Chapter 1

Introduction
Introduction

Modern science and technology have both positive and negative societal effects. Leading, on the one hand to improved health, economic growth, and less pollution, it may on the other hand lead to environmental degradation, and reduced health. This central dilemma needs to be addressed by approaches that aim to manage technology in society (Rip, et al. 1995). The challenge for emerging scientific fields, such as genomics and nanotechnology, is to realize their societal promise. But how to go about it?

For the past 20 years, numerous calls have been made for revising the relationship between science and society. The common starting point of these calls is the recognition that, in order to address complex societal problems, a more responsive science system is needed in which a broad range of actors with different views, needs and ideas have a voice. These processes, in which different actors participate in decision making processes on science and technology have been referred to as e.g. transdisciplinary research (Klein, et al. 2001), post-normal science (Funtowicz and Ravetz 1993), and mode 2 knowledge production (Nowotny, et al. 2001; Gibbons, et al. 1994). These approaches all start from the observation of a shift from traditional mono-disciplinary research that occurs in a university context, to new types of knowledge production that occur in the context of application. Outcomes of traditional mono-disciplinary research do not do justice to the underlying social, political, economic, cultural and ethical aspects of the innovation context. Since knowledge is context-specific and contains an explicit and a tacit component, thorough understanding of the innovation context is only possible if those actors who participate in that context contribute to the research process. The theory and practice of these types of interactive processes are still evolving, and questions remain about the epistemology, methodology, organization and quality standards (see e.g. Bunders, et al. 2010; Klein, et al. 2001).
In addition, various studies on the societal embedding of science and technology have shown that the societal anxiety, which is often witnessed with respect to innovations, is enhanced by the rather ‘rational’ way decisions concerning science and technology are usually made and societal tensions are subsequently managed –almost exclusively based on ‘scientific’ expert knowledge– leaving little room for the day-to-day perceptions, ideas, concerns and values of ordinary citizens (Marris, et al. 2002; Fuller 2000; Rowe and Frewer 2000; Rip, et al. 1995). For example, the ‘ambivalent’ response of the public to molecular developments and innovations is often framed by policy-makers, industry and biotechnologists in terms of (1) a lack of knowledge (resulting in programmes to educate the public through the use of improved communication strategies) and/or (2) of ‘non-scientific’ ethical and emotional concerns (resulting in the appointment of expert ethical advisers). Both strategies have not resulted in a reduction of societal tensions (see e.g. Marris, et al. 2002).

Obviously, other ways to manage science and technology in society are needed in order to realize a better societal embedding of science and technology and to be able to address complex societal problems. In this thesis, the focus is on one specific approach that has been proposed as a strategy to develop technologies with desired positive impacts and with few (or at least manageable) negative impacts: constructive technology assessment (CTA) (Rip, et al. 1995). CTA was developed as an approach to deal better with the impacts of science and technology development, by opening up the innovation process in an early phase through dialogue between actors involved and affected by the technology.

In recent years, publicly-funded research programmes on emerging technologies increasingly incorporate research into ethical, legal and societal aspects (Lambright 2002), and call for the involvement of societal stakeholders in the decision-making process. Also in the Netherlands, research programmes on e.g. genomics and nanotechnology comprise research projects on the societal aspects. However, questions remain on how to open up science and technology development to broader societal reflection. CTA approaches face the challenge of designing a dialogue about the future, and facilitating a process of ‘reflection in action’ that actually has an effect on decision making on new science and technology.

This thesis presents an empirical study of CTA on an emerging technology, producing evidence that allows for the further development of a theory of CTA.
Introduction

In the case of ecological genomics (ecogenomics) we designed, implemented and evaluated a CTA process that aimed to facilitate broad societal reflection and to guide research activities into societal desirable directions. The CTA process has been implemented within the context of the Dutch Ecogenomics Consortium. Ecogenomics is a relatively new area of research and innovation that is positioned on the crossroads of ecology, environmental sciences and biotechnology. The Ecogenomics Consortium was established in 2004. It focuses on soil ecosystems and is a collaboration between both public (universities, national research institutes) and private partners (companies). It aims to deliver challenging new scientific information, create opportunities for novel product development in the agro-production field, and provide essential services for improved environmental protection.

In the period 2004-2008 the CTA process on ecogenomics was designed, implemented and evaluated. In thesis we present this process and its results. We reflect on four central challenges that need to be addressed when designing, implementing and evaluating a CTA process: (1) dealing with the absence of concrete technologies, (2) facilitating reflexivity, (3) institutionalizing CTA, and (4) assessing the quality of CTA processes. As such, the thesis aims to contribute to the further development of the conceptual and methodological framework for CTA. The in-depth analysis of both process and outcomes of the CTA process on ecogenomics improves understanding on how to effectively broaden science and technology developments, and produces evidence for improving future CTA processes. In addition, with the implementation of the CTA approach within the Ecogenomics Consortium, the research aimed to contribute to the societal embedding of ecogenomics.
Chapter 2

Managing emerging science and technology in society
Managing emerging science and technology in society

This chapter starts with a reflection on the history and development of CTA, and on the main CTA principles and strategies that have been developed as part of the approach. As the concept of early engagement received attention in recent pleas for ‘upstream engagement’, we discuss these developments in relation to CTA. Only recently, the CTA strategies to broaden research agenda setting on emerging technologies are experimented with in practice. This chapter ends with discussing four central challenges that need to be addressed in designing these CTA processes.

2.1 History and principles of (C)TA

Technology Assessment (TA) originated in the 1960s as an approach that aimed to address the concerns about negative effects of science and technology. The approach was initially positioned as a ‘watchdog’ (Smits and Leyten 1991), using formal approaches like impact assessments aiming to support the political decision-making process around science and technology. The lack of impact of these early TA approaches on policy making stimulated a shift toward TA as a ‘tracker dog’ (Smits, et al. 2010; Smits and Leyten 1991) with a focus on analyzing and discussing societal aspects of science, technology and innovation in an ongoing process, and involving different stakeholders (e.g. end-users, researchers and policy makers). These TA approaches further developed as policy-oriented instruments, e.g. a number of TA organizations were established, often linked to national parliaments (Vig and Paschen 2000). Although the aim of TA was to provide early warning and offer a perspective on future impacts of technology, Rip et al. (1995) argue that it primarily served as after-the-fact gatekeeper and had not been able to bridge between promotion (optimize benefits) versus control (minimize negative consequences) of new science and technology. In response,
a number of TA approaches were developed that aimed to influence technology policies at the strategic level, and shape technological development paths at the early stages. Prominent examples are interactive TA, and constructive TA (Grin, et al. 1997; Rip, et al. 1995; Smits and Leyten 1991). Interactive technology assessment was proposed to better address socio-technical problems by bringing together the owners of the problem, the parties involved in the development of (technological) solutions and those who are affected (positively or negatively) (Grin, et al. 1997). Constructive technology assessment (CTA) has similar goals, but tends to be more directed to the process of technology development.

The approach of CTA challenged the separation between promotion and control by proposing to anticipate on societal aspects, and involve actors, already in the design and development of new science and technology (Rip, et al. 1995). It was proposed as a way to overcome the so-called control and entrenchment dilemma (Collingridge 1981). In an early phase of technology development many options are still open for exploration and there are good possibilities for steering. There are, however, uncertainties about the positive and negative societal effects the technology will bring about in the future and societal attention is rather weak. In later phases of technology development, this situation is reversed. Positive and negative aspects are apparent, but the possibilities for steering are limited.

CTA aims to broaden the design, development and embedding of technology in society, and, as such, make co-evolution of technology and society more reflexive (Schot 2001; Schot and Rip 1997; Rip, et al. 1995). With CTA, the emphasis shifted from political decision-making processes to technological development, implementation and use: the assessment of impacts is fed back into the technological development process (Rip 2002b). This shift in focus also implied a shift in initiators of TA approaches. This role was no longer exclusive to the government, but could be taken up by other actors as well. In general, four types of actors are involved in CTA (Schot 2001): (1) technology actors are the parties involved in the science and technology development process, (2) societal actors are those who experience the (future) impacts of technology, (3) regulating actors develop rules and regulations regarding the technology under discussion, and (4) facilitators and modulators of the CTA process.

A central assumption underlying the approach is that, if proponents and opponents jointly discuss technologies in an early phase, this results in a shared responsibility

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1 This typology represents the range of actors. In practice, however, actors may represent different types at once.
for the design process, the technology and its effects (Schot 2001). There is a strong emphasis on involving both users, producers and parties affected by the technology, and facilitate them to interact (Smits and Leyten 1991). Anticipation, learning and reflexivity have been identified as quality criteria for developing CTA processes (Genus and Coles 2005; Schot 2001; Schot and Rip 1997). Anticipation refers to stimulating designers, users, policy makers and other parties affected to search for synergies between design, market conditions and social effects. Societal learning is needed to incorporate the variety of relevant perspectives, and to identify and understand implicit core values related to the technology under discussion. Reflexivity of the actors entails the reflection about the roles played by involved parties, their own and others’ perspectives, and potential ways to improve the technology development process.

In addition to the formulation of quality criteria, three CTA strategies have been defined: technology forcing, strategic niche management and alignment (Genus 2006; Genus and Coles 2005; Rip 2002b; Schot 2001; Schot and Rip 1997). These three strategies should be combined within a CTA process in order to stimulate anticipation, learning and reflexivity (Schot and Rip 1997). The concept of technology forcing, as originally used to indicate an effect of government regulation, stresses the importance of defining desired impacts and specify them in an authoritative manner. This could either be achieved through government regulation or by broad agreement among the societal actors involved. The basic idea is that this challenges technology actors to develop technologies that meet desired impacts.

Strategic Niche Management refers to the development and introduction of new technologies through a series of experimental settings (so-called niches). Within these niches, learning of actors on aspects like the technological design, user needs, and cultural and political acceptability takes place. In order for strategic niche management to be used as an effective CTA strategy, this ‘learning component must take precedence over the goals of the technology actor’ (Schot and Rip 1997 p. 261)

As a third strategy, alignment focuses on the interactions of actors in loci: ‘actual spaces, forums and institutionalized linkages between supply and demand (...) offering opportunities to modulate developments’ (Schot and Rip 1997 p. 262)

Examples of such loci are dialogue workshops or consensus conferences,
instruments that are commonly used in the context of technology assessment. However, Schot and Rip (1997) state that these types of instruments are often used too distant from the technological design process, or as part of technology-push strategies. Within the context of CTA, they should specifically be designed as deliberation spaces.

2.2 CTA: from theory to practice

In the past decades, numerous deliberative processes around science and technology developments have been conducted. Taking a close look at these processes, shows that they have had little impact on governmental policy making or research practices (Hagendijk and Irwin 2006; Jasanoff 2003b; Irwin 2001). Questions were often restricted to the application of new technologies (i.e. the risks involved), while fundamental questions about ownership, benefits and purposes of new science and technology were not under discussion. Prominent examples are the public debates organized around biotechnology, both in the Netherlands and the UK (see e.g. Hagendijk and Irwin 2006; Kearnes, et al. 2006). Within these processes, questions about desired directions for the research were left to the formal and informal controls within science, which remained dislocated from the public (Mayer 2003). In addition, these debates were conducted at arm’s length from the actual scientific practice and decision-making processes (Irwin 2006). Another problem of these debates is that they were placed at later stages of science and technology development: choices had already been made and technologies were already developed. There seems to be an underlying assumption that public concerns are about instrumental consequences, rather than about the basic driving forces of technological development (Wynne 2005; Wilsdon and Willis 2004).

Looking at these experiences with deliberative processes indicates that the perspective of CTA is a promising one: opening up science and technology developments to broader societal reflection already in an early phase. However, up till now, technology assessment studies did not propose practical ways of broadening the design of new technologies already in an early phase. As Guston and Sarewitz stated (2002):

‘Most [Technology Assessment] literature [...] is often not useful as a practical guide to avoiding “front end” mistakes. There is very little work focusing on communication patterns at the very beginning or even anticipating major scientific and technical change and its impacts,
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to better allow us to understand, prepare for, and avoid conflict, opposition and backlash – hence, “early warning”. (p. 103)

Clearly, although clarifying the way in which science and society are intertwined, and emphasizing the need for early integration, over the past years CTA remained largely programmatic (Reuzel 2001). The strategies described in section 2.1 have not been tested experimentally (Rip 2002b), and the concept of CTA does not include a set of tools ready to be used. Reuzel (2001) specifically points to the challenge to develop practical ways to shape CTA processes:

‘Except for a few methods [...] no definite answer matches the question how to do a Constructive Technology Assessment. It is therefore that attempts to realize a workable programme for Technology Assessment are important.’ (p. 65)

2.3 Recent developments

In more recent years, there seems to be a revival of the idea of broadening the design of technology by opening up the innovation process in an early phase. For example, reflecting on the experiences thus far with public engagement in science, Wildson and Willis (2004) plea for more upstream engagement. Rogers-Hayden and Pidgeon (2007) provide the following working definition for upstream engagement:

‘Dialogue and deliberation amongst affected parties about a potentially controversial technological issue at an early stage of the research and development process and in advance of significant applications of social controversies.’ (p. 346)

It implies a discussion of the basic assumptions of new science and technology from multiple perspectives in a process in which science and society are integrated from the start. This approach aims to lead to better science:

‘Better in instrumental terms, because if scientists engage as equals in a dialogue with the public at an early stage, the likelihood of clashes further downstream is reduced. But also better in substantive terms: science that embraces these plural and diverse forms of knowledge will be more socially robust science.’ (Wildson and Willis 2004 p. 56)

Upstream engagement initiatives have been applied to nanotechnology. These initiatives mainly take the form of large public debates (for examples from the UK, see Pidgeon and Rogers-Hayden 2007; Rogers-Hayden and Pidgeon 2006).
Upstream engagement differs from CTA in its stronger focus on involving the public, i.e. actors with little or no agency. Where CTA is strongly informed by studies of technology dynamics, upstream engagement has stronger linkages with literature on public engagement. Another example, that is closer to CTA, is Real-Time Technology Assessment (Real-Time TA). Real-Time TA has been proposed by Guston and Sarewitz (2002). They positioned it as a CTA approach that has been tailored for application within the U.S., and builds on the analytic findings of science studies and innovation studies. Real-Time TA is described as a process that seeks to build learning into the process, cultivates deliberation, signals emerging problems and allows more conscious choices as research and innovation occur. Just like CTA, the focus is on opening up the innovation process, rather than on managing it after-the-fact. Its focus differs from CTA in that it aims to support natural science and engineering research in incorporating societal values in the innovation process through interaction with the Real-Time TA researchers, and not necessarily through multi-actor interaction. For the past years, this approach has been applied within the Center for Nanotechnology in Society at Arizona State University.

Within the Netherlands, CTA has recently been incorporated in two large publicly-funded research programmes. Besides the CTA process on ecogenomics presented in this thesis, CTA activities have been conducted within the framework of NanoNed, a cooperation between large research institutes working on nanotechnology. The TA projects in NanoNed focused on the design of a constructive intervention to improve the quality of innovation processes in the emerging scientific field of nanotechnology (Merkerk 2007).

These last two examples illustrate the current trend in the Netherlands to integrate TA activities in the early stages of science and technology developments. This offers opportunities to experiment with CTA strategies in practice, and further increase theoretical and methodological understanding.

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2 This integration of natural and social sciences results from the Dutch governmental funding structure, BsiK (formerly ICES/KIS), that aims to support cooperation between research institutions and businesses in order to reinforce the Dutch innovation system. These research programmes need to address societal relevant questions, and need to involve both the supply and demand side. (Source: http://www.senternovem.nl/bsik last visited: January 2009).
2.4 Challenges in designing a CTA process

Within literature, four central challenges are emphasized that need to be addressed when designing, implementing and evaluating a CTA process: (1) dealing with the absence of concrete technologies, (2) facilitating reflexivity, (3) institutionalizing CTA, and (4) assessing the quality of CTA processes (Genus 2006; Genus and Coles 2005; Rip 2002a; Rip 2001; Schot and Rip 1997). Each challenge is addressed below.

Dealing with the absence of concrete technologies

One particular challenge that has to be dealt with when conducting CTA in an early phase of scientific development is the absence of any concrete technology, which implies that an impact assessment is speculative (Rip 2008). Therefore, when CTA addresses technologies in their early phases of development, visions of the future are necessary in order to stimulate learning about possible impacts and to orient future actions (Rip 2002a; Rip 2001). There are a number of ways to look at future developments. In emerging scientific fields, expectations, promises and visions play an important role (Borup, et al. 2006; Brown, et al. 2000). They can be seen as generative in guiding actions, mobilising resources, and bridging between actor communities and organizational boundaries (Robinson, Ruivenkamp, et al. 2007; Borup, et al. 2006). From literature on the sociology of expectations (Borup, et al. 2006) and on vision assessment (Grunwald 2004; Grin and Grunwald 2000), Robinson et al. (2007) developed a typology of visions. This typology is presented in table 2.1.

<table>
<thead>
<tr>
<th>Type of Vision</th>
<th>Description</th>
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<tr>
<td>Science fiction</td>
<td>Long-term fictional ideas, which are accepted as fantasy without demands of feasibility.</td>
</tr>
<tr>
<td>Visionary linkage</td>
<td>Long-term technological possibilities, which are accepted as reality-based fantasies, which could claim feasibilities.</td>
</tr>
<tr>
<td>Guiding vision</td>
<td>Technical and planable technological futures, which imply action.</td>
</tr>
<tr>
<td>Expectation linkage</td>
<td>An evident future development, something that will happen.</td>
</tr>
<tr>
<td>Agenda (goal)</td>
<td>Future actions that should or will be taken.</td>
</tr>
<tr>
<td>Proof</td>
<td>Technological developments that have been demonstrated and are accepted as fact or reality.</td>
</tr>
</tbody>
</table>
This typology defines future representations according to their proximity to actual agenda setting. An alternative typology would be one that stresses the difference between probable, possible and desirable future representations (see chapter 4). For defining the focus of a CTA process and the type of visions to be used, it is important to reflect on the desired goals and the underlying normative assumptions. For example, a CTA process that focuses on expectations (or probable futures), will be structured in a different way than a process with a focus on visions (or desirable futures). Where the first strives to identify balanced and probable scenarios, the second focuses on constructing desirable future developments by integrating different perspectives (Merkerk and Smits 2008).

The way future assessment is currently employed in research on the ethical, legal and social aspects of emerging technologies has also been criticized. Williams (2006) warns for conducting ‘compressed foresight’, which entails presenting future visions as largely determinate and imminent. In addition, debates on science and technology often start out from a ‘risk frame’, implying that issues of potential risk and control are central to the discussions (Williams 2006; Sorensen 2004). As a result, assessing the future in terms of social benefits remains underdeveloped. A more balanced approach is needed in order to avoid on the one hand to overlook possibilities that are not considered, and on the other hand to produce too optimistic views of technological promises (Sorensen 2004).

Facilitating reflexivity
In critically considering the conceptual ideas behind CTA, Genus and Coles (2005) and Genus (2006) point to an aspect of CTA that deserves further attention from researchers and practitioners; CTA as communication and discourse. They focus on the micro-level processes within CTA, and stress issues like strategic behaviour of participants, different images and expectations, and differences in discursive capacities. Dealing with these types of issues requires reflexivity of and between participants of a CTA process. This highlights a central challenge to CTA processes: how to facilitate deliberation between participants? Also experiences with upstream engagement expose this challenge. In responding to criticism to upstream engagement endeavours that fail to be genuinely open and participative, Tait (2009) stresses the need to develop ‘rules of engagement’ that: ‘set standards for the quality and breadth of evidence that is brought to the discussions, and that encourage a willingness to listen to and accommodate, where possible, the views of others.’ (p. 21)
A similar concern is raised by Williams (2006) who observes that societal debates on science and technology often revolve around conflicting claims and priorities between proponents and opponents, stemming from the historical stance of Science and Technology Studies (STS) research to challenge the exclusive role of technical specialists in science and technology policy. He states that:

‘In the current climate, STS may need to give a more balanced attention to the promotion and control of technology, to addressing its benefits as well as its risks, to considering the full range of diverse interests [...] and even perhaps addressing the experiences of scientists and engineers, who may not recognize themselves, their imputed authority and goals in some of the more demonized accounts emerging of the field.’ (Williams 2006 p. 342)

For deliberation, a specific form of communication is needed – the dialogue – in which different points of view are discussed in an open and respectful way (Abelson, et al. 2003). Based on Habermas (1981), conditions for a meaningful dialogue have been formulated, i.e. the intention of participants to take each others’ perspectives seriously, willingness to reconsider one’s own perspective, and taking measures to avoid power plays (Abelson, et al. 2003). Structured deliberations that take into account these conditions aim at inducing a learning process between participants.

In the context of CTA, Schot and Rip (1997) stress that learning must be broad and deep. Broad learning aims at exploring possible new linkages between the technology, social demands and ideas on cultural and political acceptability. In order for these types of linkages to be anchored in the actions of the actors involved, deep learning, that involves both first- and second-order learning, is needed. The concept of first- and second-order learning is derived from Argyris and Schön (1978). Learning between participants of deliberative processes can occur on these two levels: (1) first-order (single loop) learning on the level of problem definitions and solutions (resulting in incremental changes in problem-solving strategies), and (2) second-order (double loop) learning on the level of one’s own and others’ fundamental values and world views (resulting in deeper insight in problem structures and effective solutions). These first- and second-order learning concepts have been frequently applied in policy sciences (Sabatier 1987; Fischer 1980), and in technology and innovation studies (Kerkhof and Wieczorek 2005; Hoogma 2000; Grin and van de Graaf 1996b). Following the work of Argyris and Schön (1978), Grin and Van de Graaf (1996a; 1996b) argue
that the actions of stakeholders are guided by their frames of meaning. Frames of meaning can be understood as a set of assumptions held by an actor, and operate at these two levels (see table 2.2).

**Table 2.2 Elements of frames of meaning (derived from Boon 2008)**

<table>
<thead>
<tr>
<th>Levels</th>
<th>Elements of frames of meaning</th>
<th>Definition</th>
<th>Related concepts and synonyms</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-order beliefs</td>
<td>Evaluate solutions</td>
<td>Evaluation based on efficiency criteria and causal relations between means and end</td>
<td>Technical verification</td>
</tr>
<tr>
<td>Problem definitions</td>
<td></td>
<td>Meanings are attributed to objectives, aims, solutions related to problems</td>
<td>Situational verification</td>
</tr>
<tr>
<td>Second-order beliefs</td>
<td>Appreciative (value) systems and overarching theories</td>
<td>The former is the normative framework in which an actor appraises the problem; the latter concerns the language and repertoire that helps to look at the problem</td>
<td>System vindication: systems of values and perceptions, world views and background theories</td>
</tr>
<tr>
<td>Ultimate preferences</td>
<td></td>
<td>Amongst others preferences about the social order</td>
<td>Rational social choice</td>
</tr>
</tbody>
</table>

In order for CTA processes to facilitate a deliberative process, learning between participants on both levels is crucial. In addition to stressing the need for CTA processes to facilitate ‘reflection in action’, Genus and Coles (2005) emphasize an opportunity for CTA studies to:

‘Rely upon close linguistic scrutiny of specific texts or conversation to analyse constructions, interpretations and claims (of technology, risk or benefit), which constitute social discourse and pervade struggles for and against social change’ (pp. 439).

Shaping CTA processes as deliberative processes implies a need for participatory methodologies that create room for the analysis of positions of different actors, increase their reflexivity, and facilitate learning processes between them. Furthermore, in-depth analysis of the learning that takes place during CTA processes is needed in order to gain insight in the micro-level learning processes that eventually determine the effectiveness of a CTA exercise.

**Institutionalizing CTA**
Schot and Rip (1997) envision the institutionalization of CTA as a future in which CTA is becoming a regular part of societal practices, and where researchers and those likely to be affected by the technology are in the position to negotiate. At the same time they stress the difficulty for CTA processes to organize feedback of societal agendas into actual technological development (Schot 2001; Schot and Rip 1997). Institutionalizing CTA implies a shift in roles of actors on different levels. For example, the role of the government in managing science and technology in society would ideally be one of monitoring the quality of such processes (Schot and Rip 1997). Other actors could take up the role of initiating and designing CTA processes, like research institutes (of which the two CTA initiatives in the Netherlands on nanotechnology and ecogenomics are examples). As such, institutionalization refers to a larger process of change.

Zweekhorst (2004) argues that four elements can be distinguished that affect the institutionalization of a specific CTA approach, the interactive learning and action approach (ILA): (1) the participatory methodology (which needs to be carefully selected and adopted to a specific situation), (2) the competencies of practitioners (who need to be able to design and conduct the process), (3) the institutional setting (which needs to give room for experimentation and flexibility in terms of process and outcomes), and (4) the wider context (which refers to a supportive social and political climate). In recent literature on the institutionalization of CTA and related approaches that aim to open-up emerging science and technology development to broader societal reflection, particular emphasis is put on the last two elements. Several authors point out that the context of the research system in which these initiatives take place, has a large effect on the extent to which researchers are willing and able to integrate the results in their daily work (Kloet, et al. accepted pending revisions; Schuurbiers 2010; Rip 2009). For example institutional structures, funding structures, and established ways of working are believed to play an important role. The role of these types of contextual aspects need to be explored when aiming to increase understanding of the impacts and added value of CTA processes. In addition, questions remain about how these contextual aspects can be taken into account when designing, implementing and evaluating CTA processes.

**Assessing the quality of CTA processes**

Although some general strategies and quality criteria for CTA processes have been defined, it remains unclear how the meta-level criteria for CTA (anticipation of

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3 In section 3.1 the ILA approach is introduced further.
impacts, societal learning and reflexivity of the actors) can best be operationalized in practice (Genus 2006). According to Genus and Coles (2005), CTA practitioners need to be reflexive toward the extent to which the process aims to democratize technology development, and the extent to which it facilitates societal actors or the public to participate on an equal footing with the more powerful actors. They stress:

‘Making interventions for the (democratic) better requires structural adjustment in representation, resources or influence enjoyed by respective parties, or greater clarity about the role of deliberation in technological choice.’ (Genus and Coles 2005 p. 440)

One suggestion they make is that the quality criteria for CTA need to be broadened with criteria that emphasize issues like transparency of the process, impact of voices not usually heard in debates on science and technology, representativeness, and legitimacy.

This challenge is not specific to CTA. Also with regard to participation exercises more in general, several authors argue that there is a lack of systematic and substantive evaluation (Burgess and Chilvers 2006; Rowe and Frewer 2004; Rowe and Frewer 2000), and several evaluation frameworks for evaluating (public) participation exercises have been proposed (Merkerk 2007; Caron-Flinterman, et al. 2006; Rowe and Frewer 2000; Guston 1999). These frameworks often have a focus on process or outcome criteria, or on a combination. Process criteria refer to the involvement of stakeholders, transparency of the process and equal treatment and equal access to resources. Outcome criteria refer to broad support for and identification with the end-product, and mutual learning between stakeholders. Rowe and Frewer (2004) have analyzed evaluation studies of participation exercises and concluded that these studies usually assessed different aspects and that the methodology applied was often poorly described. They, therefore, propose a more systematic and structured approach to evaluation. Also in the case of CTA, such an approach to evaluation is crucial to gain insight into the inherent and contextual conditions that determine the effectiveness of CTA exercises, and to subsequently improve CTA practices. In assessing the quality of CTA processes there lies a challenge in exploring the usefulness of additional quality criteria that have been defined for other types of participation exercises (Genus and Coles 2005).
2.5 Concluding remarks

As illustrated above, CTA has been applied, experimented with and built upon in different ways. The aim of CTA to open up science and technology developments to broader societal reflection in an early stage addresses a contemporary issue: in order to develop technologies that address societal needs and to avoid negative consequences, coproduction between science and society is crucial. CTA offers a promising perspective on ways to bridge between science and society, although there are challenges that need to be addressed when bringing the theory into practice.

Questions remain about what role future visions can play within CTA processes, how to facilitate a deliberative process of mutual learning, how to institutionalize CTA, and how to assess the quality of CTA processes. Recent CTA endeavours that are being conducted within emerging scientific fields, like nanotechnology and genomics, provide an opportunity to reflect on these types of questions, and to contribute to the further conceptual and methodological development of CTA.
Chapter 3

Research design
3.1 Objectives and main research question

In this thesis we present the design, implementation and evaluation of the CTA process on ecogenomics that has been conducted within the Dutch Ecogenomics Consortium in the period 2004-2008. The aim is twofold:

1. The research aims to contribute to the further development of a conceptual and methodological framework for CTA processes on emerging science and technology developments.
2. The research aims to contribute to the societal embedding of ecogenomics.

Critically evaluating the CTA process on ecogenomics aims to improve our understanding of whether, and under what conditions, CTA processes are helpful in taking into account multiple perspectives in innovation processes. In addition, the research provides practitioners building blocks for designing CTA processes that assist research consortia to incorporate a broad range of perspectives from different disciplines and societal backgrounds in the technology development process.

In chapter 2 we argued that there are particular challenges that need to be addressed when designing CTA processes. The design of a CTA approach involves multiple choices on e.g. aim and focus, type of participants, and type of interactive methodologies. Furthermore, insight in how to make use of visions, and how to facilitate mutual learning between participants is needed to shape CTA practices. For the present study, we formulated the following main research question:

*How can the conceptual and methodological framework for CTA be further specified, and how can a CTA approach be designed and implemented so as to effectively improve the societal embedding of emerging technologies in the field of ecogenomics?*
In providing an answer to this question, we reflect on the choices we made in designing the CTA process on ecogenomics, and their consequences for the process and its results. As such, the research contributes to gaining more structural insight in the inherent and contextual conditions that determine the effectiveness of CTA exercises.

### 3.2 Research approach

The research presented in this thesis can be considered a *social experiment* which comprises the design, implementation and evaluation of a newly developed CTA process within the context of the Dutch Ecogenomics Consortium. As a starting point for designing the CTA process, we used the Interactive Learning and Action (ILA) approach\(^4\). The ILA approach has been developed during the 80s and 90s of the last century as a CTA strategy to broaden decision making on science and technology (Broerse and Bunders 2000; Broerse 1998; Bunders and Broerse 1991; Bunders 1990)\(^5\). It was originally developed to enhance farmer-oriented innovation processes in developing countries. The ILA approach has been applied in e.g. Zimbabwe, South Africa and Bangladesh (Zweekhorst 2004; Broerse 1998). More recently it has been experimented with in the context of patient participation in decision making on health research (Caron-Flinterman 2005). Activities within the approach are roughly structured along five phases: 1) initiation and preparation, 2) in-depth study of needs and visions, 3) integration, 4) priority setting and planning, and 5) project formulation and implementation (Box 3.1) (Bunders, et al. 2010; Broerse and Bunders 2000).

These phases should not be considered as a blueprint; they provide structure and guidelines, but need to be adapted to the specific context. The key characteristics of the ILA approach are the enhancement of trust relations, involvement of end-users, identifying shared visions, enhancing coalition building, and facilitating knowledge integration. The ILA approach employs interactive and analytical tools like interviews, focus groups, dialogue meetings and the argumentation tree. Depending on the characteristics and needs of a specific ILA process, the focus is also on the design of new, interactive, research methods. The reason for choosing this approach as a starting point is twofold: (1) the approach has been extensively elaborated on and has been tested in practice in several contexts.

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\(^4\) Formerly called the ‘Interactive Bottom-Up approach’

\(^5\) The ILA approach formed the basis for designing the CTA process on ecogenomics. In the remainder of this thesis we mainly use the term CTA process.
Research design

The phases of the ILA approach guided the development of the CTA process, while at the same time leaving room for an emergent design: experiences along the way shaped the CTA process on ecogenomics toward its final form. Looking at the CTA process in terms of an emergent design implies that the design can be seen as an iterative process in which theory constantly interacts with practice. Initially, theory gives rise to setting up the CTA process on ecogenomics, the cyclic process in which the phases are subsequently designed, conducted, analyzed and reflected upon give rise to enriching the theory, which further shapes the CTA process on ecogenomics, etc. In figure 3.1 this process is visualized.

In the next section we present the steps in the CTA process, and the related research questions, in the order in which they were designed and implemented, with the remark that it was not a predetermined format. The rationale behind the steps, the choices we made, and the specific methodologies used, are presented and elaborated on in the following chapters.

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6 A ‘frame of reference’ can be viewed as a combined set of knowledge, norms and values, and (societal) background by which people weigh, value and interpret new information.
Chapter 3

3.3 Research questions and methodological design

The main question can be divided in three research questions, which determine the outline of this study:

I. How can CTA approaches be effectively tailored to the context of emerging technologies?
II. What procedures can be followed to involve societal actors in, and integrate their knowledge into, innovation processes on ecogenomics?
III. What are the impacts of the CTA process and how can the impacts on the science and technology development process be increased?

Below we present the emergence of these three research questions, the related sub-questions and the steps of the CTA process in the order in which they were designed and implemented.

The research started with the assumption that, considering the early phase of ecogenomics developments, societal actors would barely be aware of ecogenomics developments. The results of a first round of exploratory interviews confirmed this assumption, as most interviewees indicated that they had never heard of ecogenomics before (Roelofsen, et al. 2008). The concept of ecogenomics triggered a lot of perspectives and actors clearly showed an interest in the topic. Interviewees specifically expressed the need for more concrete visions of the technology in order to reflect upon ecogenomics more in depth. These results formed the starting point in the methodological design of the CTA process. Clearly, there was a need for more concrete images of ecogenomics in order for
societal actors to reflect on the topic. This resulted in the formulation of the first research question:

I. How can CTA approaches be effectively tailored to the context of emerging technologies?

As became clear in section 2.4, there are a number of ways to look at the future of science and technology developments. A thorough investigation of ways to gain insight in ‘future images’ of ecogenomics was needed. This led to the following sub-question:

a. What types of approaches to analysing the future of new science and technology exist, and to what extent can they be integrated in the CTA approach on ecogenomics?

A literature study suggested that the approach of vision assessment (VA) as proposed by Grin and Grunwald (2000) would be an interesting addition to the CTA process, given the focus in VA on desirable futures, and their guiding function. As a next step, these two conceptual approaches needed to be translated into a tailor-made methodological design. This challenge gave rise to the second research question:

II. What procedures can be followed to involve societal actors in, and integrate their knowledge into, science and technology development processes in ecogenomics?

The first, exploratory, phase of the research pointed to the need for concrete images of ecogenomics for societal actors to reflect upon. At the time the Ecogenomics Consortium started (2004), the partners within the consortium were expected to have the most concrete ideas about the future of ecogenomics. Therefore, the following sub-questions were formulated:

a. How can the visions that guide current scientific activities in the field of ecogenomics be explored?

b. What are the visions of the researchers’ within the Ecogenomics Consortium?

7 For the remainder of this thesis we use the term ‘researchers’ or ‘ecogenomics researchers’ to refer to members of the Ecogenomics Consortium who participated in the CTA process. This comprises a combination of researchers from academic departments, national research institutes and companies.
This question was addressed in the second phase of the research. In addition to providing a first contextualization of ecogenomics, the second phase of the CTA process also served as a first opportunity to introduce the CTA process to the members of the Ecogenomics Consortium. Through a combination of literature study, in-depth interviews, and focus groups, a broad range of visions were explored and discussed (Roelofsen, Kloet, et al. 2010; Roelofsen, et al. 2008). In the third phase of the CTA process, these visions were used for societal actors to reflect upon, and develop their own visions about desirable futures for ecogenomics. In designing this phase, some specific challenges needed to be addressed, which are reflected by the following sub-questions:

c. In the case of ecogenomics, what should be considered relevant publics at this stage?
d. How can participants be recruited to engage in the CTA process while they are not acquainted with the technology and, thus, not (yet) show a specific interest?
e. How can participants of the CTA process be facilitated to reflect on not yet existing technologies?
f. What are their perspectives on a desirable future of ecogenomics?

In the third phase of the CTA process, focus groups were conducted with a broad range of potential future users of ecogenomics. Participants were challenged to reflect on ecogenomics from their own practical experiences with soil use. This phase resulted in the identification of different ways of framing ecogenomics, and provides contextualization to the science and technology developments (Roelofsen, Broerse, et al. 2010). Furthermore, with the focus groups we aimed to reduce asymmetry in knowledge between potential future users and ecogenomics researchers. As such, both for the organizers and the participants, phase 3 served as a preparation for the next phase: the dialogues. During the dialogues, the aim was to integrate the visions of a broad range of actors in order to identify desirable future directions for ecogenomics. Such a process of integration of visions can be regarded as a learning process (see section 2.4). However, it is not easy or straightforward to design a process that induces learning or to actually measure whether learning takes place, as it involves the cognitive processes and actions of individuals (Schön and Rein 1994; Schön 1983). Therefore, the following sub-questions were formulated for this fourth phase:

g. How to shape a dialogue that facilitates mutual learning between
Research design

participants?

h. How can the learning processes between participants be analysed?
i. To what extent did learning take place in the dialogues on ecogenomics?
j. What desirable future directions for ecogenomics were identified during the dialogues?

In the fourth phase of the CTA process, two dialogue meetings were organized in which a broad range of actors participated. During the dialogue meetings, participants were challenged to discover linkages between research and practice, and to formulate opportunities for ecogenomics with short-term actions (Roelofsen, et al. 2011). The four phases of the CTA process as described above are visualized in figure 3.2.

**Figure 3.2 Structuring of the CTA process on Ecogenomics**

The arrows in figure 3.2 represent the idea of ‘reflection in action’ (stimulate actors to be reflexive toward their own and each others’ visions): participants start out with their own practical experiences and viewpoints, reflect on those and formulate their visions (phase 2 and 3), reflect on additional visions (phase 3), discuss each others’ visions (phase 4), and as a result reconsider their own.
In order for CTA processes to effectively broaden the design of new science and technology, it needs to facilitate such a reflexive learning process. The results of phases 2, 3, and 4 show that the CTA process was rather successful in this respect (see chapters 4, 5 and 6). Nevertheless the impacts on the science and technology development process remained modest, and there are indications that the context of the research system surrounding the CTA process plays an important role (Kloet, et al. accepted pending revisions). Starting from this observation, the third research question was formulated:

III. What are the impacts of the CTA process and how can the impacts on the science and technology development process be increased?

Several authors point out that the context of the research system in which these initiatives take place has a large effect on the extent to which academic researchers are willing and able to integrate the results in their daily work (Kloet, et al. accepted pending revisions; Roelofsen, et al. 2011; Schuurbiers 2010; Rip 2009). The changes needed in order for CTA to become a regular part of societal practices, resulting in a societal responsive science system, imply a system innovation. A system innovation or transition can be defined as a gradual, continuous process of structural change within societal (sub)system (Grin, et al. 2010; Berkhout, et al. 2003; Rotmans 2003; Rotmans, et al. 2001; Geels and Kemp 2000). Such processes of structural change involve changes in e.g institutional structures, funding structures, and established ways of working. Realising such changes within a single CTA process would be too ambitious. Nevertheless, to increase understanding of the impacts and added value of CTA processes, it is important to reflect on the longer term effects of CTA processes, and reflect on them as part of a larger process of change. Therefore, in providing an answer to the third research question we build on insights from transition theory and transition management, and address the following sub-questions:

a. How can the impacts of CTA processes be assessed?
b. What are the impacts of the CTA process on ecogenomics?
c. What role did the organization of the Ecogenomics Consortium play in creating these impacts?
d. What is the role of the dominant structure, culture and practices of the research system in creating impact of CTA processes?
e. How can CTA processes contribute to a transition toward a societal responsive science system?
The quality and impact of the process was assessed throughout the different phases on both process and outcome criteria. The data sources that were used comprised documentary data, direct observation, evaluative questionnaires, evaluative interviews and informal dialogue. Transcripts of the interviews, focus groups and dialogue meetings provided information on the learning processes that took place with, and between, participants. Direct observation was used to investigate aspects concerning the process, like equality among, and interaction between, participants and their actual inputs in discussions. Evaluative questionnaires were filled in by many participants after the various focus groups, and provided information concerning the participants’ opinions on the results and the adequacy of the procedures used during the workshops. After the process was finished, evaluative interviews were conducted in which participants were asked to reflect on whether follow-up initiatives had been initiated. Furthermore, numerous informal conversations were held with consortium members and other participants that provided additional information about how they experienced the process, and the effects on their practices.

3.4 Case description

Only recently genomics became a recognized approach in the field of ecology (Handelsman, et al. 1998). Almost all literature on ecology and genomics (often referred to as ‘ecogenomics’, ‘ecological genomics’ or ‘metagenomics’) dates from the past decade, including major steps forward like Venter’s shotgun sequencing of the Sargasso sea (Venter, et al. 2004) and the publishing of the first book on ecogenomics (Van Straalen and Roelofs 2006). The diversity of the field is illustrated by a growing body of literature dealing with the combination of ecology and molecular approaches, and world-wide several ecogenomics programmes and institutes have been established. In their book, Van Straalen and Roelofs (2006) describe ecogenomics as ‘a scientific discipline that studies the structure and functioning of a genome with the aim of understanding the relationship between the organism and its biotic and abiotic environment’. There exist multiple views on how to define ecogenomics, i.e. other researchers view ecogenomics as exploring the genetic material of all microorganisms present in a specific environment. These two approaches, model organisms ecogenomics and metagenomics, can be seen as the two main approaches to ecogenomics (Kloet, 8 One example is ECOGEN, the Ecological Genomics Institute at Kansas State University
et al. 2011). In both approaches, the technique of microarrays can be used. The microarray is a powerful genomic technology that is widely used to characterize microorganisms in environmental samples (metagenomics), to monitor gene expression under different cell growth conditions (in a model organism), and to detect specific mutations in DNA sequences. Microarrays are able to assess thousands of genes simultaneously.

The CTA process presented in this thesis was designed, implemented and evaluated within the Framework of the Dutch Ecogenomics Consortium. The Ecogenomics Consortium started in January 2004 as a six-year R&D collaboration between 16 Dutch partners (universities, national research institutes and companies). The programme received a Bsik\textsuperscript{10} funding of 11 million Euros through the Netherlands Genomics Initiative (NGI). The Ecogenomics Consortium explored the use of genomics science and technologies on soil ecosystems. This implied research across the disciplines of ecology, microbiology, soil sciences, environmental sciences, biotechnology and bioinformatics\textsuperscript{11}. The novelty of the programme lied in the collaboration between research groups from different disciplines and private partners. This implied a focus on both exploring new complex interdisciplinary questions, and on developing applications in the interest of sustainable land use for various social purposes. The Ecogenomics Consortium aimed to deliver challenging new scientific information and to provide tools for sustainable use of soils in the agro-production field, for bioremediation and for environmental quality assessment.

Within the Ecogenomics Consortium there was a strong focus on societal needs, which is stimulated by the funding structure of the programme. The research programme was selected on the basis of its scientific excellence and its potential relevance for the Dutch economy and society as a whole. The Ecogenomics Consortium included research projects on interdisciplinary collaboration and societal aspects of ecogenomics. The main assumption underlying these projects is that interdisciplinary collaboration and involvement of relevant stakeholders increase the scientific and societal value of research, result in the development of products that effectively address complex societal problems, and offer opportunities for initiating follow-up research projects. An explicit choice was made to investigate the societal implications in an interactive way in parallel with the ongoing scientific and technological projects, rather than on ex-post

\textsuperscript{9} The differences in ecogenomics approaches is further explored in chapter 4
\textsuperscript{10} Besluit Subsidies Investeringen Kennisinfrastructuur
\textsuperscript{11} www.ecogenomics.nl
monitoring.

There were several reasons for choosing ecogenomics as a case for designing, conducting and evaluating a CTA process for emerging technologies. First, there was the opportunity to embed the CTA process within the Dutch Ecogenomics Consortium. Addressing societal aspects and pursuing societal relevance was an important precondition for funding, leading to the allocation of resources to two research projects on the societal aspects of ecogenomics. Being part of the Ecogenomics Consortium offered the opportunity of conducting the CTA process in close proximity to the research activities. The fact that the CTA process was developed as part of the research of the consortium also provided initial commitment of researchers for participating. In addition, being part of the Ecogenomics Consortium from the start implied that ecogenomics research and the development of the field could be followed and anticipated on in real-time.

One of the aims of the CTA process on ecogenomics was to contribute to the societal embedding of ecogenomics. To achieve this goal, CTA focuses on broadening the aspects and criteria considered in the decision-making process. The research thus specifically focused on bridging between research and practice by initiating learning processes among a wide variety of actors in an early phase of developments. During the CTA process the focus was specifically on exploring opportunities for ecogenomics from multiple perspectives while taking into account related negative aspects. In terms of agenda-setting, the research agenda of the Dutch Ecogenomics Consortium formed the focal point for this process.

3.5 Validity

Multiple strategies have been used within this study to enhance the validity of the results and conclusions and to minimize the effects of researcher bias and influence. The strategies comprise triangulation, member checks, the use of rich data and a combination of deductive and inductive data analysis. Triangulation was applied to different elements of the research. Different methodologies were used to collect data on the same phenomenon, such as literature study, interviews, participant observation in focus groups and evaluative questionnaires. Furthermore, multiple researchers were involved in designing and conducting the research and analyzing the results. This resulted in triangulation among researchers as well, minimizing the risk of personal researcher bias.
An additional strategy that was used are ‘member checks’, which entails systematically soliciting feedback on data and conclusions from the people who were involved. During the research, interviewees or focus group participants received draft reports in order to check the interpretation of opinions or perspectives.

In addition, throughout the research primary data has been extensively documented in the form of verbatim transcripts of interviews and focus group discussions, ensuring the use of rich data.

As the CTA process was shaped as an emergent design in which theory and practice are mutually influential, two types of data analysis are combined; deductive (starting the analysis from analytical frames based on theoretical notions about CTA and related approaches) and inductive (letting themes emerge from the study of the data).

### 3.6 Research team

The research team involved a number of people. Jacqueline Broerse, Tjard de Cock Buning and Joske Bunders were involved in the overall management and supervision of the project. Literature study and interviews were conducted by the author of this thesis, the focus groups and dialogue meetings were jointly developed and organized by a number of people. The author of this thesis, Jacqueline Broerse and Tjard de Cock Buning were involved in the design of the methodologies, and as facilitators during several focus groups and the dialogue meetings. Roy Kloet, also PhD student on the societal aspects project of the Ecogenomics Consortium, co-organized several focus groups and the dialogue meetings as part of his own research. The author of this thesis had a central role in observing the focus groups and writing the reports. In analyzing the data multiple researchers were involved.

### 3.7 Outline of the book

The subsequent chapters reflect the methodological structuring of the CTA process. Chapter 4 focuses on the first two phases of the CTA process: the exploration, and the visions of ecogenomics researchers. This chapter starts with an exploration on ways to look at future developments. Based on this exploration,
the concepts of CTA and vision assessment are combined to form the basis of the CTA process on ecogenomics. Subsequently, the methodology and results of the first two steps in this process are presented and discussed.

In chapter 5 the third phase of the CTA process is presented. In this phase, potential future users reflected on ecogenomics in focus groups, using the visions of ecogenomics researchers (phase two) as input. In this chapter we reflect on our choice to involve potential future users, present the focus groups methodology and reflect on the results.

In chapter 6, the dialogue phase (phase four) of the CTA process is presented. In this chapter the focus is on the analysis of the learning processes that took place between the dialogue participants.

The impacts of the CTA process on ecogenomics, and the role of the structure, culture and practices of the research system are assessed in chapter 7. Building on insights from transition theory we point out the barriers imposed by the structure, culture and practices of the research system in which CTA processes take place. Furthermore we reflect on how CTA processes can contribute to a transition toward a societal responsive science system using insights from transition management.

Chapter 8 revisits the design and implementation of the CTA process on ecogenomics and the main conclusions are drawn. It discusses the validity of the findings and closes with recommendations for further research.