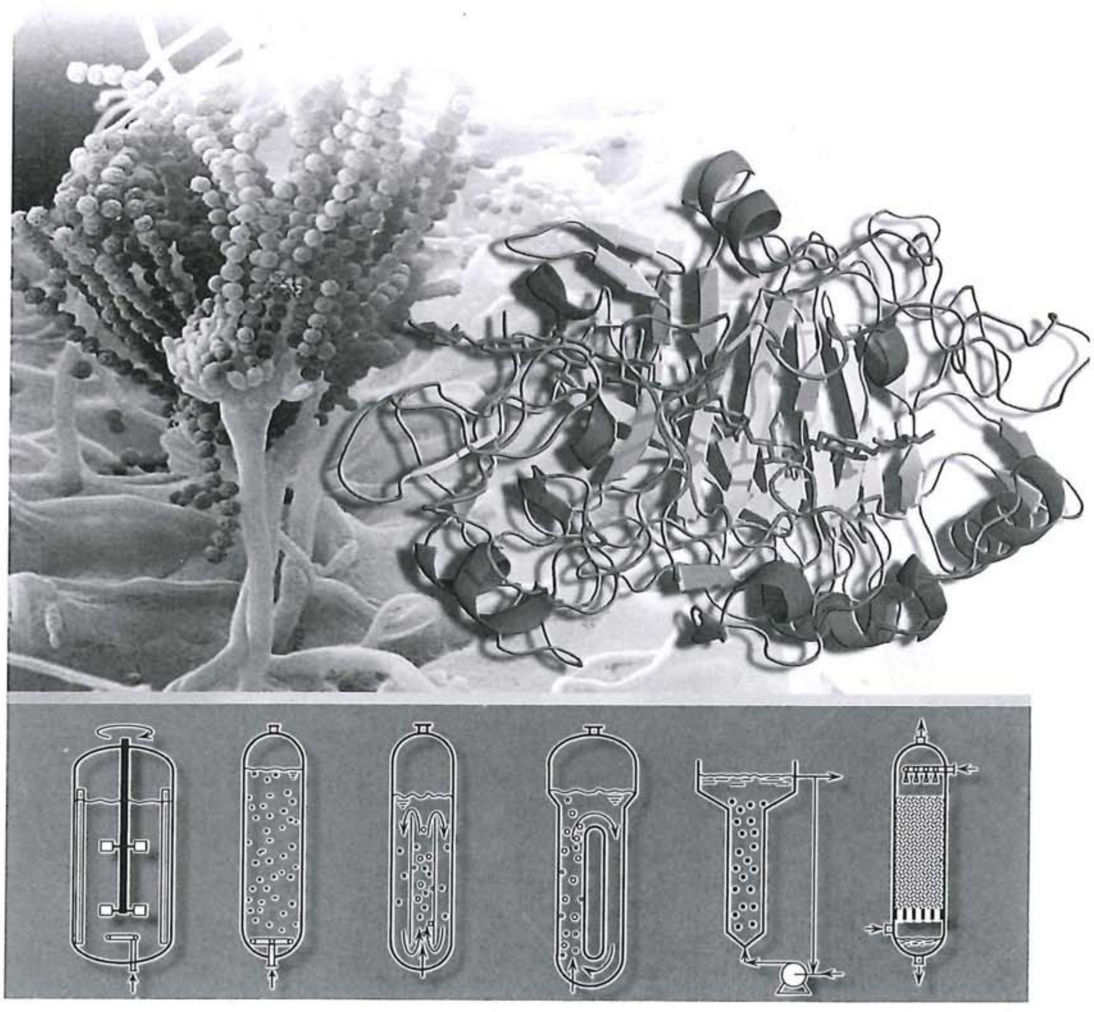
Edited by
Wim Soetaert and Erick J. Vandamme

WILEY-VCH

Industrial Biotechnology

Sustainable Growth and Economic Success



14
Societal Issues in Industrial Biotechnology

Patricia Osseweijer, Klaus Ammann, and Julian Kinderlerer

14.1
Introduction

Biofuels have become a hot topic in recent years. The burning of fossil oils has been blamed for their contribution to global warming and the price of oil has increased rapidly. So the search for alternatives is on. The media report almost every day about some issues related to biofuels, voicing supporters and opponents of this new application of industrial biotechnology. The debate particularly questions whether biofuels can indeed reduce greenhouse gases and whether we have enough land to grow the necessary biomass. It questions the impact on both Western societies and developing countries. Some commentators fear that we risk our food availability for a growing world population, that food prices will rise problematically, while others are concerned about the destruction of rainforests. In this climate of controversy politicians struggle to develop policy measures to reduce the dependency on oil-producing countries, to raise sustainability, and to gain environmental benefits.

What does this strong debate on biofuels mean for the development of industrial biotechnology? What have we learned from earlier public debates about biotechnology and how can we apply those lessons to support a further development and implementation of industrial biotechnology?

Modern biotechnology has long been viewed as a key technology promising better quality of life for all world citizens. Its development, however, has been accompanied by concern and criticism about the methods it uses. As early as 1992 countries discussing the state of the world in the twenty-first century indicated that biotechnology had the potential to enable "the development of, for example, better health care, enhanced food security through sustainable agricultural practices, improved supplies of potable water, more efficient industrial development processes for transforming raw materials, support for sustainable methods of deforestation and reforestation, and detoxification of hazardous wastes" (Agenda 21, chapter 16; http://earthwatch.unep.net/agenda21/16.php).

There were early technical concerns about, for example, the use of antibiotic markers in the development of transgenic crops and moral issues about the

Industrial Biotechnology. Sustainable Growth and Economic Success. Edited by Wim Soetaert and Erick J. Vandamme

ISBN: 978-3-527-31442-3

principles of genetic engineering leading to the charges of "playing God" and "patenting life." Later there were worries about the potential risks and opportunities for consumer choice in genetically modified (GM) food. Indeed "Frankenstein" food became so much of an issue that many supermarkets banned GM-containing products from their shelves. The public debate ultimately resulted in an effective moratorium on GM crops since 1999, which is presently slowly lifting [1]. Are these concerns relevant for the development of industrial biotechnology?

Wine, beer, bread, and cheese represent some of the centuries-old examples of industrial biotechnology which are of course widely accepted. Strains used for their production were optimized over the years, using many different techniques, including selective breeding, induced mutations by irradiation and, more recently, genetic modification. However when these modern techniques were used to produce chymosin to make cheese, for example, this was not met everywhere with great enthusiasm in spite of the fact that it would replace the use of stomachs from slaughtered newborn calves. It also seems paradoxical that modern durum wheat traits, used to produce pasta worldwide, resulting from radiation mutation breeding, seem to be accepted by a majority of producers and consumers. although considered in molecular science as a much more untargeted breeding method with unknown, random impacts on the genome. The implication is that *in situ* modification is acceptable, but inserting an infinitesimally small portion of DNA derived from another organism is unacceptable.

Within a changing society which pushed for a demand-driven economy these examples induced caution within most biotechnology companies, but even more so within the process and retail industries that use these ingredients for their products.

While industrial biotechnology aims to deliver sustainable solutions for production of consumer goods, energy, pharmaceuticals, and environmental applications it is also highly likely that these latest applications will be frowned on by at least a section of our communities as already shown above for biofuel applications. Companies are therefore hesitant to introduce these products or even develop them due to anticipated negative consumer responses stimulated especially by activist non-governmental organizations (NGOs). Policy-makers struggle to find a balance between promoting and ensuring sustainable development and anticipated public resistance.

Representation and interpretation of scientific information, methods of communication and public interaction, and ethical, legal, economic and safety issues are important elements in public opinion forming. Also strongly indicated is that timely and adequate, proactive and interactive communication initiatives help to introduce novel, socially beneficial applications. Dialog between all the main stakeholders during the early stages of development has therefore been promoted as a crucial key to realizing the potential offered by innovations in industrial genomics.

Before we can engage in effective, early engagement and interaction with the wider society we need to understand the issues at stake and identify the relevant stakeholders in such as farming, (chemical) industry, retailing, transport, local government, and regional development. We therefore need to investigate and unravel the societal implications of a more bio-based economy and to understand the possible societal issues so we can prepare for a generally accepted implementation that is likely to be successful.

This chapter therefore explores the impact of a biomass economy and the controversy about the resulting societal issues. It takes lessons from the GM debates to propose some advice on what academia and industry may do to further a sustainable introduction of industrial biotechnology that is acceptable to most in civil society.

14.2 The Impact of Industrial Biotechnology

Before we can say anything about societal issues of industrial biotechnology we need to explore its possible impact on our society. For this we use the definition of industrial biotechnology of the European Platform on Sustainable Chemistry (Suschem)[1]:

> Industrial Biotechnology is the application of biotechnology for the processing and production of chemicals, materials and fuels. It uses enzymes, micro-organisms and cell lines to make products in sectors such as chemistry, pharma, food and feed, paper and pulp, textiles and energy, materials and polymers.

With this approach industrial biotechnology aims to provide a more sustainable production of consumer goods, energy sources, and pharmaceuticals, for example, the replacement of mineral oil with biomass for feedstocks. The reduction of carbon dioxide emissions is claimed to help alleviate global warming while the application of biotechnology in production processes should demonstrably reduce the use of both energy and water and the production of unwanted by-products and waste water.

14.2.1 How Does This Influence Our Society?

First and importantly, the replacement of oil with biomass will have an impact on our economies and global trading relations. The increased production of fine chemicals and pharmaceutical ingredients by yeast, fungi, and bacteria has already greatly increased the demand for sugar with consequent increase in prices. However, when bulk chemicals, including biofuels such as bioethanol, are produced in this way, the demand for sugars and plant oils will increase much further (as demonstrated by the dependence of the sugar price on the oil price[2] [2]). As

1) Suschem brochure 2006 downloadable from website: suschem.org.
2) http://www.europabio.org/facts_white.htm for several relevant reports (downloadable).

shown in other chapters of this book, scientific research presently focuses on the use of other biomass materials such as feedstocks for fermentation processes, including household and agricultural waste materials. Although this increases the usage per unit of biomass produced, it still requires a huge agricultural input with major effect on the global trade market and hence on local economies.

Second, the bulk production of energy, chemicals, and materials through biomass will change our landscapes. Wastelands, recreation grounds, forests, and perhaps even oceans and deserts may be considered as additional producers of biomass. Small local biorefineries may replace the old concepts of water-tower and gas-station from the early twentieth century. It will necessitate a change in our transport infrastructure and require a number of large- and small-scale "biorefineries," the latter close to the location of biomass production to minimize transport costs.[3]

Third, the transition of industries to other production processes will affect the entire production chain, which will change skill needs and employment opportunities. All changes will directly or indirectly influence local communities. Farmers may have a larger market for their crops, citizens may be forced to recycle domestic waste biomass, politicians may need to provide for new incentives balancing economy against environment, industry managers may have to choose when and how (and on what scale) to invest in new production facilities. Oil countries may also need to find alternative incomes, while developing countries may have difficult choices for either food production or biomass export. Furthermore, societies everywhere may have to fully support the use of GM crops at least in coexistence, as it is very likely that only GM crops will deliver the required amount of biomass with the lowest impact on food supplies, water, and nutrient use and the lowest burden on the environment.

14.2.2
What Are the Political, Industrial, Economic, and Scientific Drivers and Obstacles?

Recent concerns about global warming have resulted in a series of reports and international agreements. The most famous one is the Kyoto Protocol, set up in 1997 and ratified in 2005 after the signature of Russia. With their ratification countries worldwide commit to reduce their emissions of greenhouse gases considerably with an average of 5.2% for 2008–2012 in relation to the levels in 1990. The United States have not signed the agreement. Post-Kyoto agreements in general aim for higher reductions. However that is not the only driver for a bio-based economy.

The main reasons for governments encouraging the implementation of a bio-based society to replace fossil fuels are:

1) to increase industrial competitiveness and innovation

2) to reduce environmental and atmospheric pollution

3) Biofuels for Transportation. Global potential and implications for sustainable agriculture and energy in the 21st century (Worldwatch Institute) *06/2006*, available from http://www.europabio.org/facts_white.htm.

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3) to replace the rapidly depleting fossil fuels for which world demands are increasing because of economic growth in rapidly developing societies such as China and India and a growing world population

4) to replace fossil fuels the use of which increases the emission of greenhouse gases which are seen as a major contributor to global warming

5) to decrease dependency on oil-producing countries.

Further reasons for national communities may include new outlets for national farmers (in Europe) or new export opportunities (for developing countries). Industries are driven by the growing oil prices and by government incentives, but this is not a simple equation as sugar prices are now linked to oil prices and most governments have not yet decided which incentives to implement. The report of McKinsey [2] indicates that the development of a bio-based society depends on:

- fuel prices
- feedstock prices
- government regulation
- availability of conversion technologies (innovation).

Scientific challenges are detailed in other chapters of this book and include the development of novel biocatalysts for production processes, and the development of second-generation biofuels and bulk chemicals by improved process conditions, microorganisms, and enzyme specificity. These developments are mainly driven by (inter)national research programmes, following the advice of road-mapping exercises prepared by experts in biotechnology from industry and academia (EuropaBio, BIO, OECD, EU, technology platforms such as Suschem and EPOBIO, etc.[4)]). Industrial challenges are the uncertainty of market opportunities and regulation, expenditure of R&D and innovative opportunities. McKinsey calculated that the industrial biotechnology market comprises 7% of the overall chemical market, equaling €77 billion in 2005. It is expected that this will grow to 10% in 2010 (€125 billion). They also calculated (on a conservative assumption) that the present feedstock supply will be enough to replace about 50% of the required transport oil. This figure is highly debatable though as it includes a number of uncertain assumptions.

14.3 Public Perceptions of Industrial Biotechnology

As already indicated in the introduction to this chapter, the development of a bio-based society is presently a topic of heated debate in the media. Strong opinions are voiced aiming to influence the political decision-making process. On October 26, 2007 the United Nations expert Jean Ziegler even requested a moratorium on

4) http://www.europabio.org/facts_white.htm for several relevant reports (downloadable).

the implementation of biorefineries to provide time for the second-generation biofuels to fully develop.[5] The question is, will this also have an impact on public support for the full development of the broader field of industrial biotechnology?

What is known about the present support for industrial biotechnological applications and what is the impact of public perceptions on political decision-making? Can we compare it with the GM food debate which took place around the turn of the century and which so dramatically influenced the implementation of GM food products in Europe?

14.3.1
What Is the Present Public Perception of Industrial Biotechnology?

In Europe, a number of surveys have been funded by the European Commission to measure public perceptions of life sciences and emerging technologies held repeatedly in a similar format over a number of years (1991, 1993, 1996, 1999, 2002, and 2005[6]) These studies cover all European Member States with a systematic sampling of about 1000 respondents by face-to-face interviews, with the later studies enabling comparison between Europe, the United States and Canada.

The latest study carried out in 2005 included a number of questions related to industrial biotechnology about biofuels (defined as "The development of special crops that can be turned into ethanol as a substitute or additive for petrol and for biodiesel") and bio-plastics (defined as "Another industrial use of crop plants is the manufacture of bio-plastics. These, as it is claimed, will be less environmentally damaging as they can be easily recycle and are bio-degradable"). It was found that 77% of European citizens supported the view that governments should support research on bio-plastics, with 71% agreeing to tax incentives. A smaller majority of 57% would (or probably would) be prepared to pay a little extra for bio-plastics. (Figure 14.1).

Figure 14.2 shows that 71% also agreed definitely or probably with the provision of tax incentives to biofuel companies. A much smaller group of 47%, however, was willing to pay more for a car designed to run on biofuels and even fewer (41%) were prepared to pay a little more for biofuels.

The Eurobarometer researchers [3] concluded that in general there is support for developments in industrial biotechnology. However, we argue that there is reason for caution.

If we compare this with the levels of support for GM food in 1996 we see a similar level of support. Although the support per country varied considerably, the average "outright support" and "risk tolerant" support for GM food was more than

5) The United Nations Special Reporter on the right to food [Jean Ziegler] called on Friday for a five-year moratorium on biofuels, saying it was a "crime against humanity" to convert food crops to fuel. Reuters, 26-10-2007.

6) Eurobarometer reports at http://ec.europa.eu/public_opinion/index_en.htm.

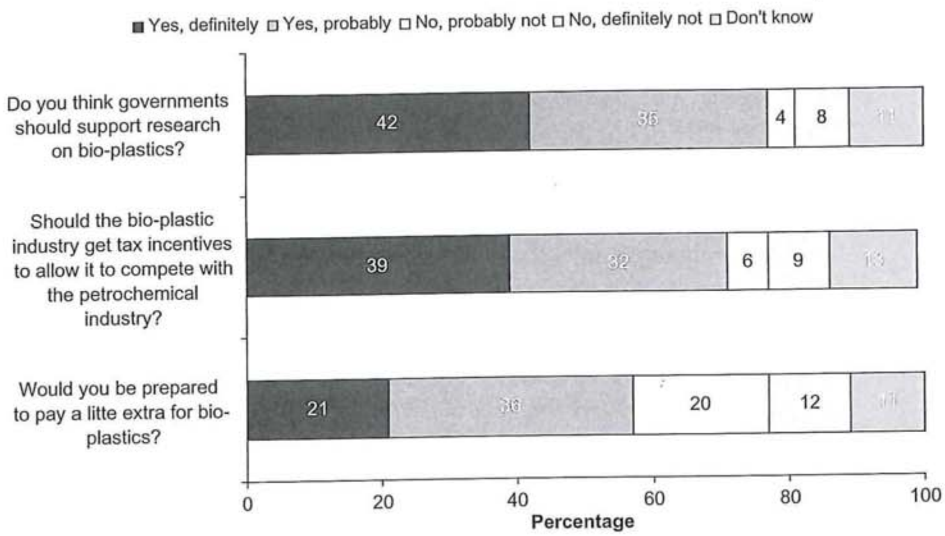

Figure 14.1 Average European support for bio-plastics, defined as "Another industrial use of crop plants is the manufacture of bio-plastics. These, as it is claimed, will be less environmentally damaging as they can be easily recycled and are bio-degradable." Gaskell *et al.* [3], Eurobarometer Studies available at: http://www.ec.europa.eu/research/press/2006/pdf/pr1906_eb_64_3_final_report-may2006_en.pdf.

60%. With the GM food controversy growing from 1996 to 1999 and issues presented emotionally in the media, this support reduced to 47% in 1999. When the media reports were fading this returned to 53% in 2002. But then it declined again to even below the levels of 1999 (Figure 14.3). Will the support for industrial biotechnology also decline now that the media covers it emotionally? What have we learned from the GM food debate? Let us start with a consideration of how public perception impacts on technology development.

14.3.2
What Is the Impact of Public Perception to Policy Development?

When the first shipment of GM soybeans entered Europe in 1996 the initial public support for GM food started to decline rapidly after heavy criticism by NGOs such as Greenpeace. It led to questions about health and environmental impacts accompanied by protests, boycotts, and increased research on risk. In 1999 Europe was faced with a *de facto* moratorium on the commercialization of GM crops and foods. Arguably, there are several reasons for this political halt. The most direct consequence, however, was that food companies took measures to alter the composition of their products to avoid GM.

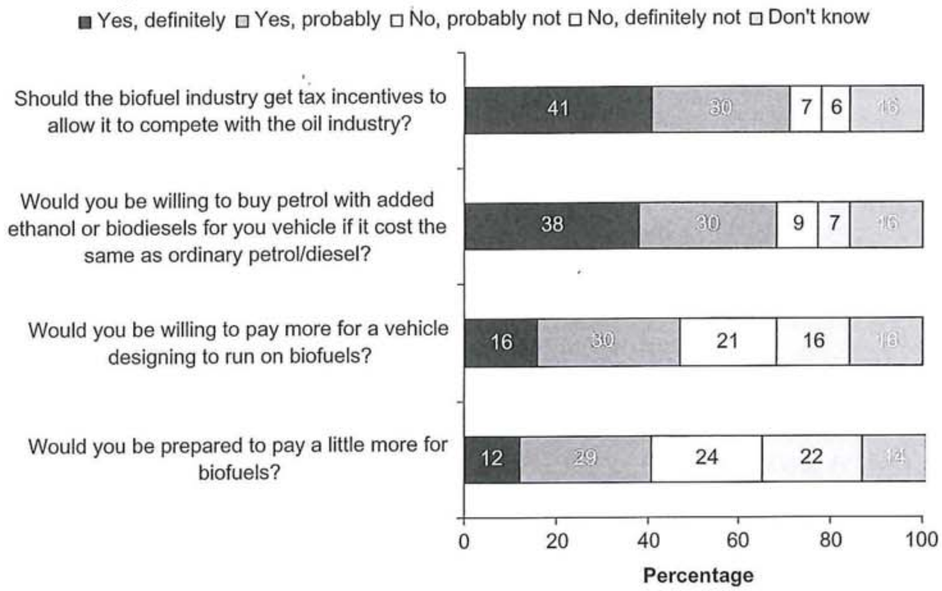

Figure 14.2 Average support by EU citizens for biofuels, defined as "the development of special crops that can be turned into ethanol as a substitute or additive for petrol and for biodiesel." Gaskell *et al.* [3], Eurobarometer Studies available at: http://www.ec.europa.eu/research/press/2006/pdf/pr1906_eb_64_3_final_report-may2006_en.pdf.

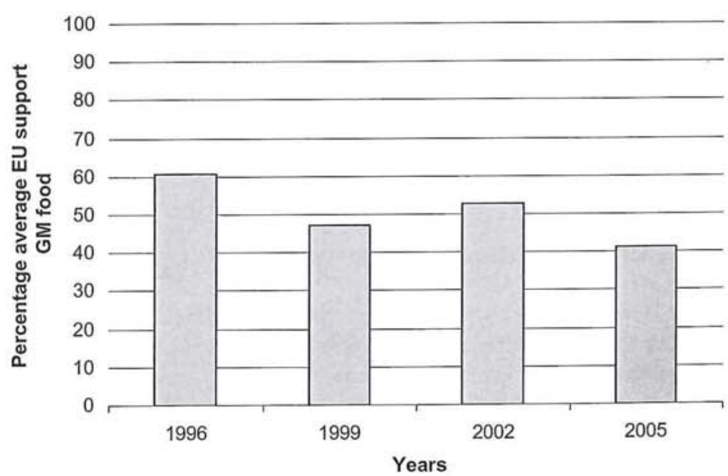

Figure 14.3 Average of EU countries respondents with "outright support" and "risk tolerant support" for GM food. After Gaskell *et al.* [3], Eurobarometer Studies available at: http://www.ec.europa.eu/research/press/2006/pdf/pr1906_eb_64_3_final_report-may2006_en.pdf.

14.3.3
Industrial Reactions to Labeling of GM Food Products

Public unease, alarmist media coverage, opportunist campaigning by some NGOs, and unwise practices by some industrial sectors have all been suggested to have played a part in the rise of public hostility to this new technology. Support for organic farming together with growing opposition to "globalization" and fear of market dominance by large multinational companies have also been mentioned as causes for the decline of public support. In addition, the coincidental emergence of bovine spongiform encephalopathy (BSE) and other food scares, although unrelated to biotechnology, were blamed for confusing the public [4]. The public scare provided the incentive for political measures in regulation. It was indeed seen as a political necessity at European and national levels to strengthen the existing Directives and increase legislation which would introduce the labeling of GM foods.

Directive 90/229, adopted in 1990, on the contained use of genetically modified microorganisms for research and non-marketing purposes was modified in 1998 by Directive 98/81. Among other things it introduced "a requirement for Member States to ensure labeling and traceability at all stages of the placing on the market of the GMO". This measure was adopted to provide consumer information as a basis for informed choice, and to enable any problems to be traced back to their source [4]. Measures were developed for authorization, traceability, and labeling of GMOs, as well as food and feed produced from GMOs, resulting in Regulation 1829/2003 1830/2003 which was enforced from April 2004. However, with the introduction of labeling, the majority of food producers changed their ingredients to non-GM, resulting in the present lack of choice for consumers.

At the moment less than 0.5% of the foods in European supermarkets are labeled to contain GM ingredients or are made with the help of GM techniques. Furthermore a number of European countries do not sell any GM products (among others, Greece, Sweden, Slovenia, Germany and Poland, and Switzerland).[7] These measures by food producers directly influenced the providers of food ingredients, who lost their European markets for anything that needs labeling and are now hesitant to introduce novel products based on the latest genomics research.

There is no rationale for this effect. Labeling was introduced to give consumers the choice to buy either GM or non-GM products. So why did the big food manufacturers replace the GM ingredients with non-GM ingredients? The non-GM ingredients were not cheaper, there were no indications that GM ingredients were more risky for consumers health[8] [5–7] and legislation provided a trustworthy information system with appropriate authorizations in place for control. It therefore seems that the food companies were either alarmed by the negative perception studies of 1999 which they perceived were likely to badly affect their sales or they were wary of campaigns by environmental organizations which could affect their image and thus their sales.

7) "Consumerchoice" final report available at http//www.KcL.ac.uk/schools/biohealth/research/nutritional/consumer/choice/download.html.

8) ENTRANSFOOD final report available at http://www.entransfood.nl/.

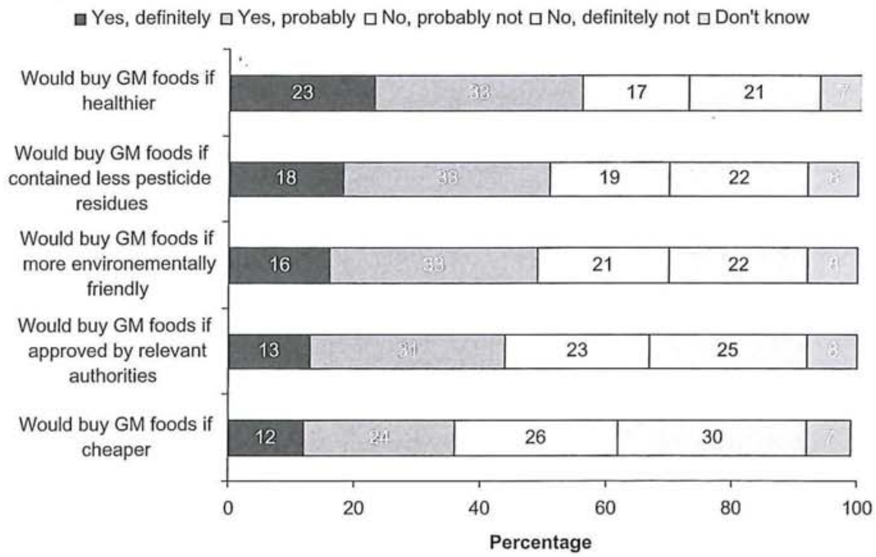

Figure 14.4 Percentage of European citizens willing to buy GM food products with particular characteristics. Gaskell *et al.* [3], Eurobarometer Studies available at: http://www.ec.europa.eu/research/press/2006/pdf/pr1906_eb_64_3_final_report-may2006_en.pdf.

It can be strongly argued that a reaction towards negative public perceptions does not provide a satisfactory answer. First, a number of social scientists had already pointed out repeatedly that public perception studies are studies of the respondents' attitudes and that they cannot be extrapolated to behavior [8–12]. More recently this has been supported by a number of studies on actual buying behavior of consumers presented with GM food products [13, 14].

Second, the results of the latest Eurobarometer survey in 2005, but also other (national) studies still showed considerable support for GM food products (Figure 14.4) [3, 15, 16]. In 2005 43% of the EU population supported GM food products. If GM food products were healthier, then even 56% would definitely or probably buy these products. Interestingly, the result for cheaper foods showed that a mere 56% would not or probably not buy GM foods if they were cheaper. This latter result further supports the point that opinion surveys cannot be taken at face value for behaviors. Gaskell *et al.* [3] suggested that some respondents reacted as citizens rather than consumers, as economics indicate that price is a key determinant in people's choices.

A further interesting point is that price is the only fact consumers can actually ascertain themselves directly. For all the other categories they need to trust some organization (authority, industry, medical research) for the information provided with the food. Whatever the reason, this highlights the doubts about opinion surveys as indicators of actual behavior.

Third, and perhaps most convincingly, the sales of products labeled as GM remained constant (orally confirmed by large supermarket chain). Although there was no reduction in sales, food companies continue to replace the GM ingredients of the products with non-GM. For example, in the Netherlands there were more than 120 products with GM ingredients with (voluntary) labels in 1999. By 2007 this number had been reduced to 19 [53].

These considerations strongly suggest that food companies and supermarkets replaced their GM products because they were afraid of emotional actions by environmentalists groups rather than being influenced by fewer people buying GM food or trying to protect people from hypothetical risks. The food companies responded to representation from a minority of consumers and the attendant media publicity, and this resulted in an effective halt to the development of cheaper, more sustainable or healthier food products.

What can be done to facilitate a sustainable and accepted introduction of applications from industrial biotechnology? From the perception studies and the reactions of scientists, industries, and governments we also learned some lessons about communication.

14.3.4
Development of Public Interaction

Looking back over the years starting from the first Eurobarometer survey in 1991 on biotechnology we can assess how the results influenced politicians, scientists, and industries. One of the outcomes of these first Eurobarometer studies showed that the public throughout Europe had very little knowledge about biotechnology and indicated that knowledge was linked to support. As a result politicians and biotechnology scientists, aiming to increase the support for biotechnology applications in the early 1990s, started information and education campaigns to educate the public. This one-way communication was based on the belief that if more information were made available then the public would understand the potential benefits and increase their support for biotechnology. This is a good example of the so-called "deficit model" of science communication. However it soon emerged that the brochures, leaflets, lectures, education programmes, etc. did not necessarily increase support [17–20]. It became clear that more information tended to lead to further polarization of opinion, whether positively or negatively.

For the 1996 Eurobarometer study on biotechnology a group of science communication experts were invited to help in getting a clearer understanding of public perception. The social scientists chose "perceived use," "risk," and "moral acceptability" as determinants of public support. People were asked whether they thought each of six biotechnology applications were useful, risky, morally acceptable and if they should be encouraged. The results led to the conclusion that usefulness is a precondition of support and in no case is a "not useful" application given support. For example, GM food products that are similar to "normal" food products but have a lower production cost are not likely to be accepted. People will accept some risk if the application is useful and morally acceptable. For instance, GM foods containing an important vaccine or new medicines produced by yeast are likely to be accepted. Moral concerns, however, acted as a veto regardless of

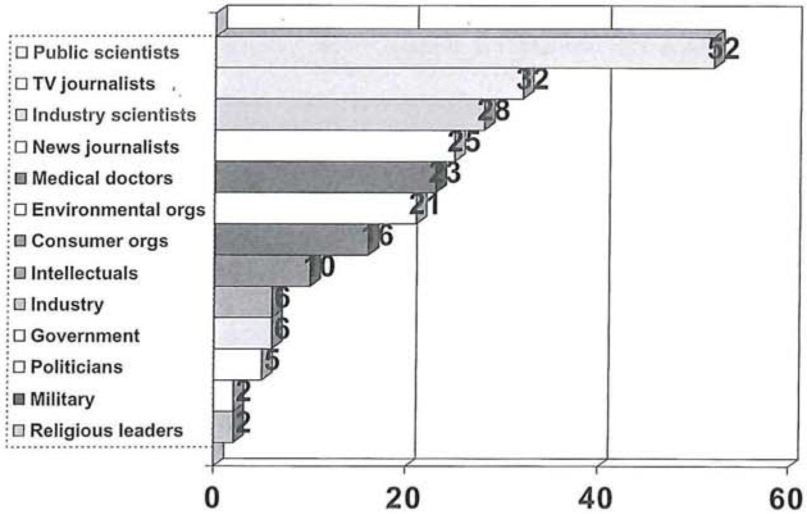

Figure 14.5 Responses of European citizens to "Who is best qualified to explain science and technology impacts on society?" from Gaskell *et al.* [3], Eurobarometer Studies available at: http://www.ec.europa.eu/research/press/2006/pdf/pr1906_eb_64_3_final_report-may2006_en.pdf.

views on risk and use. This is shown by the reluctance displayed about the production of medicines by transgenic animals. A main lesson from the study was the conclusion that "if risk is less significant than moral acceptability, then public concerns are unlikely to be alleviated by technically based reassurances and other policy initiatives dealing solely with risks" [19].

The emphasis on communication certainly shifted to show the benefits of new technology and increased the research on risk assessment, risk communication, and risk perception [21–24]. Adams showed that when risks cannot be controlled by individuals and are vague, for example as a result of scientific uncertainty, confidence decreases and an increased demand for regulation is provoked. So who are the most trusted organizations for providing information on the impact of science and technology?

As Figure 14.5 shows, the European public finds public scientists the most qualified to explain science and technology impacts on society and scientists working in industry only slightly less so. By now it had also become widely recognized that acceptance could not be achieved by simply providing information alone. Scientists had not only a role to play but also had to listen to, understand and respond to actual public concerns. The reaction of social scientists, politicians, and industry was to redevelop models of communication, as characterized by the development of a dialog model called the Mode-2 model and the upstream engagement model for communication [25–28]. Discursive models of communication have been advocated by pioneers such as Churchman [29] and Rittel, and in the last few years those approaches have been revived [30, 31].

Government committees advising on policy measures for technology development started to suggest the involvement of scientists [32–35]. The pressure on scientists to be involved in public communication was further increased by requirements for dissemination and public communication in (inter)nationally funded research projects. Increasingly, project criteria include the dissemination of results to broader audiences, followed by active involvement of stakeholders and demands for public dialogs. These forms of "proactive" communication are now seen as crucial for the implementation of novel technologies.

14.4 Societal Issues in Industrial Biotechnology

The lessons from the biotechnology debate are clear; scientists need to be involved in public communication and such communication needs to address societal issues, involve the stakeholders, etc. Several specially funded projects have been carried out over the years to explore the role of scientists, media, and industry and discuss "best practice" [20, 36]. Training courses have been developed[9] [37] and curricula for future scientists revisited. But what are the criteria for these novel forms of communication?

14.4.1 Criteria for Communication

Many academics and industrialists have concluded that biotechnology scientists need to increase their involvement in public communication to achieve greater public support. However, there are other, more urgent reasons to pay attention to communication. Independent of this wish for increased acceptance, these reasons are derived directly from the principles of a democratic society. Public involvement in decision-making processes requires public information and the social contract between society and scientific institutes demands accountability. Based on these arguments posed by present developments in society and biotechnology with its important potential impact, a set of evaluation criteria for public communication may be derived [20].

Political agendas and decisions are subject to voters' opinions. It is necessary therefore that scientists are accountable to the public about their science and their reasons for doing it so that informed decisions can be made. Scientists also have a moral imperative to communicate with the public as only they have understanding at an early stage of the possible impacts of their science for society, which they need to provide for the joint decision-making process. The complexity of novel

9) A number of courses aimed at scientists and industrialists were developed, such as those by the European Task Force on Public Perception (EU Advanced Course on Bioethics and Public Perceptions; later adapted to the Kluyver Centre Advanced Course on Strategic Communication in Biotechnology); Netherlands Centre for Society and Genomics; European Molecular Biology Organisation; Wellcome Trust.

technologies often leads people to reject new technologies but as people in a democratic system need to be able to weigh up the pros and cons themselves there is also a social obligation on scientists to provide this understanding. Furthermore, if scientists are contracted by society to develop the solutions for tomorrow's challenges, then society needs to be able to trust them. Trust acts as a summing device when full understanding is not possible. This is the general situation for modern technologies, and especially for the complexities of biotechnology. Trust is based on confidence and knowledge which is claimed to be maintained by inclusivity, transparency, and information. This relates to both factual information and emotional feelings.

A component of the contract and trust is accountability [38]. Scientists are contracted and paid for their work by society via taxation and government. They are accountable to society for the uses and outcomes of that payment. The social need for scientists to be accountable, and thereby maintain trust, is an imperative which follows from the contract between society and science.

There are also economic reasons for scientists to communicate with the public. The first relates to the fact that the generation of wealth for the functioning of modern societies wholly depends on science and technology. Biotechnology has been promoted as a major generator of wealth. In order to allow society to make informed decisions about the contribution which biotechnology may make to wealth generation, scientists need to explain its economic impact, that is, its benefits, and its costs, to society. This also includes explanation of the costs and benefits to society if a technology that is scientifically feasible is not pursued. The second economic reason is that scientists have to explain why society must return some of the wealth generated by science to science if science and wealth generation is to continue. As society pays for the publicly funded universities and research institutes, it is in the interest of all academics to communicate about their work. Society decides on the amount and distribution of public funding based on this information. However, with competing calls on limited public funds it is in the biotechnologists' own interest, as with the members of all academic disciplines, to communicate effectively.

The foregoing discussion is based on an idealized view of democracy with full public involvement in the decision-making process. However, the reality in democratic societies is that most people are simply not interested in participating in decision making, which is left to the elected representatives and their staff. They in turn tend to be influenced by communicated opinions and perceived public perceptions while subjected to often intense lobbying by special interest groups, although they are finally answerable to the electorate. Therefore the fact remains that the "silent majority" of the public at large is informed. In order to reach this "silent majority," public communication activities need to stimulate the interest of the public. Because different groups of people have different competing interests and concerns it is also necessary to know and understand their differing interests and concerns. These are not only related to the scientific and technological information, but also importantly to (bio)ethical, safety, social, and legal issues. Scientists need to be able to understand and respond to these issues.

Following from the democratic contract of science with society, these social, moral, and economic reasons dictate that scientists inform and participate in the

Table 14.1 Criteria for communication by scientists derived from the social, moral, and economic reasons for communication as partners in a contract between science and society [20].

Criteria for public communication by scientists to inform the decision-making process:
Explain science
Explain impact
Build trust
Listen and respond to ethical, legal and social concerns
Interest as many as possible
Adapt to changes in society

democratic decision-making process, which includes interaction with the public. As in any contract, good performance is in the interest of the performer. It is argued that communication is an implicit task for scientists, therefore it is in their own interest to do this effectively and it is in the interests of academic institutions to facilitate and organize this process.

From the above-mentioned arguments it can be concluded that public communication relates to:

- the availability of knowledge (information on scientific data; information on potential impact of the implementation of derived technologies in society and information on how judgments are made or can be influenced);
- the availability of skills for interaction; and
- the availability of attitude (to encourage public interest and respond to public interests and concerns).

These requirements lead to the criteria for communication by scientists summarized in Table 14.1.

14.4.2
Novel Approaches to Communication

The application of these criteria for science communication asks for novel forms of communication. Importantly the interaction should be mutual (or two-way) which requires preparedness to listen and understanding of each other's arguments by both sender and receiver. This is not easy to materialize, especially when we wish to create a solution-oriented dialog. Research on novel forms of communication is therefore looking for models with specific attention for discourse (for example focusing on respecting the symmetry of ignorance which is suggested to lead to systematic stepwise learning dynamics [39, 40] and on methods to increase participation of stakeholders [41–43] and of reaching the "uninterested" public majority through entertainment and emotion [44, 45]).

There is no doubt that the transition towards a bio-based society is a very complex design problem, which requires more knowledge than any one single person can possess and creativity to reach reconciliation of views. As we also strive for changes in consumer behavior, it is important that we combine programmes for sustainable technology and product development with programmes focusing on changes in attitudes and behavior [46] and hence in communication. The following case study of the Kluyver Center for Genomics of Industrial Fermentation will give an example of such an approach.

14.4.3
Three International Workshops Identifying Future Issues in Industrial Biotechnology: A Case Study

One of the most important and perhaps difficult challenges for politicians nowadays is the understanding of ethical, legal, and social concerns in society. In order to fully appreciate the relevant societal issues for applications of industrial biotechnology we need to understand the value systems in our (changing) society, identify present and future stakeholders, and unravel the public and political issues into regulatory, ethical, economic, and safety issues. We also need to understand the roles and responsibilities of all stakeholders so that we can define which organizations can be held responsible for addressing these issues.

The Dutch public–private partnership "Kluyver Center for Genomics of Industrial Fermentation"[10] has carried out a series of three international workshops to identify, understand, and analyze the possible future societal issues in industrial biotechnology. The workshops form part of the Center's program on genomics and society and were aimed to inform the development of novel communication activities (for a full account, see ref. [47]). The workshops brought together 25 experts from different disciplines and affiliations (such ethics, microbiology, food sciences, risk perception, cultural management from academia, industry, government, European Commission, etc.) and also aimed to develop a coordinated strategy for public dialog. The first meeting explored the scientific trends in industrial biotechnology and their linked societal issues. The second aimed to identify the organizations involved and responsible for addressing these public concerns. The third and last meeting set out to suggest novel ways of communication and recommend a joint agenda for this approach.

In their first meeting in 2004, the expert group related scientific trends such as healthy and personalized foods, novel bio-based materials and biofuels with political incentives for industrial biotechnology, concerns about overregulation and the public's low awareness but known acceptance of the contained use of microorganisms. On this basis they identified the following "future" issues:

- Safety, including questions such as those related to contamination of food products by plants producing pharmaceuticals in coexistence with food crops
- Land-use with the possible food–energy conflicts, the rise of food prices and the loss of rainforests

10) A government-funded Center of Excellence, see http://www.kluyvercentre.nl for more information.

- Energetics and eco-efficiency questioning the evidence presented on this complex matter leading to concerns of trust
- Environmental pressure, including concerns on biodiversity; soil depletion, water constraints, and mono-cultures
- Economic feasibility with respect to the dependence on oil and linked sugar prices and resulting uncertainty for industrial investment.

The second meeting in 2005 identified the main barriers as preparedness for action; economic interests of stakeholders; coordination of agendas, and clarity on regulations and incentives. The participants recommended clarifying the notion of sustainability and searching for new ways of interaction to interest the public. Additionally they recommended building trust by showing responsibility (and preparedness for action) and the involvement and training of young scientists in dealing with this.

Although many of the above-mentioned issues were viewed worthy of further exploration, the group decided to focus on biofuels and sustainability in their final meeting in 2006. They took sustainability as the "core value" and proposed a joint agenda for key stakeholders, with the aim of reducing the use of energy and fossil sources while increasing the use of sustainable sources such as biomass. (Figure 14.6). This consensus approach would bring a single message to the public, underlined by a joint agreement, but at the same time would allow organizations to keep true to their interests, shareholders, or constituencies. With sustainability as a core value, industries and academia could focus on the increase of innovation by using industrial biotechnology. NGOs could stress the importance of reduction of energy use and pollution. And governments could develop measures to stimulate both the increase of innovation and the decrease of energy use and pollution.

Recommendations

Sustainability as "core value" and joint agenda:

– reduction of use of energy and fossil sources

– Increase use sustainable sources

NGOs: ↓ reduction of energy use

Academia: ↑ sustainable applications

Government: ↓ reduction use, ↑ stimulation sustainability

Industry: ↑ increase sustainability

Figure 14.6 Recommendations of the international expert group of the Kluyver Center workshop on future issues in industrial biotechnology, Brussels, June 2006.

It was recognized that the adoption of this joint agenda would need further discussion with the stakeholders. Therefore it was proposed that "neutrally based" organizations such as local governing bodies and the European Commission would hold stakeholder meetings. These meetings should aim to openly discuss economic interests, values, and trust relations in order to increase understanding of differing viewpoints and decrease the development of wrong perceptions. The experts further recommended that politicians should focus on the removal of bottlenecks with a view to create uniform regulation. They should also focus on the development of clear incentive procedures. Last but not least, it was recommended that research on the development of novel forms of public communication should be increased with special attention on increasing the level of citizen involvement and responsibility. It is interesting to see that these predictions of the possible future issues of this expert group in June 2006 are the ones presently discussed in the media (Autumn 2007). But what do they entail?

14.4.4
Further Analysis of the Identified Societal Issues Related to Industrial Biotechnology

The first issue, safety, is a well-known phenomenon of our present-day risk-averse society. Although it presents itself as a rational and reasonable concern it is actually something much more than that. To begin with, many scientists claim that there is no known rational scientific basis for concern. They argue that fermentation is something that has been used for centuries and the application of GM techniques provides a more precise method than any previous technique used to improve the microorganisms. So far the many studies on risk assessment have not shown any significant risk from modern industrial engineering biotechnology where the regulated precautionary actions are followed. Neither have we witnessed any great accident since the introduction of industrial GM microorganisms some 30 years ago. Furthermore, there is firm and stringent legislation. The safety of GMOs used in industrial biotechnology depends on the characteristics of the organism and its interaction with the environment into which it is (accidentally) released. Safety legislation generally requires risk analysis that can identify and evaluate potential adverse effects of the GMO(s). Host organisms are chosen for their ability to produce the desired product but also for their inability to grow outside the production unit. If GM (micro) organisms are released for applications in the environment, further safety measures are required to minimize human health and environmental adverse effects.

The use of the precautionary principle has enforced a very stringent approach to safety in Europe. A definition of precaution is provided in the UNESCO document *The Precautionary Principle*, published by the World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) in 2005. The Precautionary Principle United Nations Educational Scientific and Cultural Organization. Printed in France SHS-2005/WS/21 cld/d 20/5/:

> When human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm.
>
> Morally unacceptable harm refers to harm to humans or the environment that is
>
> - threatening to human life or health, or
> - serious and effectively irreversible, or
> - inequitable to present or future generations, or
> - imposed without adequate consideration of the human rights of those affected.
>
> The judgment of plausibility should be grounded in scientific analysis. Analysis should be ongoing so that chosen actions are subject to review.
>
> Uncertainty may apply to, but need not be limited to, causality or the bounds of the possible harm.
>
> Actions are interventions that are undertaken before harm occurs that seek to avoid or diminish the harm. Actions should be chosen that are proportional to the seriousness of the potential harm, with consideration of their positive and negative consequences, and with an assessment of the moral implications of both action and inaction. The choice of action should be the result of a participatory process.

Companies, and increasingly governments, are now requesting deregulation for certain applications including industrial biotechnology, as the present situation is viewed as disadvantaging economic growth. Many supporters of biotechnology point out that the required risk assessments do not include a comparative risk assessment to existing processes, products, or practices. Additionally there is debate among regulators about the abolition of regulation on processes using GM techniques where the product does not contain any GM. Others claim that including an assessment of the potential benefits of the proposed innovation would create an incentive for beneficial innovation.

The request for deregulation stands on a sensitive level with the identified necessity for maintaining trust. Risk perception studies, such as those by Adams ([22], see also [48]) have shown that concerns increase and become less rationally based when people are unfamiliar with the actual risk of a technology or material and when they have no control themselves over its use. It is argued, therefore, that the public concerns related to safety are more likely to spring from an issue of control. It is clear that any scientific uncertainty expressed in the public domain will increase the level of public unease and, indeed, the demand for regulation. But regulation needs to be controlled by someone and that is also why maintaining and building trust has been mentioned as a crucial factor in technology innovation.

O'Neill has pointed out, however, that although an increase in regulation and control mechanisms will undoubtedly raise the trustworthiness of the system, it will not necessarily increase trust in the people who are implementing the novel technology [49]. We urgently need to further understand this relationship and find new ways to deal with scientific uncertainty and with emotive public reactions. We also need to find ways which will build or maintain public trust not only in the scientists who develop the technology (and who already are trusted by the public, see Figure 14.5), but also in those who are responsible for regulating and controlling its uses in society.

The second issue, land-use, is probably the one that presently creates the most hype. Recent media reports include emotive terms such as "disgrace," "crime against humanity," and "food robbers" in the attack of the production of biomass for non-food materials (usually biofuels). Interestingly, the articles that are positive towards biofuel development are less emotive, perhaps with the exception of Al Gore and his supporters in their claims about the use of these technologies against global warming. In essence this "land issue" is an economic one: land owners have to decide on the basis of returns on investment what they will grow. Their choices may influence food prices, for example if they decide to grow non-food energy crops. However, it will be hard to disentangle the effect of land-use from the overall effect of an increasing demand in biomass.

A more emotively expressed area in this issue of land-use is the loss of rainforests and the choices made by poor farmers in developing countries to grow bioenergy crops rather than food crops. As some point out, this may result in more local food crises in already struggling countries but also in a higher income which may enable them to import foods. It is unclear how the economy will develop and what will work best for whom.

It is interesting, though, to see how this issue on the use of land is linked to an ethical concern of much broader underlying value. While the increase of safety is often sought by people aiming for a higher level of individual autonomy and choice, the issue of land-use is actually used to support an ideology for all. The ideology includes moral values, linked to a view on the natural world but also to values of democracy, equity for people from developed and less-developed countries, and freedom of handling in less-developed countries.

Although their intentions may be very well meant, it is those from Western societies without any land themselves who are usually most concerned with these moral issues of land-use. And their well-meant moral values may differ from those of people living in developing countries, leading to accusations of "neo-colonialism." Some countries have tried to develop regulations to control the sustainable use of our global land (Cramer Report, 2007)[11]. However it is necessary to realize that people from Western societies are generally in the highest level of "Maslow's pyramid", their basic needs for water, food, housing, healthcare, schooling, and employment are fulfilled. This is not the case in developing countries were sometimes even basic requirements such as food and housing are not yet met. People in these circumstances are not able to concern themselves with issues

11) Project group "Sustainable Production of Biomass" (2007). Testing framework for sustainable biomass. Senternorem, The Hague, Netherlands.

related to "luxury" problems for next generations, such as loss of rainforest or global warming [50].

It is likely, therefore, that consensus will be difficult to achieve as those most willing to enforce it are generally in a position to be able to afford this, while those in developing countries have more urgent needs to fulfill which may prove counterproductive.

The third issue is energetics or eco-efficiency. Presently many impact studies are performed to calculate the ecological footprint in terms of energy and materials produced versus energy and materials used in a global setting. These models aim to predict the best crops for a certain desired product produced in the best (most sustainable) way. Because much of the data needed for the calculation are uncertain and the number of variables included in the calculation differ, the models produce very different outcomes. These results are seriously questioned by scientists, industrialists, and NGOs in (industrial and agricultural) biotechnology who relate to these models as predictors for research investments. This issue therefore relates to the uncertainty of evidence and scientific inquiry. Since the results of these models are often used in public interaction as "proof" of a certain viewpoint, the issue of scientific uncertainty and factual evidence is actually magnified. This undermines public trust in scientists for their ability to produce "rational facts."

The heated debate about the validity of the data may also be perceived by the public in a different way, that is, that parties in debate select and use the "facts" which most suit them because they have an (economic) interest which they wish to advance. Such a perception may further decrease the trust relationships and increase public unease with the technology. The effect of scientific uncertainty of evidence, scientific inquiry, trust, and stakeholder perceptions of interests on public unease and technology development needs further study.

The fourth issue, environmental pressure, for example for water and soil depletion, looks like another scientific issue. It could be solved as soon as we know how to work the land in such a way that we do not deplete our soil and use too much water and prevent the loss of biodiversity. For the moment this is again a concern of scientific uncertainty on the best way to handle this issue in the short term while solutions are developed for long-term and higher demands. The abolition of tillage and introduction of drought-resistant crops are used as possible solutions, but some fear that there will never be enough water to produce the total amount of crops needed for a biomass economy. This issue further relates to biodiversity, which is a concern for many years related to GM crops and industrial agriculture.

Large agricultural practises using monocultures and herbicides and pesticides are often seen as a threat to the diversity of our global plant (and linked animal) kingdom. Diversity is needed as a source of traits (DNA) for future applications in crops or for pharmaceutical products. Areas rich in diversity of species include rainforests, but also areas in extreme environmental conditions are viewed as important providers of genetic material. Presently seed-banks have been created to maintain the traits of rare or nearly extinct sources. However, it is clear that the *in situ* maintenance would be preferable as it would also allow for further evolution and creation of new characteristics. Reduction of herbicides and pesticides by using GM crops and a transition to no-tillage practises may also help to maintain biodiversity.

The issue of biodiversity and environmental pressure, however, is not only scientific but is also often related to a deeper underlying view of nature. The arguments used in the heated debates on the supposed loss of monarch butterflies in GM cornfields [51] indicate that those concerned for biodiversity are often refusing scientific solutions, but propose to go back to the "original, natural way" of producing crops (such as in organic farming practices). These views often become emotive in heated debate and lose their science-based rationality [52].

The fifth and final issue presented here is economic feasibility. This clearly is an economic issue for the industry involved and not so much a public issue. It refers to the difficulty of industries to convert to sustainable industrial biotechnology production processes. In order to achieve this, industries need to invest in innovation, manpower, and equipment but they have to decide on these matters in an environment of uncertainty. Oil and feedstock prices fluctuate wildly, innovations are still in development (such as second-generation biofuels), while governmental incentives are not clarified and regulations are still being discussed. Although industries are resourceful in creating ways of balancing these uncertainties against their shareholder values, it is clear that clarification of regulation and decisions on incentives will help to speed up the introduction of sustainable processes.

14.4.5
Other Relevant Studies and Committee Reports

Since the 1980s a whole industry of governmental, intercontinental, multidisciplinary, and multi-stakeholder committees has evolved. It reflects a change in democratic decision-making as many involve more parties in the discussion such as representatives of consumer and patient organizations, NGOs, lay people, etc. Several of these committees have produced very interesting reports, such as the UNESCO report on the precautionary principle (2005) and the Netherlands COGEM[12] report "Towards an integrated framework for the assessment of social and ethical issues in modern biotechnology" (2003). Both provide clear definitions and/or procedures for evaluation of the state of the art of governing implementation of biotechnology in society. Other studies have delivered high-profile recommendations (such as the EU-US Consultative Forum[13], 2000). The recent Cramer Report[12] provides guidelines for sustainable development of biofuels, aiming to avoid the use of rainforests and the use of other less sustainable methods.

As the players in the discursive process are extending, it is important to have such sources of information available. These studies and reports will also help us

12) Commissie Genetische Modificatie (COGEM) (2003) Towards an integrated framework for the assessement of social and ethical issues in modern biotechnology.

13) Anonymous. The EU-US Biotechnology Consultative Forum: Find Report, December 2000.

to understand the social practices around the globe and provide useful suggestions for the implementation of global sustainability. It is also important, however, to acknowledge that different stakeholders use different reports, presenting different views or even "facts." The choices between sources of information (and trust given to these sources) may play a crucial role in the discussion and needs further investigation.

14.5 Conclusions and Discussion: A Joint Agenda for the Smooth Introduction of Acceptable Sustainable Industrial Biotechnology

We have presented an account of what experts believe the impact will be of industrial biotechnology to our society. We have also showed what (European) citizens think they may support, relying primarily on the Eurobarometer surveys, and have indicated the possible social concerns that may arise from these developments. We have drawn some lessons from the GM food debate which we belief give reason for caution for an overoptimistic view to the acceptability of industrial biotechnology. These lessons taught us that more knowledge does not necessarily result in more support for a developing technology. They also gave us more insight in the risk issue and showed that risk can be overridden by moral values. Through the evidence that European citizens do not disapprove of GM foods we argued that a rational approach (in this case to provide informed choice) can sometimes be overtaken by emotional fear.

Finally the perception studies showed that scientists are one of the most trusted professionals by the public. On this basis, but also on the argument that our democratic society has a contract with scientists for which they are accountable we argued that scientists have an important role to play in public interaction on the implementation of novel technologies derived from science.

The main argument for caution in the introduction of a bio-based society is that the present debate is not based on rationality of reason and that such emotive context may easily result in equally irrational reactions from politics and industries. However, we have also pointed to the lessons learned from improved involvement of all stakeholders in and responsibility for novel forms of public interaction. This requires preparedness for action, and a preparedness to listen to the arguments and take action on concerns. It also necessitates a reconciliation of interests of all parties, which can be done if all parties adopt sustainability as a core value. This is a challenge for the public because sustainability is not something with a direct impact on the individual. And for many it relates directly to a certain view of the world. In contrast, many novel developments in healthcare are often embraced as direct improvements of people's quality of life.

It is doubtful whether new applications for the environment (and hence for future generations) will be received equally positive by all.

14.5.1
Hurdles and Challenges

Politicians are being challenged to come up with the right incentives and regulation, but they are dependent on trustworthy scientific evidence that supports their action. Unfortunately it is just this scientific evidence that is presently so much at stake in the debate. And the debate increasingly ranges from rational to emotive. Taking a position leads to polarization and political inertion. In order to reconcile different views it is important to find common aims. The experts who came together to discuss future issues in industrial biotechnology concluded that "sustainability" could be taken as a core value. They recommended the development of a joint agenda for all stakeholders involved, taking this notion of sustainability as a core value. However, we conclude that in addition to this core value, we need to make sure that plans also address the basic needs of food, health, housing, and employment.

In exploring the issues we have seen that personal views may lead to different positions, which are often not brought into the discussion, and may give rise to emotional claims. This necessitates a willingness to come together and discuss a way to reconcile positions and views.

It is good to see that this view is shared by several multi-stakeholder organizations such as the European Platform on Sustainable Chemistry together with the European trade organization EuropaBio, the Directorate Science of the European Commission, the Working Party on Biotechnology of the OECD and the World Wide Fund. They have a challenging time ahead.

14.5.2
Recommendations for Further Studies

As argued in the above text an understanding of public concerns is crucial and encompasses a much broader understanding involving values, economic interests, dealing with uncertainty, trust, and responsibility. We showed that although safety issues can represent a demand for individual autonomy, the land-use issue may represent a deeper underlying ideology for global governance. These values are undoubtedly related to different views on the relation between humans and nature, which can be controversial. The question is whether these controversial views on governance and autonomy are held by the same people and whether discussing these underlying values could help in the search for acceptable solutions for sustainable development. With this understanding we need to develop novel forms of interaction with society.

14.5.3
What Does It Mean for Citizens?

A bio-based society will change the landscape, political powers, and our national incomes – all factors with which citizens will need to come to terms. But as argued above, a joint agenda for increased sustainability also depends on a decrease of energy and material use. This requires a responsibility and change of lifestyle for all and a re-evaluation of everything we do (holidays, sports), use (traveling, packaging, etc.), and eat. In that sense it requires that sustainability will become a moral value.

Acknowledgement

This work was (co)financed by the Kluyver Centre for Genomics of Industrial Fermentation and Centre for Society and Genomics which are part of the Netherlands Genomics Initiative/Netherlands Organisation for Scientific Research.

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