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Assessments of emerging science and technologies: mapping the landscape

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	Risk analysis (n=14)	Impact Ass. (n=6)	Economic Ass. (n=11)	Ethical Ass. (n=11)	Foresights (n=10)	TA (n=9)
Impartiality	4.4	4.0	3.2	4.2	4.2	4.4
Transparency	4.1	3.8	3.7	3.2	4.2	3.7
Participation, experts	4.8	4.5	3.5	4.6	3.9	2.9
Participation, lay people	1.3	3.7	1.4	1.6	1.6	1.1
Participation, stakeholders	1.6	4.5	2.4	2.5	3.5	2.6
Scientific evidence basis	4.7	4.0	3.7	4.0	3.8	4.3
Focus on uncertainties	3.6	4.2	2.9	3.6	2.8	4.3
Explicit values/ethics	1.6	3.7	1.7	4.7	2.0	2.7

	TA	Risk analysis	Ethical ass.	Foresight	Economic ass.	Impact ass.
Nanofood	2	7	0	0	0	0
Synthetic biology	1	1	2	0	0	0
Biofuels	0	0	1	1	0	0
Cloud computing	3	2	1	0	4	0
Not case study related	3	4	7	9	7	6
Total	9	14	11	10	11	6

Not domain related	Total
7	16
7	11
18	20
10	18
	36
	101

Abstract

This paper presents comparative work from the [X] project on technology appraisal. It focuses on studies of 'advisory domains', i.e. more or less distinct traditions for assessment of technologies, such as risk analysis, foresight and ethical assessments. The purpose of the study was to increase the understanding of current assessments in order to identify whether more integrated approaches seemed to be needed. In this article we present an analytic approach for studying assessments across advisory domains and present findings from our analytic studies, showing differences in methodological characteristics across the domains. We discuss how the domains partially overlap and identify gaps. We show how most of the selected assessments address technology trajectories and science, technology and innovation policies, and few address specific applications. Finally, we argue that quality control is important for the legitimacy of advice on emerging science and technologies and that the domains are important in this respect.

Introduction

'Emerging science and technologies' (EST) is a collective phrase currently used to describe a range of technological fields including (but not limited to) biotechnologies, nanotechnologies and information and communication technologies (ICT). These technologies have been praised by some for their revolutionary potential for solving current global challenges and, not least, creating economic growth (OECD 2009 and 2013, Kroes 2011). These still early stage and novel technologies may allow us to manipulate our natural and social world in ways not previously imagined. As promising as they may seem, however, the same properties that provide new possibilities for innovation also present potential new risks. There are concerns and disagreements about the impacts emerging technologies may have on human health and wellbeing, animals and the environment. There are ethical concerns about respect for human dignity, human enhancement, new monitoring potentials, the moral acceptability of creating life, social and intergenerational justice, etc (see e.g. Budinger and Budinger 2006).

These promises, uncertainties and potential controversies give rise to what Kaiser et al. (2010) in the nanotechnology field referred to as an 'assessment regime' on the interfaces between science and policy, where a host of actions have been taken to map benefits, risks and public attitudes, engage the public in discussions, and provide evidence for policy making and regulation. National science societies, public research institutes, technology boards, ethics committees and research consortia organise actions and events including expert committees and the engagement of stakeholders and/or lay people in different participatory processes. Such activities are either self-initiated by the organisations or carried out based upon requests from politicians, ministries or other decision-makers, or conducted as part of open call research projects funded by the EC framework programmes or national research programs.

In addition to such events and assessment projects, emerging technologies are also subject to the established regulations that require specific appraisals such as risk assessments. Examples of these regulatory requirements are set out in the European Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), the European Directive on Deliberate Release of Genetically Modified Organisms into the Environment, the Novel Foods Regulation, etc. There are also regulations at an EU and national level that require impact assessments of larger projects and programs. In addition to, and as a basis of, these assessment mechanisms there is a great volume of research. However, even if a significant knowledge base on facts and values is being produced, EST fields are still characterised by controversy as to what extent these assessments capture the scientific and societal complexities and uncertainties in these fields, and whether the assessments contribute to the development of robust, responsible and sustainable technology policy and governance (see for instance von Schomberg 2012, Wickson and Wynne 2012a).

The [X] project aims to contribute to further developing frameworks for assessment of emerging science and technologies conducive to responsible technology development. The basis for such development work has been laid in studies of current assessments, through case studies of assessment of specific technologies and through studies of the different assessment approaches. In this article we reflect on the different kinds of assessment approaches as such (in the form of advisory domains). In the article we will first spell out the methodological approach in the project and present the analytic tools applied in the studies. We will then present some findings from the studies of the advisory domains and proceed to reflect on the relations between the domains. We will discuss the role of the domains before concluding the article.

The [X] approach

For an understanding of *assessment* we can start with a definition given by Van der Sluijs (2002), referring to Parson (1995), in his encyclopaedia contribution on integrated assessment:

> *Assessment* comprises the analysis and review of information derived from research for the purpose of helping someone in a position of responsibility to evaluate possible actions, or think about a problem. Assessment means assembling, summarizing, organizing, interpreting, and possibly reconciling pieces of existing knowledge, and communicating them so that they are relevant and helpful to an intelligent but inexpert decision-maker (Parson, 1995).

Assessments are often carried out in institutionalised assessment traditions, such as parliamentary technology assessment (TA), impact assessment (IA), foresights and ethics assessments. In the [X] project we have studied these traditions under the term ‘advisory domains’. Conceptually, we have abstained from attempts at building a strong epistemology for the concept of “domains”. The point has been to delimit our selection of domains from emerging or hybrid forms of assessment taking place as one-off experiments or transient phenomena and to focus instead on what may be said to be well-known interfaces between science, society and policy. With the idea of institutional domains comes some degree of tradition, some common forms of practice and some degree of establishment within public decision-making systems. However, the domains are institutionalised to different degrees and institutionalisation is an ongoing project. Moreover, the borders of the domains are often blurred. The word ‘domain’ must therefore here not be understood as referring to a definite object but to a set of more or less institutionalised practices.

The domains studied in [X] were risk analysis, impact assessment (mainly as it is carried out within the European Commission Impact Assessment framework), economic assessment, ethical assessment, foresight and TA (mainly in the context of parliamentary TA institutions). These different frameworks for assessment of emerging science and technologies were studied as a means to reflecting on the status of EST assessments and on room for improvement. The purpose of this part of the [X] project was to increase the understanding of the basic challenges in current EST assessment, ultimately feeding into the [X] reflection on the need for, and potentially the format of, more integrated approaches to technology appraisal. The work has been based on studies of practitioners’ manuals and scientific literature from the domains, on assessment reviews, on interviews with assessment practitioners and policy makers, as well as on input from a practitioner workshop organised in the project.

Studying assessments across advisory domains is a practically non-existent research field, implying a need for developing a research protocol that would provide us with the data necessary for a status overview of current EST assessments relevant for identifying the need for more integrated approaches. With no existing methodological approach that could be readily applied, the overarching method in the project was therefore an iterative process of reflection, literature review, method development, application, new reflection, further literature review and adaptation of the method.

The reflection points started with the project consortium, which include practitioners from the fields of ethics, foresight, TA, economic assessment, risk assessment and impact assessment in different EST fields such as biotechnology, nanotechnology and ICT. From our practical experience and research we had assumptions about what were relevant dimensions when studying current assessments. The reflection moments were enhanced by including the project's advisory committee, which consist of practitioners in the field of sustainability assessment and future oriented analysis, in addition to ethics and TA. Finally a practitioner workshop was organised with 32 participants covering a broad range of advisory domains.

The literature review focused on a large literature on EST governance and technology appraisal, some of which is referred to in this special issue (e.g. Beekman and Brom 2007, Kaiser et al. 2010, Decker and Ladikas 2004, van Asselt 2000, Wickson and Wynne 2012b, Turnpenny et al. 2008, Stirling 2008). The currently important notion of responsible research and innovation (RRI) is also a significant context for such dimensions (von Schomberg 2012, Owen et al. 2012, European Commission 2013).

The method development part consisted in developing an analytic approach in order to make our analyses of individual assessments in the different case and domain studies transparent and comparable. Each assessment was analysed with two analytic tables. One was originally developed for analyses in the TA field (see table 1, purpose analysis table, from Decker and Ladikas 2004), but was deemed useful for analysing the purposes of EST assessments in general. The other was developed by the consortium to address the procedural dimensions of the assessments to be reviewed (see table 2, process characterisation table).

[Insert table 1 here]

Table 1. Purpose analysis table, developed in (Decker and Ladikas 2004) and used as a part of the analytical work in the project.

[Insert table 2 here.]

Table 2. Process characterisation table developed in the project.

The dimensions in the process characterisation table reflect the outcomes of the reflective points and literature analysis. Firstly, that the main challenges in EST governance are related to scientific uncertainties, value controversies and the problem of anticipating the potential broad range of impacts in the medium to long term (von Schomberg 2012, Owen et al. 2012, Falkner and Jaspers 2012). Secondly, that the main challenges in EST assessment is that assessments are contested due to their underlying values and framings, participation, perceived (im)partiality and (non-)transparency (see e.g. Hansson 2010, Funtowicz 2006, Stirling ~~2006~~2008, Wickson et al. 2010).[1]

In the review of the assessments we did not only apply the tables but described also the background of the assessments, the methods applied in executing the assessment and to what extent the assessment aimed at integration. In order to improve the comparability of reviews within and across the [X] studies, a 'calibration group' was established to align differences in scoring practices.

All in all 1506 assessments were screened and 101 were chosen for further analysis in the case and domain studies. Table 3 shows the distribution of assessments across domain and case studies:

[Insert table 3 here.]

Table 3. Number of assessments studied in the project. Some were selected on the basis of the case studies and some with a focus on the advisory domains themselves. This implies that some assessments selected as important in the case studies could not easily be categorised into the domains and some of the domain study assessments were not related to the case studies. See below for a discussion of the role of the domains.

The assessments were identified by studying policy documents in the EST fields, by following up on references in assessments, by formal and informal interviews with advisors in the fields and by internet searches. The assessments included for further study were selected on the basis of their policy relevance with regard to the selected technology fields studied in the case studies (determined by their explicit mention in policy documents), and on the basis of being exemplary for the methodological approaches in the different advisory domains. For each domain between 6 and 14 assessments were reviewed in detail according to the protocol. As the assessment review was of a qualitative nature it was outside the limit of the project's resources to include a higher number. The results cannot therefore be interpreted to be representative other than that they provide central examples of assessment approaches in the advisory domains studied.

The two analytic tables above were used as a basis for an aggregated analysis at a case study level and at an advisory domain level, providing us with a basis for comparing findings across the domains and across case studies related to the analytic dimensions defined in the

[1] As can be seen in table 2 we were also interested in other dimensions, such as the way contextual variables were taken into account. This part of the research is presented in van Doren et al. (this issue).

tables. It also gave us the possibility to reflect on the advisory domain identities of the assessments selected in the case studies and the apparent role of the domains. Domain focused analyses following-up on findings in the case studies (such as upstream/downstream issues, as presented below) were conducted. The different advisory domains' institutions, methods and challenges were also studied by way of document and literature reviews and interviews with practitioners. It would exceed the scope of this article to give an in depth description of each domain. We will therefore proceed directly to reflecting upon data generated by comparing the domains, and subsequently to discuss how the domains might be related.

Some core characteristics of the reviewed assessments

The assessment reviews yielded a large amount of data. Some of this is presented in other articles in this special issue. Here we will discuss some of the findings that we consider most important for understanding the methodological challenges in the domains. Table 4 presents the mean scores of each of the domains on the different core process characteristics and selected core substantial characteristics (see table 2 above). We shall quickly run through the most interesting findings.

[Insert table 4 here.]

Table 4. Overview of mean scores for each advisory domain related to the different characteristics. 'n' indicates the number of assessments analysed in each advisory domain.

Impartiality is generally above 4, indicating that efforts have been made to achieve a balanced presentation of the issues, with balanced participation, or that this is a priority in the assessment. The exception is in economic assessment, where the mean is just above three indicating that this is dealt with sufficiently, but is not a focus in the assessment. This finding is explained by the many assumptions and modelling decisions that have to be made in economic assessments, which can only be done on the basis of decisions that can be regarded as partial as long as they are not properly explained, reflected on and justified. *Transparency* is lowest for ethical assessment, but the procedures and participation is still considered sufficiently characterised in this domain.

Experts are included in EST assessments across the board. The lowest inclusion of experts is found in TA, indicating that this is not an aim for the selected TAs. *Lay people* inclusion is low in all domains except IA. *Stakeholder* involvement is slightly higher, but only IA and foresight generally make this a priority. Impact assessment is the advisory domain with the overall highest inclusion of stakeholders and lay people. This is due to institutionalised mechanisms for consultation. However, we have not assessed the de facto number of lay people or stakeholders involved in all the impact assessments.

The reviewed economic assessments do not focus on *scientific uncertainties*. This makes economic projections vulnerable to grave errors if the uncertainties with regard to the potential risks and benefits of the technologies are not adequately taken into account. A surprising finding is that scientific uncertainties are not generally considered a priority in the selected risk analyses.[2] The emerging aspect of emerging science and technologies inherently implies questions of scientific uncertainties, which is the main reason why good risk assessments play an important role in responsible EST governance. One may argue that risk analyses that do not address uncertainties as a priority area neglect some basic concerns with EST.

Unsurprisingly, *ethical values* are mostly focused on in ethical assessments. Impact assessments also score high here; the reason being their transparent positioning of their assessments in a normative context. Risk analysis and economic assessments do not focus on making ethical values explicit. This may imply a disciplinary understanding in the domains that such assessments do not involve ethical values, which has been contested both within and outside the domains. It has been argued that to a large extent economic projections and quantifications (see e.g. Mongin 2006), as well as methodological choices in risk assessment (see e.g. WHO, 2002, 30-31), rest on judgements that may include normative elements and that should be reflected upon in a broader perspective. However, the findings may also be explained by conventions in the domains with regard to what kind of methodological issues are discussed in assessment reports.

The relations between the domains

The [X] analyses identify a wide range of assessments answering different questions. The assessments in the advisory domains have different intended purposes and functions. The assessors frame their topics and design their assessment processes in different ways depending on their mandate, the traditions in the domains, the intended impact, etc. However, there are also several overlaps between the advisory domains. The relations between the domains can be conceptualised in different ways and we will here present two approaches.

The assessment reviews show that IA, TA, foresight and ethics generally take a broader scope than risk and economic assessment (i.e. consider more types of impacts).[3] This is confirmed in an analysis of the overlap in the purposes of the reviewed assessments. These were analysed using the purpose analysis table (see table 1 above). When we aggregated these per domain we saw what roles the different domains most often intended to have. The findings are presented in table 5:

[Insert table 5 here.]

Table 5. Purposes of assessments in different assessment domains. Bold indicates that this is a primary purpose for the domain (more than 60 % of the reviewed assessments in the domain indicated this

[2] The term 'risk analysis' rather than 'risk assessment' was chosen as several of the selected assessments (on the basis of the policy relevance criterion for the selection of assessments) advised on risk assessment schemes rather than simply providing technical risk assessments.

[3] For instance, 5 out of 14 risk analyses and 4 out of 11 economic assessments only address one kind of impact, whereas no IA, foresight or ethical assessment (and only one of the TAs) address only one impact.

role). Not bold indicates that this is a secondary purpose for the domain (between 50 and 60 % of the domain assessments indicated this role). Brackets indicate that between 35 and 50 % of the assessments in the domain indicated this purpose. The assessments would often have several intended purposes.

Table 5 illustrates the substantial overlap of the purposes of the different assessments. This shows a possible competition especially in forming the evidence base on scientific/technological aspects, in forming attitudes on these as well as raising knowledge on policy aspects. On the one hand, policy makers can pick among several assessments with the same function to inform their policies and these assessments are likely to differ with respect to the way the evidence base is portrayed. On the other, policy makers might want to integrate the lessons from all the assessments with the same function and appraise their different assessment approaches against each other. Though this obviously is a larger task than simply picking one's favourite assessment, choosing such an option is an important recommendation of the [X] project (see Beekman et al., this issue).

Another way of comparing the domains is by relating them to stages or discourses in technology/policy development such as technology trajectories, science, technology and innovation (STI) policies, and product applications. Technology trajectories can be seen as a direction of advance in a certain technology field (see Dosi 1982). When these technology trajectories appear to potentially impact on society, STI policies may be formed as a response. These may involve research programmes, innovation incentives or development of regulation. Concrete applications will arrive as part of the trajectories and will in some cases, as in the case of food, be met with different regulatory actions requiring specific product assessments. Conceptualising these distinctions as "stages" is not meant to imply a strictly linear relation. Developments in technology trajectories, policies and applications will often run in parallel.

The table below (table 6) shows the relation between the selected assessments and the different discourses.

[Insert table 6 here.]

Table 6. The table portrays the function of the different domains related to stages in technology/policy development, based on the reviewed assessments. The numbers indicate how many of the reviewed assessments in the domains deal with technology trajectories, STI policies and specific applications. Many of the assessments address two or more of the categories, therefore the numbers add up to more than the total number of assessments.

All assessment domains, with the exception of impact assessment[4], play an important role in the assessment of varying technology trajectories. Such assessments may be carried out early in the technology and policy life cycle; often aimed at initiating and justifying political and/or

[4] As noted above impact assessment in the [X] studies mainly refers to European impact assessment, which is targeted to policies. The term impact assessment is also used in other contexts, to refer to more specific studies of impacts of projects or technologies but this is not included here.

funding action in the emerging field. STI policies are important for translating technology trajectories into technological strategies, such as regulatory measures, research and innovation programmes, etc. These are mainly assessed in impact assessments and foresights; however, we found that such policies were also assessed in TAs, economic assessments and ethical assessments. The policy relevance criterion in the project may account for the fact that most assessments of technology trajectories also involves assessment of STI policies.

From the open discussions of trajectories to the more application oriented assessments there is a political and policy making process where general concerns are translated into guidelines and premises for further regulation and priorities for funding. This is a complex, 'closing down' (Stirling 2008) process involving many actors representing different professional stances, cultures and worldviews. From the case study on nanotechnology in the food sector we saw that the early assessments were focusing on deliberative explorations of values and concerns, while the later were focused on settling risk assessment and other regulatory issues. At this later stage a number of premises are given and optimal policies and regulations are sought, realising the benefits of the technological options while avoiding the costs. Assessments at this stage have different functions than the broader ones and consequently they are carried out in different ways. At the level of mandatory environmental and health risk assessments the broad spectrum of public concerns and values that are discussed in public discourse – and also embraced in high level official documents (the concepts of safety and sustainability are two examples) – are narrowed down and operationalised in order to ensure standardised treatment.

One may also describe these stages in technology/policy development in terms of a 'stream'. Upstream governance is carried out in research policy and technology assessment, while downstream governance is carried out by regulations (including risk assessment) and market mechanisms (Fisher et al. 2006). Fisher et al. call this 'pre- and post-research and development (R&D) stages' (485) and argue for a complementary 'midstream' integration of technical and societal elements among the technoscientific community. Others (e.g. Wilsdon 2005 and Macnaghten et al. 2005) call for more upstream engagement involving stakeholders and the public in discussions about technology development while technology trajectories more easily can be shaped. The so-called Collingridge dilemma (Collingridge 1980) describes the inherent problem that impacts of a technology are not known until the technology is extensively developed, but at this point it is harder to influence on the technology as it is embedded in institutions and power structures.

When applying these concepts to table 6 we see that there are many upstream assessments but few downstream, except for some risk and economic assessments. One obvious reason for not identifying many downstream EST assessments is that these technologies are emerging and do not yet have many downstream applications. However, this is only part of the reason. Cloud computing, for instance, is already in widespread use. And there are more than 1200 nano products on the market (http://nano.taenk.dk/), albeit not many in the food sector. These consistently influence society in ways that are not fully appraised.

We should point out, however, that had we chosen genetically modified (GM) plants or animals as a case study we might have found a larger share of relevant downstream assessments. Institutions like the Netherlands Commission on Genetic Modification (COGEM) and the Norwegian Biotechnology Advisory Board produce assessments on a routine basis related to specific GM applications, applying an integrated approach covering a broad range of topics (including health and environmental risk, sustainability and ethics). With institutions like these for nanotechnology or ICTs it would be easier to ensure that broad societal concerns are reflected more directly also in practical application oriented assessments. For even if one may have sympathy with the call for upstream assessments, there is a risk that the broader societal assessments mostly refer to generic technology scenarios and not real-life situations[5]. Mechanisms for broad societal assessments of specific downstream technology issues for the whole spectrum of emerging technologies seem to be missing. It is not sufficient that broader societal issues are discussed at the level of technology trajectories or STI policies if they are not considered at the application level, as broader input to risk and economic assessments or as complementary assessments to risk or economic assessments. This is particularly critical in light of our findings in table 3 where risk and economic assessments score lower on focus on uncertainties and explicit values than other assessments.

In the lack of institutions performing broad downstream assessments across the entire EST field on a routine basis, engaging in such issues remains a challenge to the advisory domains themselves (such as ethical assessment and TA), but also to policy makers who should commission broader application oriented assessments than strictly limited risk assessments. Sustainability assessment is an established, non-reductive methodology for such problem focused assessments (see e.g. van Asselt 2000) but such assessments are hardly found in our case studies (with the exception of biofuels). Moreover, it is important that these do not themselves become routinised, technical procedures rather than broader reflective assessments. We suggest in [X] that instead of picking one unique methodology (even if it is in principle non-reductive) for dealing with such issues, there should instead be dialogue across the advisory domains, involving those who have already assessed issues at the stages of technology trajectories and STI policies, and inviting in also more specific stakeholders and experts relevant for the topic at hand (see Beekman et al., this issue).

As Collingridge pointed out there are challenges with requesting such assessments. A legal challenge is implied in the case of limiting market access to certain products on the basis of broader considerations as international trade laws may apply and non-scientific justifications may be considered illegitimate barriers to trade. A methodological challenge is that with increased practical problem orientation comes increased complexities in variables, as well as problems of delimiting the adequate scope of assessments (see e.g. Forsberg 2007, UNEP 2009). And a practical aspect is that there are too many potential applications (products, projects, possibilities for use) than is possible to assess in a broad fashion, and such a widespread broad assessment regime would be extremely costly. However, for some issues

[5] A point also recognised by von Schomberg 2012, referring to Selin 2009.

– issues that become potential policy problems – such challenges should be offensively faced in order to ensure responsible technology development.

Table 6 also indicates that in addition to this need for vertical, upstream/downstream communication, there is also a need for *horizontal* communication across the advisory domains and with stakeholders and policy makers. As we have seen above there is a certain division of work between the assessments but there is also sufficient overlap that indicates that results from any given assessment may affect the assumptions in other partly overlapping assessments. The implications of, for instance, an economic assessment revising an earlier belief that a technology is likely to yield large efficiency gains may lead to a need to do a new TA because it may change how risks are justified. Similarly, a new public deliberation event may come up with new policy options to be considered in an IA. However, we have in our studies not found any mechanism that facilitates such cross domain communication. This does not mean that there is no information exchange, but that the extent to which neighbouring assessments are considered in a common perspective likely is dependent on the network, interests and resources of the involved assessment professionals or civil servants.

Too strong institutionalisation of the domains may be a barrier to communication, as values become naturalised, implicit and cemented (see e.g. Forsberg et al. 2012 for a study of ethics and institutions). Too strong internalisation of assessments within policy/decision making (with assessments carried out completely internally in a ministry, a corporation or an NGO as an extreme) is another. Finally, a proper conceptual apparatus to engage meaningfully with other domains is a third communication challenge for horizontal dialogue. The [X] approach to integrated assessment includes a framework for clarifying, discussing and justifying assessment assumptions and choices. In the project we found that all domains institutionally have a focus on methodological development, trying as domains to tackle the complexities and uncertainties implied by emerging science and technologies. However, we also found that they do not systematically discuss such challenges with practitioners from other fields. Even if there are many overlaps between the domains in terms of both topics and methods, there is a lack of infrastructure for communication between the domains (with some notable exceptions such as the COGEM subgroups). From the project practitioner workshop we learned that cross-domain dialogue was appreciated.

The role of the domains

The final point we would like to make before concluding the article is about the role of the advisory domains. 45 out of a total of 65 assessments reviewed in the case studies could not be easily characterised as belonging to any of the domains above but had nevertheless a certain prominence in the case studies. Of these 45, some were carried out by research consortia (such as the Synbiosafe consortium), some by consultants (such as ADAS UK Ltd.), some by stakeholders (such as the ETC group), some by international organisations (such as OECD) and some were deliberative events specifically set up by public agencies for the purpose. These were included in the case studies because they appeared to have policy relevance. This high share of non-domain assessments may raise the question of why it is still important to discuss domains.

For answering this question we need to turn to the document and literature studies of the domains. These indicate that advisory domains are important because the institutions contribute to the quality control of their working procedures. Risk analysis, for instance, possesses a tool box that has gained legitimacy over the years. This does not mean that there are no methodological controversies about this toolbox but that the domain practitioners are involved in methodological discussions that take objections into account, develop their methods to new contexts, and have internal mechanisms for quality control through domain societies, conferences, journals, etc. Moreover, in order to maintain legitimacy assessment domains – as institutions – need to adapt to expectations from their surroundings, on which they are dependent on resources or other support (see Suchman 1995 for an institutionalist account of legitimacy). This means that there is a societal responsiveness in the domains.

Some assessments or reports that are not institutionally anchored in any established advisory domain may use methods from a domain in their assessment, and may identify with the domain and be part of their learning practices (journals, conferences, etc.). If so, the reflections accompanying their methodological choices will relate to the methodological toolboxes of the domains to which the assessment relates. Other assessments may have less of an identity. The assessments with no clear identity may be perfectly legitimate when they demonstrate appropriate transparency about their assumptions and methods. In the cases where they do not have such methodological discussion, it is harder to distinguish what criteria should be applied to assess their quality. When there is an unclear description of what domain the assessment belongs to, this may in some cases reflect methodological unawareness and thus unjustified method choice. Such quality deficiencies may affect the assessments' legitimacy as input to policy making. With less of an institutional structure for ensuring transparency and justified choices, assessments from non-institutionalised assessment domains must be carefully evaluated before taken as legitimate input to policy making.

Of course, it should be said that the fact that an assessment is generated within an advisory domain does not in itself warrant for high quality. The varying scores in table 4 above suggest the existence of quality problems that needs to be addressed also in the established advisory domains (or our findings should at least be further investigated). Quality requirements apply to all assessment, within or outside established advisory domains. However, the advisory domains do have resources and infrastructure for quality improvement that makes them important in discussions of improvement of technology appraisal. In this study we found no institutionalised cross-domain mechanisms for judging the quality of assessments that influence policy. Moreover, there was very limited transparency with regard to the impact of the different assessments on policy (corresponding to Cruz-Castro and Sanz-Menéndez' (2004) observation about the indirect and complex nature of the impact technology assessments may have on political decisions). The potential need for amending such gaps should be further discussed in the academic literature and in practical policy dialogues.

Conclusions

In this article we have presented a novel analytic approach for studying assessments across advisory domains. We found that this analytic approach was useful for generating data on important quality dimensions of assessments, and we encourage further methodological development in this field. We have also presented a number of results from our analytic studies, showing interesting differences in methodological characteristics of the different advisory domains. The validity and potential explanations of the findings in table 4 should be further discussed within the domains themselves. We have discussed how the different advisory domains partially overlap and where there are gaps. We have shown that EST assessment in our case and domain studies generally is upstream and that broad downstream assessments seem to constitute a current gap. Finally, we have argued that quality control is important for the legitimacy of EST advice and that the advisory domains are important in this respect.

We believe that with the combination of evidence from different sources our reflections, conclusions, and recommendations are likely to be relevant and informative, even if they would not hold for any selection of assessments in the field. Broader cross-domain studies should be carried out in order to further validate our findings and to expand the knowledge base of EST assessment. Ultimately this knowledge base will be important for further developing assessment frameworks conducive to responsible EST policy.

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Focus of the assessments		Role of assessment in policy making process		
		Cognitive – raising knowledge	**Normative – forming attitudes**	**Pragmatic – initialising action**
Object	**Scientific/ technological aspects**	**Scientific Assessment** a) Technical Options Assessed and Made Visible b) Comprehensive overview on consequences given	**Agenda Setting** f) Setting the agenda in the political debate g) Stimulating public debate h) Introducing visions or scenarios	**Deframing of Debate** o) New action plan or initiative to further scrutinise the problem at stake p) New orientation in policies established
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Table 1. Purpose analysis table, developed in (Decker and Ladikas 2004) and used as a part of the analytical work in the project.

Assessment [name]	Description in words	Coding
Core process characteristics		
A. Impartiality	Does the report appear well balanced? Is there well-balanced participation in the assessment? Do they explicitly address the topic of impartiality?	5: Priority in assessment 4: Efforts made to achieve 3: Dealt with sufficiently 2: Not an aim 1: Not mentioned
B. Transparency	How transparent is the process? How well characterised is the participation and procedures?	
C. Participation, experts	What role have experts had?	5: Interactive participation – used in conclusion 4: Interactive participation – not used in conclusion 3: One-directional participation – used in conclusion 2: One-directional participation – not used in conclusion 1: No participation
D. Participation, lay people	What role have lay people had?	
E. Participation, stakeholders	What role have stakeholders had?	
Core substantial characteristics		
F. Scientific evidence basis	How important is the scientific status in the assessment? To what extent is the assessment scientifically informed? Scientific here means technological/natural science knowledge.	5: Complete coverage of references; majority of references are from peer-reviewed literature 4: Majority of facts and assumptions are backed by references, generally from non-reviewed sources 3: Limited references are given; majority of references are from peer-reviewed sources 2: Limited references are given; majority of references are of from non-reviewed sources 1: No references are given related to given facts or used assumptions
G. Focus on uncertainties	To what extent are scientific uncertainties related to the technological and natural science status addressed?	
H. Explicit values/ethics	To what extent are ethical values addressed and discussed? To what extent does the assessment have an explicit value basis?	
I. Impacts considered	Are environmental (Env), social (Soc), security (Sec) and/or economic impacts (Econ) considered?	Env/Soc/ Sec/Econ
J. Retrospective/anticipatory	Is it considering the current status or considering future developments and options?	**Retrospective**: R1 (0 -5 years), R2 (0 – - 15 years), R3 (0 – > - 15 years), R – unspecified retrospective **Anticipatory**: A1 (0 - 5 years), A2 (0 – 15 years), A3 (0 – >15 years), A = unspecified anticipatory
K. Considers narratives/worldviews/visions	Does the assessment address these?	Narratives: Na / Worldviews: W / Visions: V / Scenarios: Sc
Core practical characteristics		
L. Self-reported success/efficiency	How does the report/respondent characterise the success of the assessment? High / Medium / Low	H/M/L
M. Cost	Cost: High (>€ 60 000), Medium (€25 000 – 60 000), Low (<€ 25 000)	H/M/L
Core contextual characteristics		
N. Assumes liberalisation	**RY**: Trend is explicitly discussed and the authors conclude that the trend is in play in the case **RN**: Trend is explicitly discussed and the authors conclude that the trend is not in play in the case **R?**: Trend is explicitly discussed and the authors do not know whether or not the trend is evident in the case **UY**: Trend is not explicitly discussed, but there is evidence that the authors think that the trend is in play in the case **UN**: Trend is not explicitly discussed, but there is evidence that the authors think that the trend is not in play in the case **U?**: Trend is not explicitly discussed and no indication as to its role in the case is given	RY/RN/UY/UN*
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Q. Assumes policy integration		RY/RN/UY/UN*
R. Assumes consumer acceptance		RY/RN/UY/UN*
S. Addresses sustainability		RY/RN/UY/UN

Table 2. Process characterisation table developed in the project.

	TA	Risk analysis	Ethical ass.	Foresight	Economic ass.	Impact ass.	Not domain related	Total
Nanofood	2	7	0	0	0	0	7	16
Synthetic biology	1	1	2	0	0	0	7	11
Biofuels	0	0	1	1	0	0	18	20
Cloud computing	3	2	1	0	4	0	10	18
Not case study related	3	4	7	9	7	6		36
Total	9	14	11	10	11	6		101

Table 3. Number of assessments studied in the project.

	Risk analysis (n=14)	Impact Ass. (n=6)	Economic Ass. (n=11)	Ethical Ass. (n=11)	Foresights (n=10)	TA (n=9)
Impartiality	4,4	4,0	3,2	4,2	4,2	4,4
Transparency	4,1	3,8	3,7	3,2	4,2	3,7
Participation, experts	4,8	4,5	3,5	4,6	3,9	2,9
Participation, lay people	1,3	3,7	1,4	1,6	1,6	1,1
Participation, stakeholders	1,6	4,5	2,4	2,5	3,5	2,6
Scientific evidence basis	4,7	4,0	3,7	4,0	3,8	4,3
Focus on uncertainties	3,6	4,2	2,9	3,6	2,8	4,3
Explicit values/ethics	1,6	3,7	1,7	4,7	2,0	2,7

Table 4. Overview of mean scores for each advisory domain related to the different core process characteristics. 'n' indicates the number of assessments analysed in each advisory domain.

<table>
<tr><th colspan="2" rowspan="2">Focus of the advisory domain assessments</th><th colspan="3">Role of assessment in policy making process</th></tr>
<tr><th>Cognitive – raising knowledge</th><th>Normative – forming attitudes</th><th>Pragmatic – initialising action</th></tr>
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Foresight
TA</td><td>Risk
IA
Economic
Ethical
Foresight
TA</td><td>IA
Ethical</td></tr>
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TA</td><td>IA</td><td>Ethical</td></tr>
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Economic
Ethical
TA
Foresight</td><td>Foresight
TA
IA</td><td>(Foresight)
(Ethical)</td></tr>
</table>

Table 5. Purposes of assessments in different assessment domains. Bold indicates that this is a primary purpose for the domain (more than 60 % of the reviewed assessments in the domain indicated this role). Not bold indicates that this is a secondary purpose for the domain (between 50 and 60 % of the

domain assessments indicated this role). Brackets indicate that between 35 and 50 % of the assessments in the domain indicated this purpose. The assessments would often have several intended purposes.

	Foresight (n = 10)	Technology assessment (n = 9)	Ethical assessment (n = 11)	Economic assessment (n = 11)	Impact assessment (n = 6)	Risk analysis (n = 14)
Technology trajectories	7	8	9	7		8
STI policies	10	3	4	5	6	
Specific applications				2		6

Table 6. The table portrays the function of the different domains related to stages in technology/policy development, based on the reviewed assessments. The numbers indicate how many of the reviewed assessments in the domains deal with technology trajectories, STI policies and specific applications. Many of the assessments address two or more of the categories, therefore the numbers add up to more than the total number of assessments.

Focus of the assessments		Role of assessment in policy making process		
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