in terms of important public choices, etc. Moreover, continuity was not guaranteed, particularly on account of a change in government during the realization of the project, and, perhaps, on account of the fear of competition (whereas it was rather a complementary exercise) with another study being carried out simultaneously inside the Ministère de l'Industrie. The impact of the Delphi exercise in France has thus been somewhat limited up to the present day compared to Germany and Japan [29].

4.1.2. The 100 key technologies

Another approach to technological foresight has been developed along the same lines by the Ministère de l'Industrie: "The 100 key technologies" [30].

Table 3
Synthesis of several experiments in the field of environmental foresight

	United States	Great Britain	Germany	Netherlands
Backer	Congress/OSTP/private sector/EPA/public and private research institutes	UK Cabinet Office (government)	Federal Ministry of Science, Research and Technology (BMFT)	Ministry of Science and Education
In charge	Rand Corporation/private sector/NGOs/Science Advisory Board (SAB), "Think Tanks"	Office of Science and Technology (OST)	Fraunhofer-Institute for System and Innovation Research (ISI)	RMNO/TNO-STB/OCV
Co-ordination	No coordinating body	Foresight Steering Committee (FSC)	Steering Committee for the 3rd Delphi	Foresight Steering Committee (OCV)
Objectives	Identifying priority research technologies and a better allocation of funds. Seeking out competitiveness opportunities. Raising number of patents	Increase British competitiveness. Creation of industry/research/government associations	Research organization; investment priority; improvement of links between industry and science; responding to environmental policies, anticipating them	Responding to the stakes of sustainable development
Place of social demand	Not concerned with quality of life (or social demand) as it must follow innovations. But the EPA needs public support	Integrating social demand in the new program (1999)	Not yet integrated but planned for the next program	Socio-cultural changes have always been heeded. Social acceptability of technological innovation is primary
Type of foresight	Technological foresight Culture of foresight	Increasingly participative foresight	Technological foresight	Social and technological foresight. Participative or not, by theme or broad category
Place of the environment	Study on use of foresight for environmental protection. Several special environmental studies	A panel of environmental experts. A great number of questions concerning the environment in the "Knowledge Pool"	A field concerned with environment and related areas. Environmental concerns given priority	Several foresight programs entirely on environment and sustainable development.
Methods used	Critical Technologies; Road Map; Delphi method; scenarios method multicriteria analysis	Panel of experts; Delphi method, scenario method; social demand workshops, 1999	Relevance Trees Method; Delphi method; Experts' Panel	Scenarios method; multicriteria analysis; Experts' Panel with high actor representation
Results	Commercial implications except for "Critical Technologies"	Development of partnerships between industry and research. Priorities taken into account by research organizations	Broad dissemination of Delphi study; panel of experts	High awareness of environmental policy. New research programs based on OCV recommendations. Impacts on all political decisions

This exercise was intended to identify the technologies important for French industry and the areas of high priority action to promote development on the relatively short time scale of 10–15 years.

The methodology used in this project corresponds perfectly to the tradition of "technological foresight" exercises using the "Critical Technologies" method. It started with the setting up of a coordinating committee made up of members of the government, and representatives from the research and industrial sectors. This committee then adopted nine criteria, one of which being the environment, for the selection of technologies. Then, the following stage consisted in organizing groups of experts (composed of about 20 members) meeting periodically (1993–1994). This work resulted in a list of 676 realizable technologies,136 of which were classified as being strategic. In a fourth stage, these technologies were evaluated according to the competitive position of France. Finally, 105 technologies were labeled "key technologies". The approach is very similar to that used in the German exercise entitled "German Technologies at the Beginning of the 21st Century" [31] or to the one used by the United States in its Critical Technologies exercises and presented in the preceding section.

The impact and success of this purely technological foresight exercise have been important thanks to its pragmatic approach but also thanks to the institutional support it enjoyed unlike the Delphi study presented above. The announcement that this exercise was to be continued very early on in the process also turned out to be a factor of its success. The Ministère de l'Industrie in fact launched a second exercise in 1999, entitled "Key Technologies — 2005".

4.2. A social foresight in the environmental field

In 1995, the Ministère de l'Environnement, the ADEME and the CEA launched a foresight study of a national nature on "the long-term evolution of the environmental social demand and its application in terms of R&D" [32].

The aim is to discern the present-day social demand and the demands projected onto the 2010–2020 horizon in terms of the environment.

To grasp the social demand in the environmental area, the following approach was adopted:

1. The realization of a "free forum" centered on the representations of the public at large in terms of the environment. Unlike the usual methods of opinion-gathering which avoid open questions and impose their categories on the persons questioned individually, a "free" space was created for a group of participants of different origins. This is obviously far from a statistically representative sample of the French population but this was not the aim: the methodology used, in fact, concerns participative techniques such as focus groups that we presented in the first section.
2. The organization of four "demand" workshops, each one bringing together 15 social actors selected according to pre-defined profiles (locally-elected officials, representatives of associations and companies, journalists, artists . . .) and experts from the areas involved (nature and landscape, towns and territories, health and risk, global problems).
3. Semi-directed meetings (20 or so) with representatives of public research organizations.

4. A face-to-face confrontational supply and demand workshop. It convened, for a whole day, certain actors who had participated in the demand workshops and representatives of R&D organizations. Their aim was to validate the structure and content of the precursory axes (approximately 70) of R&D from stages 1 and 2 devoted to the analysis of demand.

This foresight exercise, using scenario-type methods, is based on an original version of "participation" between different categories of actors including technical and scientific experts (particularly in the last workshop). The purpose is of simultaneously highlighting a certain number of emerging environmental problems (or ones which could emerge) and certain leads for solving these. These leads can be simultaneously institutional, organizational, cultural, technological, etc. In this way, the exercise constitutes an experiment with a certain interest in terms of "social foresight" applied to the environmental and sustainable development areas. This is true despite the fact that the exercise necessarily has some methodological weaknesses, on account mainly of its innovative character and, above all, its lack of mastery of participative techniques and methods. However, once again, if the diffusion of results was better than in the Delphi survey, it was limited to a small circle of actors. It also suffered from being perceived in competition with the exercise we present in the following paragraph (and vice versa). As we explain afterwards, they were actually two complementary exercises.

4.3. An international exercise in scientific vigilance in the environmental field

In 1993, the Ministère de l'Education Nationale, de la Recherche et de la Technologie and the Ministère de l'Aménagement du Territoire et de l'Environnement were involved in the setting up of an international survey [33]. The aim was to understand how environmental priorities linked up with each other and to identify the emerging themes from the scientific world which would contribute to the long term reflection of the decision-makers in the private and public domains. For this, researchers were invited to participate directly in the debate on present-day environmental priorities and future themes by explaining their own criteria for setting up hierarchical orders. Thus, it was possible not only to gather the visions that scientists from different parts of the world have of the multiple problems of the environment and their interaction but also to show from a convergence analysis, a certain number of "weak signals" as defined in our first section.

Fourteen thousand researchers from the five continents were contacted by mail between March 1995 and June 1996 [34].

This study turns out to be a huge scientific vigilance operation with little or no equivalent on the global level in the environmental field.

It certainly suffered from the lack of a foresight reflection in upstream which would have focused the area of questioning in a more disciplined way. In fact, this work suffered from such an accumulation of data as we explained in the first section, that the treatment of it has not yet been finished. That is why we think that this environmental vigilance exercise should have been undertaken, for example, after the "social foresight" in the environmental area that we presented above which would have helped to better define its area of investigation.

Nevertheless, some very interesting data were included in the report, which appeared in 1997. However, it had only a limited circulation and has led to few publications or developments up until now. Once again, the institutional support ended when the report was handed in.

5. Conclusion

As an outcome of this analysis, some main results appear important.

We are witnessing the appearance of a participative dimension (and methods) in foresight exercises where experts' opinions and the consultation of social demand are sought. Through such a process, a pro-active confrontation between scientific and technological opportunities and social demand can be carried out and lead to a reconciliation between science and technology and the needs expressed by society in terms of environmental risk.

From this point of view, any foresight exercise can be attempted not only according to the two traditionally assigned dimensions of level of expertise and level of creativity, but also in terms of its opening up to the participative dimension which explains our triangular diagram.

In these conditions, it is no longer possible, as in the past, to dissociate scientific and technological policy from environmental policy as they are necessarily linked by social demand.

It is then a question of promoting the setting-up of "social foresights" in addition to "technological foresights" particularly in the environmental field. This improves the chances of moving towards a sustainable future and developing technological innovations with socially acceptable outcomes.

It would be difficult for France to go in the opposite direction of the international developments in terms of conception and realization of foresights especially since she had previously gained an undeniable methodological advantage in the setting up of both technological and social foresights particularly in the environmental risk area.

References

[1] Institute for prospective technological studies — IPTS — 1999, Technology map, Futures Report Series, Vol. 11, Joint Research Center, European Commission.

[2] S. Faucheux, J. Gowdy, I. Nicolaï (Eds.), Sustainability and Firms — Technological Change and the Changing Regulatory Environment, Edward Elgar, Cheltenham, UK, Northampton, MA, USA, 1998.

[3] OECD, Special Issue on Government Technology Foresight Exercises, STI Review, Science, Technology, Industry, No. 17, 1996.

[4] H. Grupp, Foresight activities: introduction to special issue "National Foresight Projects", Technol. Forecasting Soc. Change 60 (1) (1999) 1–3.

[5] S. Faucheux, E. Muir, M. O'Connor, Neoclassical natural capital theory and "weak" indicators for sustainability, Land Econ. 730 (1997) 528–553.

[6] P. Lascoumes, "La scène publique, nouveau passage obligé des décisions?" Annales des Mines, Avril, 1998, pp. 51–62.

[7] J.P. Bailly, Prospective, Débat, Décision Publique, Journal Officiel de la République Française: Avis et Rapports du Conseil Economique et Social, extrait du rapport no. 16, Paris, France, 1998, pp. 13–129.

[8] B. Fischhoff, Risk perception and communication unplugged: twenty years of process, Risk Anal. 15 (2) (1995) 137–145.
[9] M. O'Connor, The VALSE project — an introduction, Ecol. Econ. 34, special issue: Social Processes of Environmental Valuation, 2000, pp. 165–174.
[10] B.J.R. van der Meulen, The impact of foresight on environmental science and technology policy in the Netherlands, Futures 31 (1999) 7–23.
[11] S. Faucheux, M. O'Connor, "Technosphere versus Ecosphere. Quel arbitrage? Choix technologiques et menaces environnementales: signaux faibles, controverses et decision", Futuribles no. 251, 2000, pp. 29–59.
[12] EPA — Environmental Protection Agency, Futures: Detecting the Early Signals, 1999 Science to Achieve Results (STAR) Program, Office of Research and Development (ORD) http://es.epa.gov/ncerqa/rfa/bfutur.html, 1999.
[13] B.R. Martin, Technology foresight as a tool for strategic management, in: J. Anderson, R. Fears, B. Taylor (Eds.), Managing Technology for Competitive Advantage, Cartermill International, London, UK, 1997, pp. 31–47.
[14] S.W. Pooper, C.S. Wagner, E.V. Larson, New Forces at Work: Industry Views Critical Technologies, Report, Rand Corporation, Washington, USA, 1998.
[15] Office of Science and Technology — OST, Progress Through Partnership, No. 11, Agriculture, Natural Resources and Environment, Collection: Technology Foresight, HMSO, London, UK, 1995.
[16] J. Anderson, R. Fears, B. Taylor (Eds.), Managing Technology for Competitive Advantage, Cartermill International, London, UK, 1997.
[17] G. Stokes, 1999, Critical technologies for the environment, in: Proceedings of the Budapest Workshop on Technology Foresight and Sustainable Development, 11 décembre 1998.
[18] W.E. Halal, M.D. Kull, A. Leffmann, Emerging technologies: what's ahead for 2001–2030, The Futurist, World Future Society, 1997.
[19] W.E. Halal, M.D. Kull, A. Leffmann, The George Washington University forecast of emerging technologies — a continuous assessment of the technology revolution, Technol. Forecasting Soc. Change 59 (1998) 89–110.
[20] Office of Science and Technology — OST, Blueprint, For the Next Round of Foresight, DTI, London, UK, 1998.
[21] E. Masood, UK eyes social goals for next Foresight, Nature 393 (1998) http://toc.edoc.com.
[22] B. Martin, R. Johnston, Technology foresight for wiring up the national innovation system: experiences in Britain, Australia and New Zealand, Technol. Forecasting Soc. Change 60 (1) (1999) 37–54.
[23] K. Cuhls, T. Kuwahara, Outlook for Japanese and German Future Technology — Comparing Technology Forecast Surveys, Technology, Innovation and Policy, Series of the Fraunhofer Institute for Systems and Innovation Research (ISI), Vol. 1, Physica, Heidelberg, Allemagne, 1994.
[24] J.A. Héraud, The Comparison of a Delphi Foresight Survey on the Environmental Technologies of the Future in Japan, Germany and France, Working Paper BETA No. 9906, Université Louis Pasteur, Strasbourg, France, 1999.
[25] U. Kuntze, Resource-efficient technologies — results and methodological aspects of the German Delphi'98 survey, Technology foresight and sustainable development, in: Proceedings of the Budapest Workshop, 11 December 1998, Working Group on Innovation and Technology Policy, OECD, 1999, pp. 26–48.
[26] F.A. Vollenbroek, R. Weterings, M. Butter, Technology options for sustainable development, Technology foresight and sustainable development, in: Proceedings of the Budapest Workshop, 11 December 1998, Working Group on Innovation and Technology Policy, OECD, 1999, pp. 83–94.
[27] R. Weterings, J. Kuijper, E. Smeets, 81 options technology for sustainable development, Report for the Ministry of Housing Physical Planning and the Environment, TNO Center for Technology and Policy Studies, Apeldoorn, Pays Bas, 1997.
[28] B. Carlson, R. Stankiewicz, On the nature, function and composition of technological systems, J. Evolutionary Econ. (1) (1991) 93–118.
[29] J.-A. Héraud, F. Munier, K. Nanopoulos, Méthode Delphi: une étude de cas sur les technologies du futur, Futuribles, No. 218, Mars, Paris, France, 1997, pp. 33–53.
[30] Ministère de l'Industrie (DGSI), Les 100 technologies clés pour l'industrie française à l'horizon 2000, Paris, France, 1996.
[31] H. Grupp, Technology at the beginning of the 21st century, Technol. Anal. Strategic Manage. 6 (4) (1994) 379–409.

[32] Ministère de l'Aménagement du Territoire et de l'Environnement, l'ADEME et le CEA, De la Science Autrement: Etude prospective de la demande "environnement" et sa traduction en termes scientifiques et techniques à des fins de programmation de la R&D, 1997.
[33] Ministère de l'Education Nationale, de la Recherche et de la Technologie et Ministère de l'Aménagement du Territoire et de l'Environnement, Recherche et Environnement. Thèmes prioritaires et thèmes émergents. Enquête internationale auprès de la communauté scientifique, octobre, 1998.
[34] A. Pavé, C. Courtet, J.-L. Volatier, "Mille chercheurs hiérarchisent les urgences", La Recherche, Paris, 1998.