Technical University of Denmark

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*Publication date:*
2003

*Document Version*
Publisher's PDF, also known as Version of record

Risø-R-1421(EN)

# Debating the future of genetically modified plants - - bridging knowledge dimensions

## A technology foresight study

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November 2003

**Abstract**

Rapid developments in, and the controversial nature of, biotechnology call for communication, networks, partnerships, and collaboration in research, not just among researchers but also between researchers and research “users” in industry, government, and elsewhere. Technological foresight appears to offer a coordinating method for developing and strengthening those linkages. To test this, a technological foresight study was performed on genetically modified (GM) crop technology in the Danish context. The background to the study was the conflict and intense debate in Denmark over applications of gene technology, and especially over the deliberate release of GM crops. However, the current debate characteristically involves sharply opposed fronts. In it, stakeholders and experts on both side of the conflict advocate widely differing opinions. Without a proper, generally intelligible dialogue, the broader public audience finds it hard to comprehend this type of debate. The study pursues the notion that public dialogue can act as a driver of future applications in the technological domain, specifically GM crops. The study concluded with a stakeholder workshop that revealed three key issues that might provide helpful starting points for a more free-flowing and open-minded debate about the future of GM crops. The issues were those arising from the following statements: a broad perspective on risk is crucial; international regulation must make allowance for developing countries; a better configuration of the risk debate is needed. These issues are discussed in more detail in the report, along with the foresight method we used to reveal these issues.

ISBN 87-550-3242-7 (Internet)
ISSN 0106-2840

# Contents

# Preface

This report concludes a two-year technological foresight study considering the commercialisation of gene-modified plants. The study was inspired by our previous experience of commercialisation of gene-modified crops and how difficult it is to delimit and establish a deliberate dialogue between scientists, stakeholders and other experts.

The study has been supported by the Carlsberg Foundation and carried out under the auspices of the Centre for Bioethics and Risk Assessment at the Royal Veterinary and Agricultural University in Denmark.

# 1 Introduction

The debate on the application of gene technology has been intense in Denmark, dating back to the last half of the eighties, where the first GMO's had just been introduced, and a legislation on gene technology had just been passed in the parliament. As a participatory policy instrument the Danish Board of Technology held the first consensus conference entitled 'Industrial and Agricultural Gene Technology' in 1987. The debate has kept going especially on the deliberate release of genetic modified plants (GMP) in agriculture. However, this has not resulted in a clarification of the policy in the field, and the debate has reached a deadlock. Thus a characteristic of the current debate is sharply opposed fronts, where opposing opinions are advocated with absent of proper dialogue. This power battle has left the public on the sideline, while scientists, stakeholders and other experts are in dispute.

When the experts disagree, and uncertainty and benefits simultaneously are thought out and intensified on both side of the conflict policy makers are placed in an inconvenient situation, and the public react by distrust (van Dommelen 1999). When a concept like risk with its multiple and difficult facets is to be discussed, it is necessary for the experts to communicate cross disciplinary, which experts often find difficult probably due to different traditions or different epistemic cultures (Knorr Certina, 1999).

Dialogue is a problematic affair due to differences in professional language and culture. Michel Gibbons (1999) has pointed at the European debate on GMO as an example of breakdowns in social authority arising because this dialogue is inadequate established: *Since expertise now has to bring together knowledge that is itself distributed, contextualized and heterogeneous, it cannot arise at one specific site, or out of the views of one scientific discipline or group of highly respected researchers. Rather it must emerge from bringing together the many different 'knowledge dimensions' involved. Its authority depends on the way in which such a collective group is linked, often in a self-organized way.*

Dialogue between stakeholders must be prompted, where the risks and uncertainties of the future is debated considering both scientific and societal matters. Such dialogue is especially necessary in controversial areas such as the commercialization of GM crops, since the relevant benefits and risks here have an impact on society, the environment, policy questions, agricultural management and the economy. Issues also arise here, of course, for the biotechnology industry, where many companies are poised to prosper from GM crop technology. However, the so-called 'biotech companies' often remain silent in the public debate, and only a few have taken steps towards developing transparent tools to manage the potential risks and uncertainties that GM crops involve (Stirling & Mayer, 1999; Lafourcade & Chapuy, 2000; Borch & Rasmussen, 2000a). This reluctance will only postpone a sustainable development and judicious application of the technology.

The conflicts about plant gene technology and the unsuccessful attempts to soften it has stalled commercialization of GMP in the EU for several years and has implicated a decline of plant science in several EU countries both in private and public sectors (Hodgson, J. 2000, The Economist 2002). The direct reason is the *defacto moratorium* that has been in effect since 1999, where Denmark, Greece, Italy, France, and Luxembourg, formed a minority group that by voting together would, in effect, oppose any Europe-wide commercial approvals of GM crops. The *moratorium* would be in effect at least until the 90/220 directive (covering the release of GMOs into the environment) was revised to provide a stricter legal framework covering not only safety, but also labeling and traceability. Whether the revised directive, called 2001/18, which came into force on October 17, 2002, will approach the public hesitance towards this technology and its products, remains to be demonstrated. The directive is biased towards managing information and data that are operational and reproducible. This can result in too much emphasis on experts' scientific knowledge, and too little emphasis on the more elusive socio-economic and ethical questions. But, the latter are important from the point of view of public acceptance.

# 2 Aim and approach

In this report we suggest a procedure to identify, rate and rank topics that will be most central elements of the future debate on GMP technology due to importance and perceived impact in the view of disagreement and controversies between stakeholders. The aim is to facilitate and qualify the future debate on GM technology by bringing disagreements forward to elucidate and inquire the attitudes and assumptions behind in a process where a representative group of stakeholders confront each other as equals. We anticipate that this can contribute to identify the central topics in the risk debate and in that way also contribute to unlock the debate through a heuristic dialogue between key stakeholders.
From a methodological point of view the purpose is to develop a framework that can support strategic planning and regulatory policy-making related to GMPs in agricultural systems. A technology foresight (TF) framework involving dialogue was used. It amounts to a systematic inquiry into the long-term future of science, technology, the economy and society. The aim in the present context was to recognize and exploit generic trends that will have an impact in the commercialization of GM crop technology. Technology foresight addresses information, viewpoints, controversies etc. that cover different knowledge dimensions (economy, technology, environment, society, policy, and values). Foresight is about recognition of patterns of influences that leads to speculation about what may happen. Foresight can be carried out by a broad set of analytical and participatory methods ranging from desktop research, expert groups, and stakeholder involvement to interactive brainstorming processes or broad participatory arrangements.

# 3 Methodologies

To gather data and provide intelligence from the stakeholder community of plant biotechnology we used a process of iterations between questionnaire and workshops. Initially this process had an explorative or divergent nature, which later focused or converged on what appeared to be central issues. Therefore, the overall method can be described as a technological foresight framework and a step-by-step procedure of iterations between questionnaires and workshops moving from an explorative phase towards a more focusing phase. Each step gave input to proceeding steps:

1. System modeling on case based on a Life Cycle Inventory (section 3.1)
2. Explorative questionnaire and co-nomination of stakeholders (section 3.2)
3. 1st focusing workshop (section 3.3)
4. Focusing questionnaire (section 3.4)
5. 2nd focusing workshop (section 3.5)
6. Findings, reflection, interpretation (chapter 4)
7. Report

## 3.1 System modeling - Life Cycle Inventory

A Life Cycle Inventory (LCI) on a Danish breeding company's activity on plant gene modification (Borch & Rasmussen 2000b, Borch & Rasmussen 2002) both acted as a starting point and a delimitation of the study. The LCI gave us an initial list of members of the "stakeholder community", and a more substantial list was produced by asking these persons to identify further stakeholders through a so called co-nomination procedure (Nedeva et al, 1996). All persons in the list of the "stakeholder community" later received questionnaires.

The overall objective of the plant breeding company's activity, was to produce a variety of GM-ryegrass plants which are incapable of producing stems and flowers during grassland farming (biological encapsulation). Without stems and flowers, the transgenic ryegrass would have a reduced presence of the poorly digestible lignin, and this would enhance its nutritional value. The test case focused on ryegrass planted as fodder. The cultivation of ryegrass for seed production, turf, lawns, football grounds and so on was not considered.

The present study involved a discussion of a conventional perennial ryegrass system compared to a hypothetical system with genetic modified perennial ryegrass. As one of the systems is hypothetical, it has been chosen to perform a qualitative "What-if" discussion of the two systems on basis of a life cycle inventory of the conventional ryegrass system. The structure of the LCI/TF approach of the two different ryegrass production systems is presented in Figure 1.

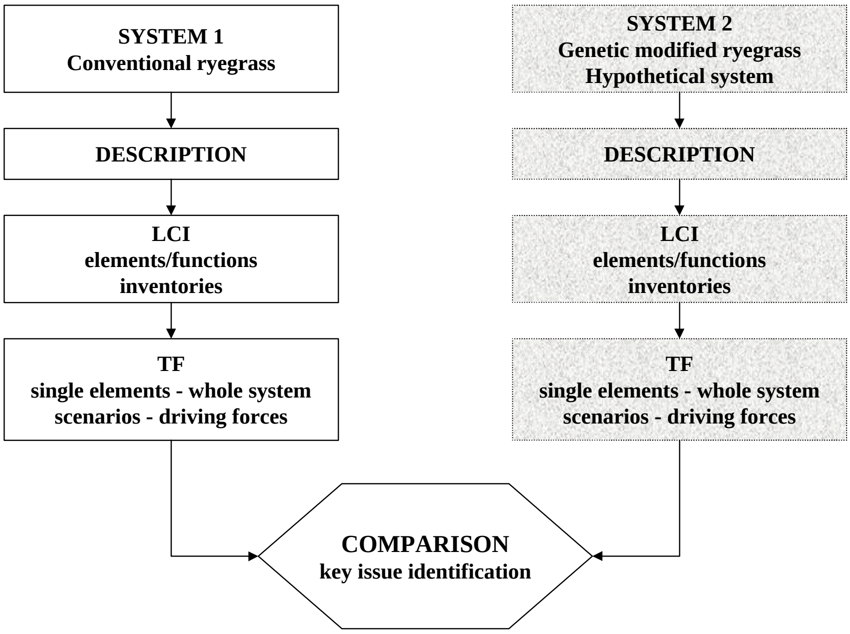


*Figure 1. LCI/TF of ryegrass system.*

The structure and procedure of the system modeling is described in more details in previous work (Borch and Rasmussen, 2000b).

## 3.2 Explorative questionnaire and co-nomination of stakeholders

The LCI exercise (including literature studies), interviews and a survey of the media debate identified a group of stakeholders who received an explorative questionnaire introductory asking for information on education and main professional activity. Out of the 112 responds 89 could be analyzed. The majority conducted academic research with educational background inside life science (see Figure 2 and 3). Further they were requested to give three statements in favor for GMP technology and three that opposed the use of GMP technology. The stakeholders were also asked to give information on additional persons with knowledge about GMP technology and its potential use or who otherwise could contribute to the project. This co-nomination procedure (Nedeva et al 1996) identified 243 Danish persons with expertise in or interest for GMP technology and the project who all received the explorative questionnaire. Out of the 243 nominated persons 112 responded resulting in about 600 statements on future needs/possibilities on one side and negative consequences/worries on the other. These were clustered in the categories and subcategories shown in box 1.

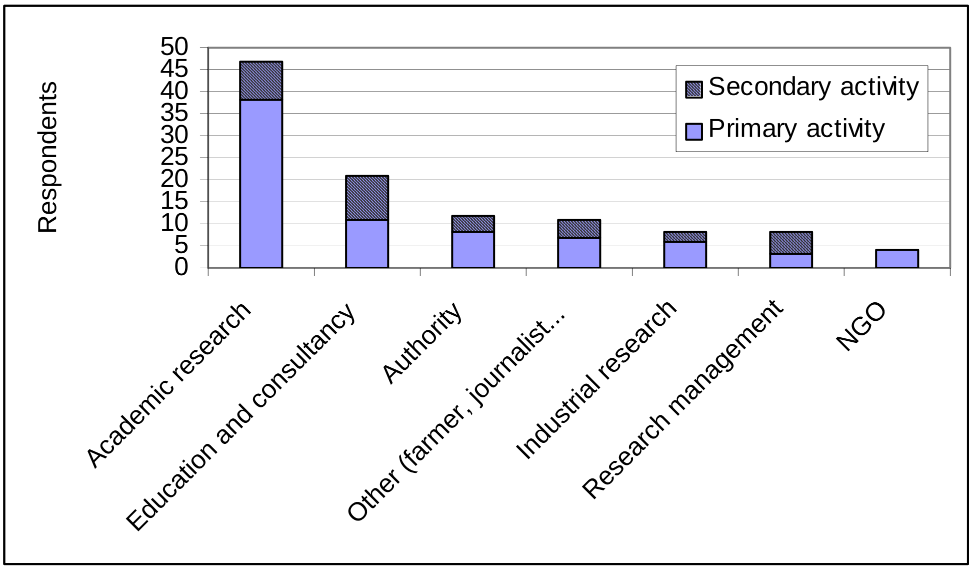


*Figure 2. Distribution of respondents according to primary and secondary professional activities. The total number of analyzed responses was 89.*

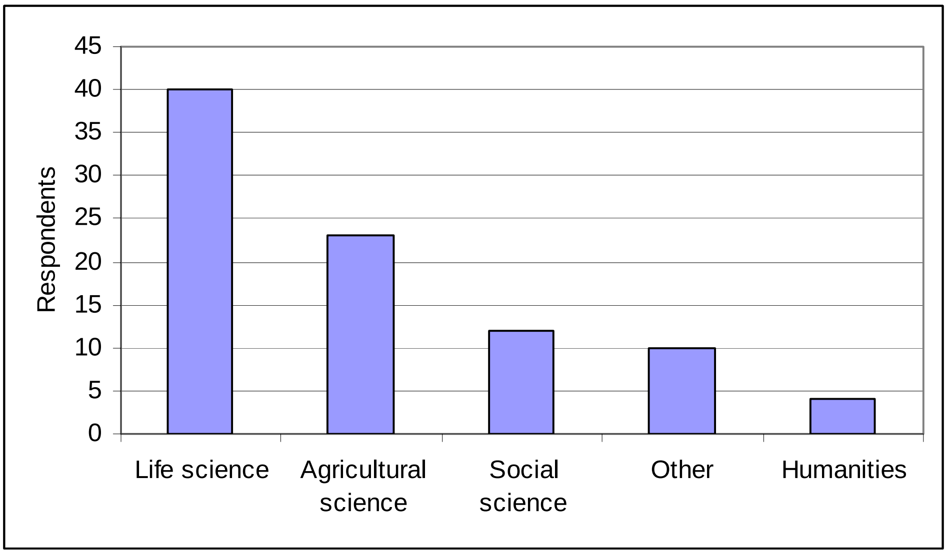


*Figure 3. Distribution of respondents according to educational background. The total number of analyzed responses was 89.*

| Box 1 Arguments against GM crop technology |
|---|
| **Theological argument**<br>Tampering with DNA is interference with creation and should be left to God. |
| **Order of Nature**<br>The manipulation of DNA is to disturb the order of nature, and is ethical wrong. |
| **Risk arguments** |
| - Harmful effects on human and animal welfare<br>- Harmful effects on the environment for example: |
| Direct and indirect non target effects<br>Introgression (incorporation of genes from transgenic crops into wild plants)<br>Creation of new viruses<br>Displacement of wild plants<br>Undermining of pest resistance as ecological niche<br>Increased use of pesticides |
| **Argument of precaution –** arguably GM plant technology constitutes risk of harmful effects and should therefore not be utilized with reference to the precautionary principle. |
| **Slippery slope argument** - if we allow the development of gene technology it will lead to more and more questionable projects as for example cloning of humans |
| **Profit argument (monopoly) –** large transnational corporate companies can achieve monopoly which is ethical problematic because they only develop products to gain profit. |
| **Technical fix –** GM plant technology is problematic because it only fix the symptoms rather than dealing with the fundamental problems in modern food production. |
| **Lack of trust**<br>The public does not feel that experts and decision makers take their worries seriously. |
| **Skepticism towards new technology** |

| Box 2 Arguments in favor of GM crop technology |
|---|
| **Developing countries**<br>- Stress tolerance<br>- Higher yield<br>- Healthier crops e.g. A vitamin enriched rice |
| **New industrial products based on gene modifies crops**<br>- Novel food/feed products<br>- Allergy friendly crops<br>- Production of enriched food and feed<br>- Non-food products (plant factory)<br>- Polymers, enzymes<br>- Pharmaceuticals<br>- Vaccines, hormones |
| **Environmental benefits**<br>- Reduced use of pesticides<br>- Pests resistance<br>- Higher yield<br>- New principals of forming<br>- Low input plants<br>- Better composition for feed<br>- Phytoremediation |
| **Economic gain**<br>- Lower consumer prices<br>- Lower production cost<br>- Higher earnings to biotech industry |
| **Improved food quality with GM crops**<br>- Better taste, longer shelf life and esthetic appearance |

## 3.3 1st focusing workshop

The stakeholders identified through the co-nomination procedure were clustered according to their expertise and area of interest. From these clusters stakeholders who had received the greater number of nominations were invited to participate in a workshop. The following composition of the workshop panel reflecting our attempt to cover main perspectives and interests in the area:

- Scientist (natural science) specialized in plant risk assessment from a public research institution
- Scientist (natural science) specialized in molecular plant biology from a public research institution
- Philosopher specialized in bioethics from a state university
- Social scientist specialized in risk communication from a state university
- Social scientist specialized in technology and society
- Policy-maker from the Danish Forest and Nature Agency
- Agronomist from a major Danish NGO[1]
- Agronomist from a major national agricultural organization
- Scientist employed by the plant breeding company

The workshop was designed as an explorative brainstorm where the categories found in the first questionnaire acted as a catalogue of cues for inspiration. The stakeholder panel was asked to formulate two statements each based on the cues. These statements where then presented in a plenary session where the rest of panelists were allowed to comment briefly. After the workshop the statements were clustered and reformulated into 36 value-laden statements.

## 3.4 Focusing questionnaire

A Delphi questionnaire (in Danish) was prepared (Table 1), where the 36 statements were grouped into four categories. The respondents from the first questionnaire were then asked to consider whether they agreed or not with the 36 value laden statements. Furthermore, the respondents were asked to discount that the statement was value laden and only consider the neutral issue addressed in the statement (e.g. ”Experts communicate poorly with one another” would become the issue: “Communication between experts”). The issue was then judged with respect to what role it would play in the future debate; a major or a minor role. The results made it possible to sort and prioritize the statements after two principles (se figure 4):

- by level of agreement on a specific statement among the respondents
- by the influence on the future debate of the issue behind the statement

1 It turned out to be problematic to find a representative from NGO’s due to mistrust in the project intensives assuming it to be biased in favour of the GMP technology.

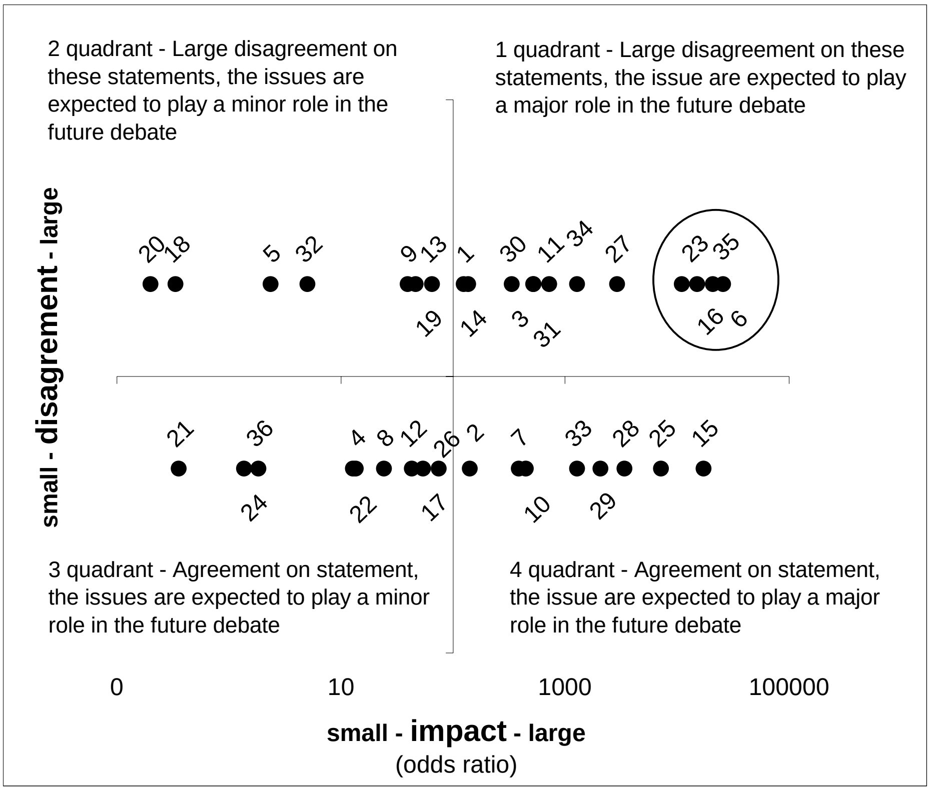


*Figure 4. Matrix in which the issues can be sorted with respect to importance and disagreement among the stakeholders; the labels refer to statements in table 1. The prioritized issues for this analysis have been encircled in the 1 quadrant.*

Prioritizing the level of agreement is done straightforward by putting the statements first where the same number of "votes" was split evenly between disagreeing and agreeing. Those statements where most respondents either disagreed or agreed to the statement were put last. Thus irrespective whether most stakeholder agreed or disagreed with the statement it was prioritized the same.

To prioritize the statements in accordance to their anticipated role in future debate we used weighted expert opinion, taking into account the different levels of expertise (for details see Borch & Rasmussen 2002).

Using the described prioritization four statements stand out (no. 6, 16, 23 and 35, Table 1):

- GM crops are a prerequisite to meet the developing countries need for food (no. 6).
- Pesticide resistant crops will lead to a reduced use of pesticides (no. 16).
- GM crops do not show the way to more environmental farming (no. 23).
- Knowledge about long-term consequences cannot be obtained (no. 35).

*Table 1. The statements in the order they appeared in the second questionnaire distributed among the stakeholders. The statements were edited in order to fit the format of the questionnaire.*

| | |
|---|---|
| 1 | Restrictions (indemnification, labeling etc.) on GM products undermine the economy |
| 2 | Capital needs for developing GM crops will reduce locale influence due to monopoly |
| 3 | Only patent owners can make a profit on GM crops |
| 4 | GM technology will not reduce time required to breed new varieties |
| 5 | The farmers will only use GM crops for competitive reasons |
| 6 | GM crops are a prerequisite to meet developing countries need for food |
| 7 | Which type of breeding technology in the developing countries is needed is their business to decide |
| 8 | GMP will become an important source for vaccines against tropical disease |
| 9 | A-vitamin needs in developing countries can be solved in a better and cheaper way than A-vitamin enriched GM rice |
| 10 | Risk assessment of GM crops in the developing countries must be prioritized high |
| 11 | GM crops for processing pharmaceuticals will become reality in the future |
| 12 | Allergens and toxic substances can be reduced in food using gene technology |
| 13 | Non-food products will be primary areas for future utilization of GM crops |
| 14 | Environmental friendly production of industrially products can be advanced by GM crops |
| 15 | Gene technology will not be used in food production in near future |
| 16 | Pesticide resistant crops will lead to reduced use of pesticides |
| 17 | GM fodder that better can be utilized by the animals, will reduce manure pollution |
| 18 | GM crops will imply better land utilization (more amenity areas, less farming of marginal land etc.) |
| 19 | Pesticide resistant GM crops will lead to increase in biodiversity |
| 20 | It takes a high education level in the agricultural industry to handle GM crops safely |
| 21 | Phytoremidiation is an area where GM plants will be utilized in the future |
| 22 | Stress tolerance (drought, cold etc.) in GM crops can solve some of the problems caused by climate change |
| 23 | GM crops will not lead to more environmental benign farming |
| 24 | Biotechnologist need to bee more holistic oriented |
| 25 | Gene spreading can never be prevented |
| 26 | Demands on legitimacy are especially tough when gene technology is commercialized |
| 27 | Only public and independent research can promote gene technology in common interest |
| 28 | Nonchalant announcement about the low risk of gene technology reduce public trust |
| 29 | There must be more room to discuss uncertainty in the debate |
| 30 | The politicians must set out guidelines for modern agriculture |
| 31 | Intellectual property rights restrain the research |
| 32 | There is a lack of forums where the public can express their uneasiness of controversial technologies |
| 33 | More resources is needed for consequence and utility value assessment |
| 34 | Gene technology will lead to decreased crop diversity |
| 35 | Knowledge about long-term consequences can not be obtained |
| 36 | Experts communicate poorly with one another |

## 3.5 2nd focusing workshop

To the second and last workshop we invited the stakeholders from the first workshop to participate. However, only half of these could join us for the second time for various reasons. Other members of "stakeholder community" were then invited until the workshop again covered main perspectives and interests in the area. Unfortunately, the participant from the major national agricultural organization and the participant specialized in molecular plant biology from the public research institution cancelled too late to find a substitute. Furthermore, the "social scientist specialized in risk communication" was substituted by a prominent writer and debater who could reflect the developing countries perspective.

Another deflection from the first workshop was the use of a professional facilitator. The intention with the involvement of a professional facilitator was on the one hand to introduce a person for the panel to whom the panelists were not prejudiced and on the other hand to hold the context of the dialogue (Senge, 1990).

The main purpose of the 2nd focusing workshop was to discuss the four statements from the questionnaire where the respondents disagreed most and where the issue is anticipated to play a major role in the future debate (statement no. 6, 16, 23 and 35, Figure 4).

Prior to the workshop the four statements were forwarded to the participants and they were asked to pick the one they found most interesting to discuss. The majority of the participants picked statement no. 35: "Knowledge about long-term consequences can not be obtained". The reasoning for this choice was that this issue embraces many important subjects, allowing for a more general discussion. From a procedural perspective, however, a general discussion is difficult to delimit and you run the risk of having a superficial discussion.

Next in the workshop the facilitator invited the panelists to interview each other in groups of two or three addressing the issue "Knowledge about long-term consequences can not be obtained". They were asked to emphasize on the content, the prerequisites, and values and logic behind their own viewpoints and attitudes. On shift the interviewers then presented loyally the interviewed persons viewpoints and attitudes on the issue. In this way all panelists were forced to try to understand and clarify the attitudes and viewpoints from another perspective than their own hopefully providing a better basis for discussion and reflection.

# 4 Findings, reflection, interpretation

We hypothesize that the debate will be a main driver of change for the future of GMPs and therefore it is essential to identify central issues that will shape this debate. The iterative process of questionnaires and workshops to provide intelligence from in the stakeholder community gave the opportunity to identify and prioritize the perceived key issues that the stakeholder / expert community expect to be dominating for the future GMP debate in Denmark. The criterions for prioritizing was: 1) a high degree of disagreement between the stakeholders about the value laden statement, and 2) agreement on importance of the issue for the future debate on GMP.

In the following we present the main findings from the 2nd focusing workshop addressing statement no. 35: "Knowledge about long-term consequences can not be obtained", which was selected by the panelists as the main starting point for the discussion. During the workshop it became quite clear that this statement can be discussed from different perspectives focusing different aspects, and in order to present the main issues of the workshop we have chosen to cluster the issues and the belonging reflections around three sub-themes:

a) a broad perspective on risk is needed
b) developing countries and market power
c) configuration of the risk debate

Further, we have tried to relate the main issues to statements, results and view-points found in the open literature.

## 4.1 A broad perspective on risk is needed

Initially the panelists revolved about the need to understand risk in a "broad" perspective, as opposed to the traditional "narrow" perspective formulated within and associated with natural science. Although the panel discussion contested the official "risk window" for being rather limited and biased considering the multi-dimensional perception of risk held by the public. Thus it was a cloud point to the panelists how the authorial risk assessment weigh societal and value laden issues in proportion to natural scientific issues. If authorities and experts cannot meet this multi-perception of risk, it is expected that the public will remain hesitant towards GMP and seek consultation with alternative authorities like e.g. the NGO's. This seems to be in disagreement with the second questionnaire, which suggests that the comprehensiveness of biotechnologist is of minor importance compared to the other statements (statement 24; table 1). When analyzing the questionnaire in more details it appears that the respondents highly agree that biotechnologists need to be more comprehensive and consider other aspects than pure technical. However, respondents with a background in nature science are divided whether the issue will play a major or minor role (30 vs. 31, data not shown), whereas respondents with a different background than nature science tend to express that the issue has a higher importance (13 vs. 7, data not shown). It is also necessary to keep in mind that the later workshop lacked a "hard core" molecular biologist due to a late excuse. In fact the first workshop showed some difference of opinion on this matter, which will be discussed below under the heading "trust".

Anyhow present risks of GM crops are assessed predominantly on basis of natural scientific evidence, with relatively little focus on uncertainties, while ethics are treated as a separate issue (Carr & Levidow, 2000). This may not come as a surprise since it is mainly experts from the field of natural science (biology, genetics, agronomy, medicine) who have drafted the legislation on GMP focusing on ecology, agriculture and health.

The point is that risk assessment on GM crops is performed by scientific expertise that rests on the arguable assumptions that interpretations and predictions of scientists are rational because they are based on data gathered through objective procedures. However, it is difficult to judge what consequences to be expected when particular GM crop is applied in the field, when empirical data is lacking. The biosafety controversies this bring about can be interpreted as disagreements of what is to be a sufficient set of relevant questions for the purpose of hazard[2] identification of GM crops (van Dommelen 1999). Thus, the concept of risk clearly has a normative component, namely the judgment of the acceptability of effects and consequences.

The workshop discussion agreed that there is almost no interaction between natural sciences on the one side and social sciences and the humanities on the other regarding the GMP risk issues. The predominant opinion expressed in the second questionnaire was also that communication between experts is not good enough (statement 36, table 1), however it is fifty-fifty across background

2 Hazard identification is the attempt to recognise possible unwanted effects of some endeavour

whether or not this will have major implication for the future debate compared to the other statements (data not shown).

From the questionnaire it thus appears that communication between experts have a relative low importance for the quality of the future debate. However, at least two intellectual currents inside modern science sociology namely post-normal science and the transition from Mode 1 to Mode 2 science contest this. In the following we will discuss communication between experts in relation to these two intellectual currents separately.

The first intellectual current post-normal science typically involves issues where facts are uncertain, values in dispute, stakes high, and decisions urgent, e.g. risk assessment of GM crops. In these problem situations applied science and professional consultancy are often inadequate, and something extra must be added onto their practice, which bridges the gap between scientific expertise and a concerned public. This is post-normal science, comprising a dialogue among all stakeholders in a problem, regardless of their formal qualifications or affiliations (Funtowicz & Ravetz 1992). The concept of post-normal science can be characterized as a way to create insight on the changing contexts in science and society. Normal science is largely associated with certainty, based upon optimism about eventual human control over nature, but the post-normal science concept argues, that the normal way of practicing science is no longer adequate since society faces new transnational and transgenerational problems. A new scientific practice has to be developed, acknowledging the irreducibility of certain risks and uncertainties and aiming at managing these irreducible risks and uncertainties instead of eliminating them (Ravets & Funtowicz, 1999). The post-normal science approach indicate that inevitably various sorts of uncertainty and value-commitments enter into decisions on risks, and because of that the scientific side of the work must be complemented by other considerations, deriving also from its policy aspects (Marchi & Ravets, 1999).

The second intellectual current inside modern science sociology has been described by Gibbons (1999), as a developing a new social contract between science and society. Under the prevailing contract, science has been expected to produce reliable knowledge (i.e. in areas as defense and nuclear), provided merely that it communicates its discoveries to society.  The contract under development must ensure that scientific knowledge is 'socially robust', and that its production is seen by society to be both transparent and participative. *"'Socially robust' knowledge has three aspects. First it is valid not only inside but also outside the laboratory. Second, this validity is achieved through involving an extended group of experts, including lay 'experts'. And third, because 'society' has participated in its genesis, such knowledge is less likely to be contested than that which is mere 'reliable'."* (Gibbons, 1999). This change in knowledge production is by Gibbons et al. (1994) characterized as a transition from Mode-1 knowledge production to Mode-2 knowledge production. Mode-1 knowledge is generated within a disciplinary, primarily cognitive context and Mode-2 knowledge is created in broader, transdisciplinary social and economic contexts. Mode-2 knowledge production has not only lead to an increase in 'knowledge' workers and a proliferation of sites of 'knowledge' production, but has also tended to erode the demarcation between traditional 'knowledge' institutions as universities and research institutes and other kinds of organizations. Novel 'knowledge' institutions are arising as e.g. small and medium-sized high technology companies. 'Knowledge' institutes have to become learning organizations in order to develop their intellectual capital. (Nowotny et al., 2001).

The problem of inadequate dialogue between science based experts and stakeholders prevails because sciences are discipline oriented with different epistemic cultures that have difficulties in understanding one another's perspective (Kahn & Prager 1994). Properties of multidimensionality and incommensurability are crucial and intractable features of technological risk (Stirling 1999) and in line with the workshop discussion several authors argue that a more integrated and interdisciplinary approach is needed. A new approach must highlight the subjective and value laden nature of risk and conceptualize the act of defining and assessing risk as a game in which the rules must be socially negotiated within the context of a specific problem (Slovic, 1998). Knowledge elements from various scientific disciplines should be structured in such a manner that all relevant aspects of a social problem are considered in their mutual coherence for the benefit of decision-taking including uncertainties and ethics (van Asselt 1999, Carr & Levidow 2000).

Accordingly the workshop participants advertised for new risk appraisal tools. Stirling & Mayer (1999) has suggested that such tools should be: flexible and broad in scope; open to divergent interest and values; able to acknowledge uncertainty; whilst being systematic, transparent, verifiable and accessible as well as practically feasible and efficient. Especially tools for judging utility value need to be developed for application in this field, as it has been in other scientific disciplines where it is known as decision analysis (German Advisory Panel on Global Change 1998).

Assessment of substantial benefits, socio-economic impacts and ethical questions, are difficult to make operational, and the workshop discussed benefits from involvement of public panels and ethic committees (e.g. the influential EU committee of ethics) in the risk assessment procedure. Thus there seem to be a need for a public space, outside the institutionalized approval procedures, where more generic issues and more principal questions can be discussed by a broader group of actors and stakeholders (Rasmussen & Borch 2002). A big challenge, however, is the different attitudes towards ethics and utility value between the EU member states, where the EU directive functions as the lowest common denominator. For example has utility value so far not been considered in the EU directive on deliberate release on GMPs as it is the case with the Norwegian legislation on deliberate release of GMPs where it appears that there is attached importance to societal utility value and that release of GMOs should promote a sustainable development. (The Norwegian law on gene technology "genteknologiloven", Chap. 3 § 10).

**Trust**

The panelists emphasized that new technologies like GMP implicate both risk assessment based on existing knowledge and uncertainty, which must be dealt with separately. Therefore it is problematic if risk assessment only operates with uncertainty as a degree of accuracy excluding lack of knowledge. It was reminded that recognition of uncertainty in risk assessment was one of the lessons learned from the Bovine Spongiform Encephalopathy (BSE) inquiry in the UK (BSE Inquiry Report 2000).

The question was raised how to assess risk, when empirical data are absent or inadequate? The workshop discussion suggested the allowance of scientific experts to openly articulate their intuition based on professional insight and experience. A prerequisite for this however, is credibility and to establish credibility it is necessary to generate trust, which for the time being seem to be lacking for scientific experts (Eurobarometer 52.1. 2000).

During the workshops especially the social scientist pointed out that the biotechnology milieus to some extent fail to realize that they them selves induce distrust among lay people, and that natural scientists can contribute to trust building by a broader understanding of and reflection on the role of technological research in society (statement no. 26) (Meyer & Sandøe 2001). Not surprising this viewpoint raised some discussion between the panelists, where the biotechnologist could not accept that the only explanation of the distrust is the inadequacy of the natural scientists reflections and understanding of societal matters. Thus social scientists understanding of nature science and their willingness to take responsibility for decisions related to technological development was requested. Jackson (2001) addresses this subject by proposing the perspective 'critical systems thinking and practice'. 'Critical systems thinking' is derived from two sources: social theory and systems thinking. It recognizes that social theory and systems thinking possess complementary strengths and weaknesses. The social sciences are strong in theory but they are weak on practice. Applied systems thinkers, on the other hand, are dedicated to practice but often neglect theory. Critical systems thinking can provide its greatest benefits only in the context of paradigm diversity, and the point of critical systems practice is that it brings appropriate methodologies and tools to bear on problem situations whatever their nature.

Several authors, e.g. van Asselt (1999), has stressed that a better understanding of uncertainty and how uncertainty is dealt with analytically is a prerequisite for improved decision-support. Information about uncertainty and imperfect knowledge is essential for risk communication between risk assessors, policy-makers and decision-takers, but the theory of decision-taking under uncertainty is a specialized subject, and often not transparent to policy-makers and decision-takers not trained in this methodology.

Importance of trust and also lack of trust in relation to particular actors and/or institutions has in particular been studied by Brian Wynne (1996). Here the focus is the relationship between experts, lay people and the authorities, and with the different types of knowledge forms. It is suggested that trust in collective actors and institutions is crucial for the experience of risk. This implicates that no-risk guarantees from a distrusted actor/institution is not likely to be accepted. In effect they are at risk of falling prey to the quite opposite effect of inducing a conviction of risk.

Thus attempts to conceal the limits to scientific knowledge do not prevent controversies from arising: rather the opposite, since they may undermine lay trust in business and public authorities. The respondents to the questionnaire very much agree to this attitude (statement no. 28, Table 1). A policy of openness about the different dimensions of uncertainty, and their implications for political choice, should therefore be pursued instead. In the long run, such a policy would be more likely to increase trust in scientific risk assessment. There is, of course, no guarantee that glasnost of this kind will lead to public acceptance of GM crops, but the lesson from Europe is that openness and dialogue are prerequisites of public acceptance (Lassen, personal communication).

## 4.2 Developing countries and market power

Over 800 million people remain seriously malnourished including at least 250 million children. A matter of debate and conflict has been whether deployment of biotechnology holds the potential to help developing countries achieve higher yields, improved pest control, greater drought resistance, and reduced dependence on chemical fertilizers, shorter growing seasons, and increased nutritional value of crops. It appeared from the workshop discussion that the panelists acknowledged the potentials of plant biotechnology to improve plant breeding and crop production in developing countries. However, concerns were raised because private interests seem to gain more power to decide on the technological development due to a global tendency of increased research activity in the private sector, while governments is cutting down on public research in the agricultural sector.

Plant biotechnology has led to a major concentration of technologies, intellectual property rights (IPRs) and plant breeding in transactional companies (Ministry of Foreign Affairs/Danida, 2002). Heisler et al. have addressed the problems with this development: "Public sector involvement in plant breeding may have benefits to society that the private sector's activities may not, fostering greater sharing of information and more work on traits of plant varieties (such as environmental suitability and nutritional characteristics) that may be under-researched by private breeding programs.

The questionnaire also expressed expectations across professional background and self rated level of expertise that the issue of reduced local influence due to monopoly (Statement 2, Table 1), would play a role for the future debate on GM crops.

For the developing countries concentration of IPRs in the private sector has even more serious consequences because a specific country only has access to new technologies if a private is interested a co-operation and investment in the country. This is not possible for the poorest countries with the smallest markets. The consequence is that the poorest countries lag further and further behind. (Vilby, 2002 p. 49).

Public research in developing countries certainly has difficulty keeping up with the private sector. This can be illustrated by the entire CGIAR (Consultative Group on International Agricultural Research) research budget of 331 US $ in 2000 (CGIAR, 2000). This is only a small fraction of the research budget of one large transnational biotech company albeit CGIAR is the worlds largest scientific network performing research to promote sustainable agriculture for food security in the developing countries.

The discussion also touched on the difficulties in the developing countries to control market forces, which results in difficulties in giving qualified opposition to the industrial research. Thus FAO has raised concern about the fact that market forces are inadequate for tackling poverty. Thus market forces have tended to concentrate financial flows on a handful of countries and sectors with higher prospects for returns. Agricultural development and support to food security in the low-income food-deficit countries are among the areas to have been most severely affected by reductions in financial flows (FAO, 2000).

In their book "Seeds of Contention" Per Pinstrup-Andersen, leader of International Food Policy Research institute in Washington DC, and Ebbe Schiøler argue that GM crops may be one element in the solution to poverty and hunger, and that people in developing countries should have information about benefits and risks and the freedom to make their own decisions about whether or not to grow and consume these crops. However they stress that GM crops are only partly a solution. Many other problems like infrastructure, political injustice etc. have to be solved before GM crops can improve food supply for the 800 million people who do not know what to eat the next day (Pindstrup-Andersen and Schiøler, 2001).

Therefore there is a call for international regulation especially because the contemporary regulations mostly make allowance for the rich countries. Hence, there is a need for strengthening African capacities to deal with issues such as WTO negotiations. Regarding this, the International Food Policy Research Institute (IFPRI 1999) has emphasized the importance of creating and expanding a supportive international trade and financial environment for least-developed countries.

Although WTO also operates with a limited and biased risk concept the panelists believe that WTO can play a central role in market regulation. But critics were raised against the WTO tendency to push toward a liberal market and away from political regulation. This needs to be addressed if developing countries are to succeed in a market-led growth strategy. Also based on experiences in Egypt UNDP states that: "opening to international trade has not necessarily been growth enhancing in itself. It should rather be part of a broader development strategy targeting growth and poverty alleviation."

Also the response in the questionnaires showed some ambiguity towards the statement that GM crops are a prerequisite to meet the developing countries need for food (statement 6; 1).

## 4.3 Configuration of the risk debate

During the workshop discussion it was argued that the risk debate in Denmark has become elitist where mainly experts, NGO's and politicians participate while the public has become detached. It seems strange that inasmuch Denmark is perceived as an exemplary model of public participation in political process (e.g. the diligent use of consensus conferences and hearings) it has not prevented the dead lock in the GM crop debate. The representative from the authorities explained their difficulties in communicating risk issues in a popular and comprehensive manner without loosing important information - let alone the danger of compromising the truth. The Danish authorities acknowledge that utility value is a central matter for the public, however, the current legislation only allow for information and data that are operational and reproducible. The revised directive 2001/18 do to some extend allow for more normative considerations, but it still remain be demonstrated how to do this in practice.

Experience with public debates indicates that the more controversial an issue is, the greater the necessity to maintain a multi-perspective dialogue between the stakeholders. However, these debates are often highly normative, reflecting the degree of aversion to risk and uncertainty especially among lay people. Authorities and their scientific advisers often find these kinds of subjective discussions quite difficult. This results in too much emphasis on experts' scientific knowledge, and too little emphasis on the more elusive socioeconomic and ethical questions. But, the latter are important from the point of view of public acceptance. Funtowicz & Ravetz (1992) has proposed that scientific discussions need to be extended to a wider peer community, incorporating more participants who have an involvement with the issue. However a forum or "public space" for dialogue emphasizing on more generic and fundamental issues in relation to the utilization of GM technology seem to be missing (Lassen and Jamison, 2001).

The Danish consensus conferences can be seen as a mechanism to institutionalize public controversies regarding technology and way to bypass staged confrontations occurring in parliamentarian debates (Hansen & Lassen 2001) (Hennen 1994). However, the unfortunate elitist tendency in the Danish debate has also been reflected in the consensus conferences held on the subject of GM crops. To illustrate this Hansen & Lassen (2001) have compared and evaluated two Danish consensus conferences held in 1987 (Industrial and agricultural gene technology) and in 1999 (Genetically modified foods). One of their observations was that the '87 conference composition of the expert panel was balanced representing scientific experts with a positive as well as a negative attitude to GMP, but in the '99 conference viewpoints against GMP were solely represented by NGOs and not by representatives from the scientific community. Hansen & Lassen write: "*As a result, the consensus conference in 99 was, to some extent removed from an Harbermasian ideal [that discursive procedures enable a rational testing of validity claims, which, in turn, can provide agreement or understanding on both cognitive and normative issues] and turned into a battlefield where the lay panel witnessed a staged confrontation of the different positions, seriously delimiting the possibilities of a genuine discursive deliberation among experts and lay people on booth descriptive and normative aspects."* (Hansen & Lassen, 2001).

Rasmussen and Borch (2002) have suggested the establishment a forum for dialogue and discussion between authorities, scientists and interested and affected parties (Fig. 5). Risk assessment of GM crops is a rather new area with an ongoing discussion of criteria and principles reflecting a need for more principal debates among stakeholders. Topics for the forum could be: values in risk decisions, acceptance criteria, system boundaries for risk assessment, prospective analysis of GM technology, feedback to policy-makers, special Danish interests according to EU legislation. One problem with this is to select forum members such that all parties are treated in a democratically acceptable way. Another thing, there is no reason to think that such a forum will reach consensus and what does that mean for application of their work. Further, it has to be decided how much power and influence to be delegated to the forum. (Jensen et al., 2001). Finally institutionalization of this kind may hamper the spontaneity of the debate or otherwise restrict it, however this was not discussed in workshop.

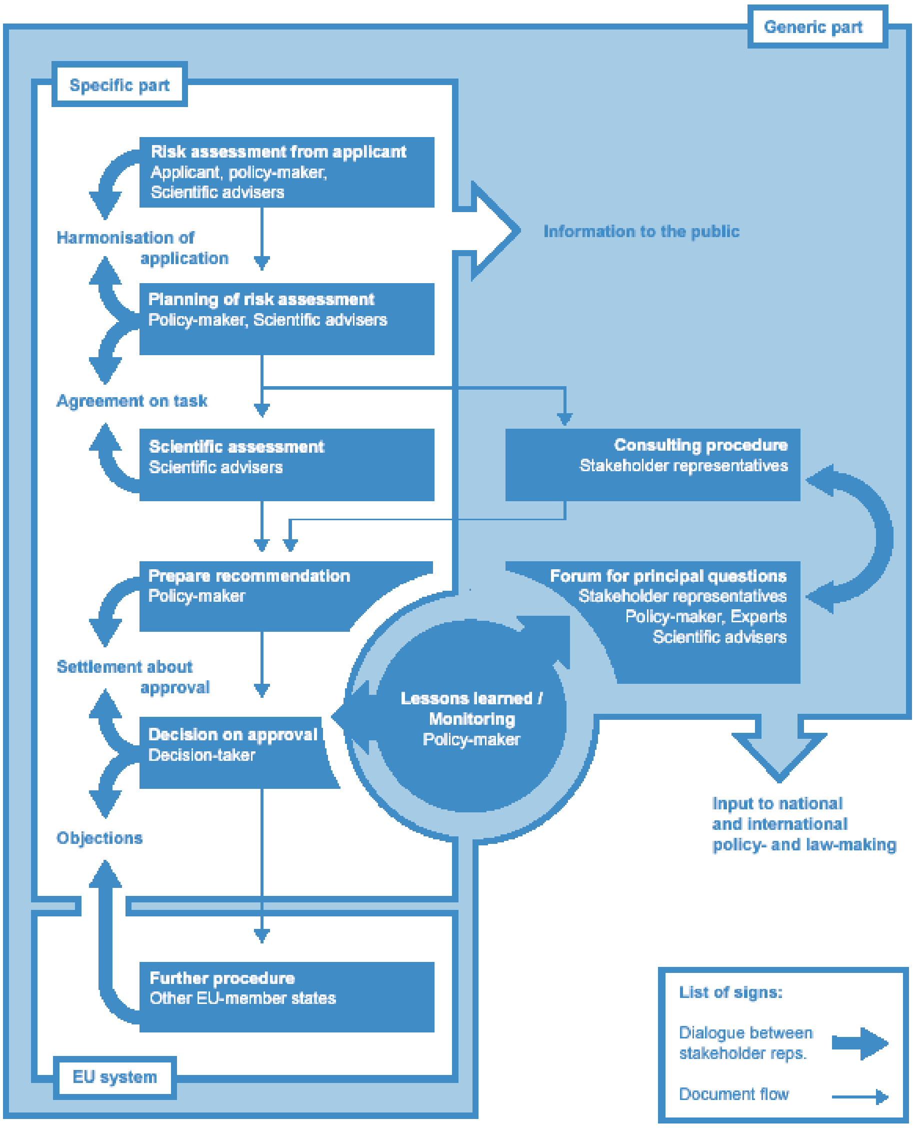


*Figure 5. Suggested overall framework for risk assessment of GM crops. <u>Decision-taker</u>: a person with the authority to take a policy decision.*
*<u>Policy-maker</u>: a person or organization charged with assessing a decision-taker in reaching a decision by providing policy analysis, generating policy options, or by conducting risk assessment.*
*<u>Scientific adviser</u>: a person or organization responsible for providing scientific input to policy-making or decision-making.*
*<u>Stakeholder representatives</u>: a person or organization representing the interests and opinions of a group with an interest in the outcome of a particular policy decision (Rasmussen and Borch, 2002).*

The workshop advertised for political guidelines concerning what direction the technological development inside agriculture should take. New technologies create new possibilities and solutions but also new problems, controversies and uncertainties. It is generally acknowledged that the accelerating development of new technologies will have a profound impact on society in the years to come, and in the future policy-makers and decision-takers have to deal with intensifying social concerns about new technologies (mainly ethical and safety concerns). Successful and acceptable exploitation of technology has become critical to achieving economic competitiveness as well as for achieving sustainable consumption and production processes. The care for environment and sustainable development demands a forward-looking approach and a vision on what future(s) is desired (HLEG 2002). It is the responsibility of politicians to catch this vision through an adequate configuration of the debate on controversial technologies like GM crops. This insight could provide the necessary insight to the political decision makers in order to set out the advertised guidelines for a sound technological development in accordance with societal desires.

# 5 Discussion

## 5.1 Methods

In this study the methodological frameworks of LCI (a modified LCA) and technology foresight have been brought together. The rationale behind combining LCI and technological foresight is to prepare a multi dimension framework for prospective technology studies which can be used within the perspective of a single firm (e.g. aiming at a new corporate strategy), or within the perspective of a technological domain (e.g. aiming at a new government policy).

We have used LCI as mapping tool to get an overview of the agricultural systems in question as well as a mean of comparison between the systems. We have tested this procedure in a previous study (Borch and Rasmussen, 2002). The mapping was the starting point for the foresight analysis and gave an initial picture of the stakeholder community, which was a good foundation to make a more profound list of the “stakeholder community” through co-nomination procedures.

To be more specific we used a modified LCA, which can be described as a Life Cycle Inventory. In contrast to LCA the LCI describes the activities qualitatively and graphically and since no empirical data exist for a GM ryegrass system this is the only option here. LCI was used as a frame to delimit the system and to organize information. The impact assessment stage was excluded because the necessary data and information for quantification is naturally unavailable for the GM ryegrass. However, substantial differences between the GM grass system and the conventional reference grass system could be identified and be subject for a qualitatively discussion (Borch et al, 2000b, 41 pp.).

The inventory process seems simple enough in principle. In practice, it was subject to a number of practical and methodological problems. Agricultural production systems are highly complex, and vary from estate to estate. The necessary information to describe the system adequately is scattered across numerous persons, disciplines and institutions. For a biological system the starting and ending point of the life cycle have to be defined arbitrary since a biological system in principal has no start or end. Furthermore, the leading element of the life cycle can be chosen in several ways.

The LCI gave us an overview of the grass field system and common basis for analyzing the system including familiarity with the terminology used within this specific area. This understanding was important in subsequent identification of stakeholders and key issues in the preparation the questionnaires and workshops. In line with Norus (2002, p. 222) we believe that it is necessary for researchers to understand how the technological systems, communities of practice and organizational factors interact to perform in-dept analysis of complex systems. Although LCI analysis is a fine tool to get this insight it also may limit a panel discussions because it focus on detailed aspects of the specific crop system. While agricultural specialist are comfortable with this other panel members considering themselves as lay people are more interested in discussing GM crops in a broad context.

Technology foresight usually focuses on the technology and its function and does normally not include a perspective of the different life cycle stages of the technology. It is our experience that an LCI can compliment technology foresight, and the approach provides a good platform for integration of knowledge from different areas of expertise. The focus on this case has been of normative character addressing ecological risks and public debate in relation to deliberate release of the GMP into the environment.

We used questionnaires and workshops as the main method for collecting data in the foresight part of the study. Thus responses to questionnaires distributed in the stakeholder community functioned as input to succeeding workshops. The initial questionnaire gave numerous eligible opinions on possible advantages and drawbacks on the utilization of gene technology. The clustered opinions functioned as catchwords in the first workshop and were very efficient in triggering an interdisciplinary and spirited discussion, which also revealed clear disagreements. Statements from this discussion were the foundation for the second questionnaire. To fit the questionnaire format, however, they had to be somewhat reworded. This is tricky since you run the risk of introducing second opinions, namely your own, in the questionnaire. Also the responses of cause are very dependent on the wording, which is a weakness when the data from the questionnaire is used to prioritize issues for further discussion.

Another weakness is the overrepresentation of biotechnologists among the respondents. However since some of the strongest opinions about new technologies are found among those who develop it this will probably also influence the future debate. On the other hand a few NGOs refused to answer the questionnaires since they feared the project would play somebody’s political game.

Although we did ask the respondents to which extend they agreed to the statements the questionnaire (especially the second) cannot be regarded as an opinion poll. The reason is that we examined how the answers where scattered between the possible responses. Thus we did not worry whether the respondents agreed or disagreed with the statement. Rather if they disagreed with one another we took it as a measure of disagreement. For example imagine two cases: All, or almost all, of the respondents agreed with a statement. And all, or almost all, of the respondents all *dis*agreed with a statement. In both cases the issue addressed by the statement was categorized as if the issues would not be a matter of discussion. The reasoning behind this is that the more scattered the opinions are about an issue the more potential for discussion in a future debate on GM crops. We also directly asked to what extend it was possible to make a firm statement about the issue and to a large extent found agreement between these two procedures of recording disagreement and thus the issue would be a matter of debate in the future.

The second questionnaire gave rise to some comments by the respondents to the format of the questionnaire. Most felt that the statements where too rigid, and they needed more background information. However, this is an inherent limitation with questionnaires, which is difficult to circumvent. Some of the respondents expressed that they needed to know whom the originator were since that would enable them to better understand the meaning. This may be a special Danish phenomenon because the "stakeholder community" is rather small and thus often having the opportunity to meet and thus have an insight of individual opinions and their reasoning.

We prioritized the issues to be discussed in the second and last workshop as described by Borch and Rasmussen (2002b). With this procedure four issues clearly stood out from the rest and therefore used as introduction in the workshop. Clearly each of these four issues holds material for lengthy discussions, and therefore we asked the workshop participants to select one of them for further discussion. Although the selected issue touched on the other three a more optimal and fair procedure would be to have additional workshops each addressing the remaining three issues, however, we did not have resources for more than one workshop.

Taught by experience from the first workshop and inspired by Senge (Senge, 1990, 246 pp.) we introduced a facilitator from "outside" to manage the discussion. If this was the reason for absence of larger disputes between the panelists or if it was due to the absence of more "hard core" biotechnologists is not clear. Another reason for a constructive debate could be that the panelist initially interviewed one another on the selected issue, and thus better understood the logic behind the individual opinion formation.

The workshop discussion gave us a material that may represent the essence of the future debate. In order not to let the workshop stand alone we surveyed the literature for additional opinions and hold it against the workshop discussion. Using the essence of the workshop discussion to guide the literature survey helped us focus the interpretations and reflections of the findings in this prospective technology study, which hopefully can support the stakeholder community in the future debate.

## 5.2 Findings

In section 4 of this report we have discussed the issues that was brought up during the workshop discussion.

The idea of bringing together key persons inside a technological field but with different practice and perspectives and ask them to discuss prioritized issues suggested by the large community of the same technological field, has been fruitful. Fruitful in the sense that numerous subjects surfaced that we could not have identified nor focused on by our selves.

Knowledge about long-term consequences was the issue that the panelists selected to discuss. This is a very broad issue, which quite well could be essential for both laypersons as well as experts in a future common dialogue. Experts would probably dominate a more narrow issue as for example pesticide resistant crops because their professional knowledge and experience can cover enough of the underlying issues to intimidate lay people with their different type of knowledge.

The issue of broadening the perspective on risk to supplement today's more narrow nature science based risk assessments, seems relevant and would be an adequate response to the public hesitance towards plant gene technology because also normative considerations could be included. This, however, amounts to a change of practice for experts and authorities assessing risk that allow for uncertainty and value-commitments influence decisions on risks as addressed in the post-normal science theory (e.g. Ravets and Functowich, 1999) also among the scientific community behind the technology which has been described as a transition from Mode-1 knowledge production to Mode-2 knowledge production (Gibbons et al, 1994; Gibbons 1999, Nowotny et al, 2001). Measures of this kind probably would improve trust in the relationship between experts, lay people and the authorities (Wynne, 1996). However only few have given indicative guidelines of how these measures could be performed in practice (Rasmussen and Borch, 2002a,b; OXERA, 2000).

The argument that GMP technology can alleviate the food situation in developing countries seem to be an important issue in for the future debate and is an argument that seems to mitigate public hesitance towards GM technology (Lassen et al., 2002). According to the workshop discussion a judicious utilization of the technology has potential to alleviating the food situation. However, GM crops are only partly a solution. Many other problems in the developing countries like infrastructure, political injustice etc. has to be solved to alleviate the food situation (Pindstrup-Andersen and Schiøler, 2001). There is also a call for better international regulation to counter act that developing countries are weak actors on a liberal international market as argued by UNDP.

Configuration of the risk debate it self is important to achieve a sound discussion about GM crop technology. Denmark has a reputation of being an exemplary model for public participation in the political process, mainly due to the diligent use of consensus conferences. Apparently this has not mitigated the public debate on GM crops. Although consensus conferences allow representatives of lay people to raise their concerns towards the policy makers and decision makers there has been a tendency of strong positions on both sides of the conflict to dominate the discussion. This has hindered a discursive deliberation among experts and lay people on booth descriptive and normative aspects (Hansen & Lassen, 2001). Another problem seems to be the authorities emphasis on experts' scientific knowledge, preventing them from participating in the debate on the more elusive socioeconomic and ethical questions, which is important for public acceptance of GM crop technology.

Scientific discussions need to be extended to a wider peer community, incorporating more participants who have an involvement with the issue (Funtowicz & Ravetz (1992). However, something extra must be added onto practice of scientific expertise in order to bridge the gap between scientific expertise and a concerned public. We have suggested institutionalizing of a forum for dialogue and discussion between authorities, scientists and interested and affected parties (Rasmussen and Borch, 2002). Such a forum with an adequate configuration could provide political decision makers with the necessary insight needed to set out advertised guidelines for a sound technological development, which are in accordance with societal desires. Another feature of such a forum is that it will help make the decision-making process more transparent.

# 6 Acknowledgement

We wish to thank the participants in the two workshops: scientific officer Gitte S. Poulsen, professor Preben B. Holm, professor Peter Sandøe, journalist and author Knud Vilby, chief of section Søren S. Kjær, professor Andrew Jamison, senior scientist Dr Rikke B. Jørgensen, associate professor Dr Jesper Lassen, communication expert Thomas Breck, chief consultant Bruno Nielsen, plant breeder Dr Vibeke Meyer, consultant Rikke Lundsgaard, consultant Henning M. Jørgensen.
Also we would like to thank those who took the time to answer and evaluate the questionnaires. We acknowledge the Carlsberg Foundation for the support to the project "Dynamic dialogue processes in the creation, development and utilisation of new technology".

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**Bibliographic Data Sheet** **Risø-R-1421(EN)**

Title and authors

Debating the future of genetically modified plants – bridging knowledge dimensions
A technology foresight study

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| ISBN | ISSN |
| --- | --- |
| ISBN 87-550-3242-7 (Internet) | ISSN 0106-2840 |

| Department or group | Date |
| --- | --- |
| SYS/TES | November 2003 |

| Groups own reg. number(s) | Project/contract No(s) |
| --- | --- |
| psp 1220132 | |

Sponsorship

Carlsberg Foundation

| Pages | Tables | Illustrations | References |
| --- | --- | --- | --- |
| 29 | 1 | 5 | 47 |

Abstract (max. 2000 characters)

Rapid developments in, and the controversial nature of, biotechnology call for communication, networks, partnerships, and collaboration in research, not just among researchers but also between researchers and research "users" in industry, government, and elsewhere. Technological foresight appears to offer a coordinating method for developing and strengthening those linkages. To test this, a technological foresight study was performed on genetically modified (GM) crop technology in the Danish context. The background to the study was the conflict and intense debate in Denmark over applications of gene technology, and especially over the deliberate release of GM crops. However, the current debate characteristically involves sharply opposed fronts. In it, stakeholders and experts on both side of the conflict advocate widely differing opinions. Without a proper, generally intelligible dialogue, the broader public audience finds it hard to comprehend this type of debate. The study pursues the notion that public dialogue can act as a driver of future applications in the technological domain, specifically GM crops. The study concluded with a stakeholder workshop that revealed three key issues that might provide helpful starting points for a more free-flowing and open-minded debate about the future of GM crops. The issues were those arising from the following statements: a broad perspective on risk is crucial; international regulation must make allowance for developing countries; a better configuration of the risk debate is needed. These issues are discussed in more detail in the report, along with the foresight method we used to reveal these issues.

Descriptors INIS/EDB

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