Scientific transparency for sustainable biotechnology

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Abstract: The increasing use of new biotechnologies for industrial production represents a potential contribution to sustainable development. To realise this potential a learning process of stakeholder involvement is needed, supported by a practical tool to make biotechnology debates less confused by stakeholder controversy and more scientifically transparent. We suggest a mechanism of 'learning-by-questions' to bridge communication divides between stakeholders and to promote sustainable applications of biotechnology. This new methodology for stakeholder involvement is needed since an innovative realm of genomics-based *industrial biotechnology* is ready for launch, while the less effective debate on *agricultural biotechnology* is still frustrating its sustainable development. The aim of this approach is to introduce a more transparent tool for stakeholder involvement, by which possible benefits and costs can be included in a balanced way. For this purpose, we present an integrated perspective on *stakeholders*, on *sustainability* and on *science*.

Keywords: industrial biotechnology; biofuels promotion; stakeholder involvement; decision-support; philosophy of science.

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1 Introduction

Imagine how helpful it would be if policymakers could avail themselves of some advanced tool on their desk from which an all-knowing voice would tell them which turns to take next and which choices to make, in order to arrive safely and surely at some desired outcome. It would indeed be a great relief if it were possible to apply a trustworthy navigation tool which could guide us on the road from where we are today towards a more sustainable world (Raskin et al., 2004). Such an imaginary 'sustainability navigator' would have to integrate many functions, such as to set development priorities, to suggest alternative roadmaps and to balance trade-offs between stakeholder concerns. This combination of purposes would require an explicit and detailed 'knowledge roadmap', providing insight in the (type of) data and indicators that are needed to strive for a more sustainable development of our world (Doering, 2004). The 'sustainability navigator' would face the task of doing justice to a diversity of stakeholders who are fellow-travellers on a road to sustainable development and at the same time avoid the confusion that may easily arise when different drivers are trying to steer one vehicle.

Such a multifunctional travel guide is not available, of course, but considering the feasibility of a 'sustainability navigator' may help us to reflect on the required ingredients of such a policy tool (Van Dommelen and De Snoo, 2005). By creatively considering its characteristics, we may gain more insight into the daunting task of transition management for sustainable development. To provide useful travel instructions on the road towards sustainable development, this navigation tool would have to incorporate a host of relevant knowledge and would therefore need to answer many types of questions, such as for example:

Where are we on the sustainability map in our present state of development? What specific effects may be expected from any new step or decision and will these effects contribute positively or negatively to sustainable development? What knowledge is required for a future roadmap which could provide indicators to monitor our progress or deviations? What potential contribution may be expected from new technologies and which of them will yield the most positive return on our investments? What specific benefits or costs may be expected from some policy choice and how will these affect different stakeholders? What degree of acceptance by stakeholders is required for effectively following some transition trajectory? How can trade-offs between *People*, *Planet* and *Profit* be made in a balanced way? What is the methodological status of different sources of relevant knowledge? What level of trust can be reached among those involved in some context of policy choices?

In this contribution, we explore the general question: which set of indicators can help us to navigate towards a sustainable development for the industrial biotechnological production of biomaterials, biochemicals and/or biofuels? To find out which specific indicators could qualify for this complex task, it is necessary to facilitate an effective process of stakeholder involvement in which the separate stakeholder concerns may be included in the assessment as specified questions that merit consideration (US General Accounting Office, 2004). By involving different (types of) stakeholders in this process of finding relevant questions, the possibility is created to identify useful indicators for assessing the social, ecological and economic sustainability of some decision.

2 Towards scientific transparency

To deal effectively with a complex situation, we must be able to depend on a transparent basis of relevant knowledge for our decision making. We define 'scientific transparency' as sufficient clarity about the knowledge requirements for decision making: what knowledge would be necessary and sufficient to make balanced and informed decisions for the objective of realising sustainable biotechnology? Without scientific transparency there can be no successful striving for sustainable development.

Consider an example of policymaking for which the knowledge basis is presently not sufficiently clear or which lacks 'scientific transparency', thereby leaving room for obstructing confusion in the discussions among stakeholders. Biofuels are propagated as an option to make our energy consumption more sustainable. It is promising to see that there is considerable international optimism about this possibility, sometimes with disregard of more critical voices: "It is disappointing that many of the inputs were omitted because this misleads US policy makers and the public" (Pimentel and Patzek, 2005). To assess the validity of any claim on the sustainability of using biofuels, we need to have an inventory of the specific research questions that were actually addressed in the underlying empirical studies.

The starting point for scientific transparency is in the recognition that the validity of any claim can only be assessed upon the basis of the research questions that gave rise to it. However, a practical situation of different stakeholders trying to steer one vehicle in their own preferred directions, creates a risk of confusion about setting priorities and about possible ways to realise them. It would therefore be a serious loss of momentum in the development of sustainable biotechnology if such a generalising and thereby confused debate on biomass for energy production would now arise, without adequately recognising the details by which a sustainability navigator could actually find a common way forward for this purpose (DeWulf et al., 2005). To facilitate this debate a practical tool for communication and policy support would be highly welcome.

3 Stakeholders and sustainable development

Sustainable development of industrial biotechnology is only feasible if its desirability is sufficiently recognised and supported by the stakeholders who are involved in the process. In order to take full benefit from the diversity of interests and viewpoints, stakeholder involvement can be appreciated as a rich and important source of possibly relevant questions. Stakeholders are all who are potentially affected by some development and in this capacity they can contribute as experts on matters of their own special concern. Farmers as stakeholders, for example, represent essential expertise on questions about how to sustain agriculture. Proper clarification of the included issues of debate and the underlying scientific transparency will subsequently help to focus the policy options. Identifying and involving the stakeholders is the more important since the process of striving for sustainable development requires us to seek a balance between concerns about *People*, *Planet* and *Profit*. What knowledge (and thus what research) is most relevant will also depend on which concerns are considered most important by stakeholders.

Choices need to be specified in order to allow for case-by-case evaluations such as for example on the use of cellulosic biomass (including grasses, wood wastes and crop residues) with the help of advances in industrial biotechnology: “Progress toward making better use of such biomass will come from improvements in the enzymes needed to digest cellulose and some of the other complex biopolymers that make up biomass” (Fox, 2002). Thus, more transparency will not only provide more clarity about possible obstacles for sustainable development, but it will also help us to identify potential roads to improvement (Van Wyk and Mohulatsi, 2003).

What approach could make debates on new biotechnologies less confused and more scientifically transparent (cf. Taverne, 2005)? We suggest a mechanism of ‘learning-by-questions’ to bridge communication divides between stakeholders and to promote sustainable applications of biotechnology. This new methodology for stakeholder involvement is needed since an innovative realm of genomics-based *industrial biotechnology* is ready for launch, while the less effective debate on *agricultural biotechnology* is still frustrating its sustainable development (Ball, 2004). The aim of this approach is to introduce a practical and transparent tool for stakeholder involvement, by which possible benefits and costs can be included in a balanced way.

In an optimal situation, a tool for enabling a constructive dialogue and stakeholder involvement would be (almost) as advanced as the biotechnologies under consideration. Such a tool for advanced stakeholder dialogue should help its users to: ensure transparency, build mutual trust between stakeholders, enable learning process and produce a good grasp of relevant knowledge. If it were possible to develop an accepted standard for these purposes, then this could improve communication in support of sustainable development.

To take full societal benefit from developments in industrial biotechnology, it is time to step back and reflect on options for making interactions between stakeholders as constructive as possible (Ammann and Ammann, 2004; Cantley, 2004). Stakeholders are indispensable in the process of avoiding the omission of relevant inputs by contributing the relevant research questions they consider instrumental to address their diverse concerns. This may well imply that some stakeholder concerns need to be translated into relevant research questions first, such as for example the concerns that farmers may have about what choice of crop will be more attractive as a feedstock for bioethanol production. Such a learning process must rely on an integrated perspective in which the relationship between science and the stakeholders of sustainable development serves to avoid confused expectations.

Discussions on possible benefits and costs can be made more scientifically transparent with reference to an overview of the relevant research questions as they are raised (explicitly or implicitly) by the involved stakeholders. A continued repetition of opposing claims does not contribute to transparent decision making and has not helped to bridge communication divides between stakeholders, but a dynamic procedure to focus on relevant research questions may prevent confused and unproductive debates.

By being specific about sustainability indicators which reflect stakeholder concerns and the underlying research questions, a focus can be created on what type of innovations in industrial biotechnology could contribute to sustainable development. A practical roadmap of relevant knowledge is a prerequisite to steer away from unsustainable developments and to set priorities for this purpose. Even where such a roadmap includes knowledge that we cannot produce yet (or any time soon), it can still support us to explore a sustainable trajectory for the development of biotechnology. What procedures could successfully generate this overview of relevant knowledge and how can we make it effective?

4 Finding relevant questions

Creating transparency for sustainable development is further complicated by the fact that it needs to cover different dimensions of concern. The OECD has made an initial step towards the objective of promoting the sustainable development of industrial biotechnology in its attempt to develop a so-called 'green index' for *The Application of Biotechnology to Industrial Sustainability.* This OECD study comes to the conclusion that, to realise the potential of industrial biotechnology: "Further development will need to take account of sustainability in its full sense – economic, social and environmental – if it is to meet industry's needs" (OECD, 2001).

Different stakeholders contribute different viewpoints on which characteristics would constitute a sustainable development of industrial biotechnology. Some are inclined to put more emphasis on economic concerns, while others give priority to environmental or to social concerns that may come with new technologies. Since these different concerns may easily give rise to conflicts of interest and interpretation (and thus to confused debates), a communication tool is needed to effectively include concerns in so far as they are relevant. Given the diversity of viewpoints among stakeholders, a roadmap of relevant knowledge can serve as such a tool for decision-support. It may help us to keep track of the scientific understanding that is (often implicitly) presupposed in future scenarios.

How can a variety of different stakeholders be involved in one decision-making context, without having to compromise the methodological rigour of scientific findings? This question goes to the heart of science-based transparency and to address it we need to be explicit about our understanding of scientific research. The process and outcomes of science are not always easy to appreciate, maybe the more so in an applied context. However, a practical attempt to make scientific claims and findings more accessible is a prerequisite for transparent communication on the merits of science. In a simplified comparison we might consider that whenever a *musician* strikes a false note in a concert hall, most people in the audience will instantly be aware of this because it so clearly discords with the harmony of the music. We could argue that most music has a high level of 'transparency' in this respect and this also explains why so few people qualify to play in concert halls.

In contrast, whenever a *scientist* makes a false claim in an academic or policy context, then it is usually not so easy for the learned or lay audience to immediately recognise a misguided inference. This is at least partly due to the fact that the 'transparency' of science is usually embedded in a larger 'narrative' and often not immediately accessible to our understanding and scrutiny. The explicit inclusion of one (more) specific research question as relevant may in practice suffice to demonstrate the 'untruth' of some claim (falsification). Any attempt at verification of a scientific claim, on the other hand, is necessarily based on a limited set of relevant questions and will therefore always bear a 'truth' validity which is limited to this specified set of scientific questioning. Any change in the set of questions that we consider relevant, may thus affect our view on the validity of an associated scientific claim. Thus, the challenge for the sustainable development of industrial biotechnology (or any other technology) boils down to finding a set of relevant questions that is a sufficient basis for transparent decision making (to be implemented in the sustainability navigator).

The difficulties of realising scientific transparency for policymaking have been addressed by several thinkers from different perspectives (cf. Collingridge and Reeve, 1986; Toulmin, 1990). It remains desirable to find ways of opening up the 'blackbox' of science and to gain access to its content of actual research, such as expressed by Latour: "There is a philosophy of science, but unfortunately there is no philosophy of research. There are many representations and clichés for grasping science and its myths; yet very little has been done to illuminate research". Putting a focus on the processes of 'research' will help us to develop a more dynamic perspective on 'scientific transparency': "[s]cientists now have the choice of maintaining a 19th-century ideal of science or elaborating (…) an ideal of research better adjusted to the collective experiment on which we are all embarked" (Latour, 1998). What do we expect from the sciences in support of sustainable and effective policymaking, and in how far can they deliver?

5 Relevant questions breed useful answers

Research questions are the initial trigger and inspiration to all investigations and as questions are nagging or illuminating us, they can be seen as the 'seeds' from which science may grow (given sufficient nurturing). The spark of an inspiring question will often do more for the understanding of science and for scientific transparency than the 'mere' presentation of a resulting answer which may be open to criticism from other experts.

Thus, even in the bosom of scientific methodology there lies a divide which may obstruct the effectiveness of our communication for sustainable development. This divide can be described in terms of a discourse on resulting 'answers' which has its counterpart in a discourse on the preceding 'questions'. These two basic 'discourses' of scientific investigation, can be seen as the flip sides of one coin and in practice researchers easily jump back and forth between the question- and answer-mode. Putting a focus on this distinction may help to highlight the complex methodological relationship between the two as well as the fact that this complexity is not always communicated clearly enough when results are leaving the 'lab'.

One element of this complexity is, for example, in the fact that many research questions can be formulated quite well, but at the same time cannot (fully) be answered by present-day science or only with unrealistic investments. Can such research questions, which a scientist considers necessary to ask but which cannot (yet) be answered by the sciences, be *therefore* considered irrelevant to policymaking? Whereas scientific answers can be judged with respect to their 'validity', the research questions preceding them can be judged with respect to their 'relevance' in view of some specified objective.

An example of a persistent communication divide in policymaking can be found in the troubled trade relations between the EU and the USA with respect to the regulation of transgenic crops in agriculture. Here too, our understanding of scientific methodology is involved. The EU proposes to take a *precautionary approach* on the matter, whereas the US demands a demonstrated *risk-based approach* instead. There is good reason to consider this specific communication divide here, since other disputes in the context of applied biotechnology may be seen (at least partly) as variations on this theme: to what extent should the policy-balance of considering possible impacts be more risk-based or more precaution-based? Failure to deal with this divide between different stakeholder perspectives may result in a prolonged 'dialogue of the deaf', obstructed by a seemingly unbridgable gap between avoiding risk and taking precaution.

By promoting an explicit concern for the transparency of science, we may be able to bridge this communication divide between a proper interpretation of 'risk' and of 'precaution'. The question-mode of a precautionary approach puts us on a track of taking research questions seriously and the answer-mode of a risk-based approach reminds us of the fact that we must limit our concerns to those questions which are made sufficiently specific to actually be relevant. Thus, an operational balance between avoiding risk and taking precaution can be struck by requiring our investigative *questioning* of possible impacts to be *specifically* relevant and not just based on generalised concern. A science-based reconstruction of this communication divide thus leads to the requirement of case-by-case transparency for policymaking.

We argue that developing a roadmap of relevant questions will support a global process of learning and will help to actually produce the useful answers that we are seeking. Thus, an inventory of relevant research questions can actually provide the transparency to avoid the inadvertent omission of sustainability indicators: "Various knowledge systems appear to coexist almost independently of one another, each interpreting 'facts' (about which there is also often little agreement) in its own way and, as a result, reaching its own conclusions" (Moses, 2004). The challenge here is to take full benefit of different knowledge systems by way of an inclusive learning process, without being caught in a stalemate of competing perspectives. Our best chances for sustainable development must be sought in a balanced inclusion of the combined understandings.

6 Learning-by-questions

Industrial biotechnology holds a promise of contributing to sustainable development, but for the moment it seems quite fair to note that: "there's a giant gulf between here and there" (Herrera, 2004). If we want the imaginary 'sustainability navigator' to show us the way across this gulf, we need to address the challenge of how to avoid the omission of relevant inputs. To create more transparency and to bridge this gulf between the present situation and a desirable future, we need to deal with the complexities that come with stakeholder involvement, with multidisciplinary science and with sustainable development. What can be done to preserve and improve scientific transparency?

Consider as a practical example the following policy effort to address this integrated challenge: the EU Directive 2003/30 "on the promotion of the use of biofuels or other renewable fuels for transport". This directive holds the optimistic projection that in 2010 the biofuel component for transportation should be no less than 5.75% in Europe, whereas the expectation to be reached by the end of 2005 is only about 1.6%. How realistic is the promise or expectation to make this policy projection come true? A skeptical observer has expressed concern that: "Europe tends to issue regulations first and ask questions about cost and feasibility later" (Herrera, 2004).

What scientific understanding is presupposed in this future scenario or, to put it more specifically, which research questions would need to be included to support this regulation and to promote the chances of a successful directive? One important option for this purpose is to mobilise the insights and concerns of the relevant stakeholders in this process. As it is phrased in EU Directive 2003/30: "The optimum method for increasing the share of biofuels in the national and Community markets depends on (...) the appropriate involvement of all stakeholders/parties" (EU Directive 2003/30/EC).

What could be an effective tool for the 'appropriate involvement of all stakeholders'? Conflicts of interest will usually come along with the involvement of different stakeholders and can easily lead to an unbalanced consideration of sustainability aspects. By bringing together the relevant concerns of sustainable development in the format of a questions and impacts matrix, the different stakeholders may separately contribute to the effectiveness of science-based policy and regulation. If it becomes possible to operationalise an integrated communication on stakeholders, sustainability and science in one tool for transparency, then this format can help us to promote the sustainable potential of industrial biotechnology. An inventory of the relevant stakeholder questions can contribute to bridging the divide between the present-day situation and a desirable future with respect to industrial biotechnology.

How could a process of assembling and mapping these relevant questions be organised, so as to provide a pragmatic and accessible scientific background to the efficacy of policymaking? This aspect of practically organising the process of understanding and implementation may well be the more important for industrial biotechnology, since experiences with the development of agricultural biotechnology have been disappointing in this respect. At the *Institute of Environmental Sciences* (CML) of *Leiden University*, an international project on 'finding relevant questions' (and their proposed answers) for the sustainable development of industrial biotechnology is being developed. One underlying premise of this approach is that creating more transparency about the scientific roadmap required to actually progress 'from here to there', will help policymaking and stakeholder involvement to be more realistic and more effective.

An explicit challenge of a tool for transparency is to clarify how the specified research questions are relevant to a knowledge roadmap for sustainable development. Although still widely dispersed (or implicit) in the scientific literature, already a number of concerns and questions has been put forward and studied empirically in recent years with respect to full sustainability in terms of *People*, *Planet* and *Profit*. The preliminary examples of relevant questions and expected impacts on sustainable development presented in Table 1 give an initial impression of the wide scope of relevant research questions which have already been the focus of scientific investigations in relation to biofuel promotion, covering a multitude of scientific disciplines as well as a variety of stakeholder interests.

Brought together and contributed on the basis of stakeholder concerns, this multidisciplinary matrix of relevant questions can provide the transparency needed to steer away from lurking pitfalls on the road of sustainable development. This format implies that many other concerns could relevantly call for inclusion, such as for example the possibility of using feedstock based on genetically modified crops which are enhanced for more efficient fermentation or the effectiveness of tax measures for the propagation of biofuel components in transport fuels.

Table 1 Tool for scientific transparency: schematised matrix format of relevant research questions with expected positive and negative impacts of using bioethanol for transport fuels

Questions and impacts matrix format	*Research questions on People sustainability*	*Research questions on Planet sustainability*	*Research questions on Profit sustainability*
(+) Expected positive impact on sustainability	Q: 'What role for stakeholder involvement?' A: "optimum method to increase the share of biofuels depends on (…) appropriate stakeholder involvement" (EU Directive 2003/30/EC)	Q: 'What efficiency can be realised in the fermentation of biomass?' A: "Further improvements in substrate utilization can be expected" (Jeffries, 2005)	Q: 'What benefits from alternative options for biofuel feedstock?' A: Use of stover generates considerable annual ethanol capacity "before costs begin to rise rapidly" (Sheehan et al., 2004)
(−) Expected negative impact on sustainability	Q: 'What social priority for 'growing' biofuels?' A: "also, ethical questions are related to diverting land and precious food into fuel" (Pimentel, 2003)	Q: 'What other environmental impacts of biofuel combustion?' A: "motor fuels mixed with ethanol (..) produce increased levels of toxins" (Herrera, 2004)	Q: 'How cost-effective are biofuels for transport to reduce greenhouse gases?' A: "biofuels [are] a very expensive greenhouse gas reduction option" (ECN, 2003)

Note: One illustrating question (Q) and answer (A) in each sustainability domain.

7 Tool for transparency

If we wish to aim for the development of sustainable biotechnology, then this presupposes a way to distinguish it from unsustainable biotechnology. This requires a sufficiently diverse and multidisciplinary perspective on its potentials and pitfalls to be included in our imaginary 'sustainability navigator': "By unlocking the secrets of the genome, biotechnology may allow us to sidestep some environmental and resource problems, but it may create wholly new ones" (Anex, 2004). The development of industrial biotechnology holds the promise of creating more sustainable ways to deal with (bio-)chemical processes. Since the chemical innovations of the previous century have initiated the first major wakeup calls for our environmental awareness, it would be quite unforgivable to expect that biotechnological alternatives to these chemical processes would not need careful monitoring also: "…, the chemical technology experience suggests that we should approach new technologies with considerable humility and try to ensure that they do not escape social understanding and control as a good many chemical products have" (Cranor, 2003).

Taking the research-oriented perspective of a 'discourse on questions' will stimulate a constructive exchange between different knowledge systems. The involved stakeholders can be 'heard' across the communication divides, because they can all contribute the research questions that they consider relevant. As Beck (1992) has argued in his book on the *Risk Society*, we need the 'sensory organs of science' to make possibly unwanted effects 'visible' at all. The threat of confused debates about biotechnology and the complex challenge of striving for sustainability should make us realise that these 'sensory organs' must be the result of a concerted effort in which scientists reach out to understand the concerns of stakeholders, who must actively communicate their interests and their expectations of sustainable development. The sustainability navigator must be informed by scientists as well as by stakeholders and the communication between these diverse parties can be supported by bringing together the questions that each of them considers necessary to include. This implies that aiming for the sustainable development of industrial biotechnology will necessarily involve discussion about which of these 'sensory organs' (interpreted more practically here as 'research questions') will suffice for their purpose.

Which issues must not be omitted lest we will be faced with disappointments concerning sustainable development? In practice, different stakeholders will give priority to different aspects and thereby to different 'sets of relevant questions' (Van Dommelen, 1999). By bringing these perspectives together in a dynamic database of relevant questions and the potential sustainability impact of their answers, we are creating a tool for science-based transparency which can support fruitful stakeholder involvement. The steps that will lead to the most effective use of this tool must be further developed, a process that we have embarked upon now. Here lies a possibility to make the accompanying stakeholder dialogue as advanced (or almost) as the (bio)technology itself, which would be a true novelty to begin the 21st century with – as well as a step towards making a sustainability navigator less imaginary.

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