Environmental Assessment of R&D Programmes

The Case of the Danish ForskEL Programme

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Abstract

Despite their important role in shaping the technologies of the future, public research and development (R&D) programmes are rarely based on systematic assessments of the environmental effects. R&D programmes thus allocate a huge amount of financial resources to projects, which potentially may cause severe negative environmental impacts.

This paper presents an innovative environmental assessment practice on R&D programmes in Denmark. It reports on the challenges and experiences of assessing the Danish R&D programme ForskEL, which promotes R&D projects within the electricity sector. The programme is characterised by uncertainty about impacts and incomparable project types and technologies.

A methodology for dealing with these challenges is presented, and experiences from a testing of the methodology on the 2012 programme are reflected upon. Finally the assessment is discussed in terms of its potential for making a difference in terms of the future development and deployment of renewable energy.

Keywords: R&D; environmental assessment, renewable energy; uncertainty

1. Introduction

In terms of the deployment of renewable energy (RE), the field of environmental assessment (EA) is widely focused on spatial planning, project development, and single technologies. In Europe, plans and EAs are developed on the location of wind farms (e.g. Danish Energy Agency, 2008, Marine Scotland, 2010), most RE projects are part of EIA legislation (cf. appendix 1 and 2 in the EU EIA Directive 85/337/EC), and academic studies are made on environmental impacts of RE, for instance bioenergy expansion (Owens, 2007). Apart from these levels of decision-making on RE – and also interacting with these levels (Lyhne, 2011) – are the strategic decisions on research and development of technologies, which are supported and governed through multiple international, national, and private sector financial support initiatives. These initiatives influence which technologies will be available for the deployment of RE and they thus play an important role in shaping the environmental impact of the future energy sector. An example of the important role is a Danish R&D project that developed a technology which made it possible to combine solar shading devices with photovoltaic in window glass – with an efficiency of 5 % (PhotoSolar, 2008). The potential of this technology on a global scale is notable in terms of energy production, energy savings, and related reductions in greenhouse gas (GHG) emissions. Denmark has an ambitious political target of 100 % RE in electricity and heating systems by 2035 (The Danish Government, 2011) and R&D plays a central role.

The importance of R&D goes beyond the energy sector development: "[E]nergy R&D and the technologies that the R&D process yields broaden or narrow the portfolio of choices available to policymakers on a number of important issues" (Runci and Dooley, 2004, p. 443). R&D may, however, lead to considerable unwanted impacts and therefore, "decision support and policy making require information on the potential consequences of the introduction of new technologies before they are widely implemented, i.e. at early stages of their development when the direction of the innovation process already can be influenced but its implication can hardly be foreseen" (Fleischer et al., 2005, p. 1113, see also Feller, 2007). Furthermore, advances in environmental performance in R&D projects "may allow regulations to change or it may improve the environment under the existing regulations" (NRC, 2001, p. 87).

The important role of R&D for the deployment of RE is widely overlooked in academic literature on EA. Assessment of R&D activities is typically done as ex post evaluations within the evaluation discipline, but "The trend is towards ex ante questions directed at providing analytical frameworks, metrics or methodologies relevant to future decisions, rather than ex post questions related to whether programs are working or had worked" (Feller, 2007, p. 681). Using the words of the EU Commission (2005, p. 1), ex ante assessment of R&D are "particularly difficult" and Feller (2007, p. 684) points at "disquiet about the capacity of existing procedures to accurately identify and select and assess high risk, at times, interdisciplinary research". In general, assessment of R&D programmes faces the Collingridge dilemma which states that impacts cannot be easily predicted until the technology is extensively developed and used, but when the technology is extensively developed and used, it is difficult control and change the development of the technology (Collingridge, 1980).

The strong history and capacity within the EA discipline of making ex ante assessments is drawn upon in this paper to clarify environmental performances and risks as well as to point at potentials for changes at an early stage in the research and development process. Within journals in the field of EA, only few reports on experiences and methods of assessing R&D programmes can be found and this paper aims at raising awareness towards the potentials within the field of EA of public energy R&D programmes.

One reason for the lack of focus on EA of R&D is that R&D programmes set up no binding framework for future development and have no direct environmental impacts. Therefore, R&D programmes do not fall within legislative requirements like the EU directives and UN protocols on strategic environmental assessment and environmental impact assessment. In 1990, research was part of the scope of the draft on the EU Directive on strategic environmental assessment, but EAs of R&D were met with scepticism in terms of methodology, resource demand, and restraints on room for manoeuvre (Kleinschmidt, 1994). Another reason for the lack of focus may be the special characteristics of R&D programmes that involve variety and uncertainty in the supported R&D projects. Such characteristics constitute a methodological challenge for the assessment and selection of these projects.

This paper reports on efforts made towards developing an ex ante environmental assessment methodology for the Danish R&D programme ForskEL. The ForskEL programme is a public service obligation administrated by the Danish transmission system operator, Energinet.dk. It has an annual financial frame of

DKK 130 million (compares to 17.5 million euros) which is financed through the electricity tariffs and it covers R&D activities ranging from computer models to prototype testing and in some cases also demonstration activities. In terms of environmental effects, it is interesting since it supports "R&D projects developing environmentally friendly technologies for electricity generation" (Energinet.dk, 2012a). The focus on environmentally friendly technologies was part of the reason for initiating the environmental assessments of the programme, since Energinet.dk felt a need to make sure that the supported projects also had a decent environmental profile. The assessment is applied as a conclusion of the tender phase where the projects for funding are selected, but before the final agreement about the funding is made. At this stage in the R&D programme, the assessment is "operational ex ante" (Meyer-Krahmer and Reiss, 1992, p. 48), since the projects in the programme still can be directed to use more environmentally friendly processes in their development and to set more environmentally friendly targets for their technology. However, the assessment is ex post in terms of the selection of projects in the programme. The EA methodology is innovative in the sense that it proposes a new way to deal with programmes rarely dealt with before in the field of EA.

The objectives of this article are to use the ForskEL programme as a case for outlining characteristics of R&D programmes that challenge environmental assessment methodology and proposing an ex ante EA methodology that overcomes these challenges.

The article is structured as follows. It commences with a brief review of international reports on environmental assessment of R&D programmes. This is followed by a presentation of the Danish ForskEL R&D programme and the objectives of the EA methodology. Based on the objectives, the challenges of assessing environmental consequences are reflected upon and a methodology is proposed and discussed. Then, the article reports on the testing of the methodology on the 2012 ForskEL R&D programme. The article is concluded with a discussion of key findings.

2. International Experiences on Ex Ante Assessment of R&D

Evaluation literature comprises a wealth of methods and experiences for ex ante evaluation of R&D (Hong and Boden 2003, Shapira and Kuhlmann 2003, Bozeman and Melkers 1993, Poh et al. 2001). Strikingly, assessment of environmental consequences is scarcely described. The initiatives and experiences on assessing environmental consequences are outlined.

In the early 1990s, a methodology development on R&D was made in Germany as preparation for the United Nations Conference on Environment and Development (Kleinschmidt, 2012, email). Photovoltaic was used as a case for a comprehensive study on environmental assessment of research activities with the aim of identifying impacts on human and nature of a technical development early in the research process (Hirtz et al., 1993, p. i). The EA methodology shared similarities with the later SEA Directive, but it importantly also included a "Nachkontrollphase" to check the validity of the assessment after the research activity. Meyer-Krahmer and Reiss (1992) worked with ex-ante evaluations of R&D which, at this point in time, were rare. They emphasised that "[t]he concept of evaluation has to match the phases of the development of public technology and innovation policy" (p. 48).

In the past decade, ex ante assessments have received increased focus and started to become institutionalised. As an example, the Korean Government has enacted a law for ex ante evaluation for national R&D programmes (Lee and Park, 2011). Also in evaluations of research programmes, environmental aspects have received increased focus. Environmental consequences were part of NRC's framework for evaluating public energy R&D programmes in their 2001 study (NRC, 2001). NRC defined their scope of environment as "Environmental net benefits are based on changes in the quality of the environment that have occurred, will occur, or may occur as a result of the technology" (NRC, 2001, p. 15) and based the assessment on comparison with the 0-alternative: "Environmental benefits result only if there is a net improvement in environmental quality from what would have been the case absent the DOE program" (p. 17). NRC based their retrospective assessment of environmental consequences on a limited number of impact types and on quantification by use of economic valuation methods with the inherent uncertainties of such valuation methods.

Methodological problems on assessing impacts of R&D programmes are notable. Within the field of evaluation, the US National Research Committee concluded that "[n]o theory exists that can reliably predict which research activities are most likely to lead to scientific" (NRC, 2007, p. 89). Which theory and method

is most suitable is dependent on the characteristics of the programme and the timing of the assessment. The impact assessment of EU's comprehensive 7th Framework Programme for Research and Technological Development includes environmental considerations, but the abstract level and the applied econometric models do not provide clear answers about environmental impacts of the programme. Not only environmental impacts of R&D are difficult to assess; in the efforts of developing an ex ante evaluation framework for regional benefits of R&D, Roper et al (2004) made an extensive literature survey, but "failed to identify any existing methodology or approach to measuring ex ante the benefits of publicly supported R&D" (Roper et al., 2004, p. 488)

3. Background and Objectives for the EA of ForskEL

Apart from the implementation of the EU Directives on SEA (2001/42/EC) and EIA (85/337/EEC), the Danish legislation on environmental assessment covers government bills and other parliament proposals (Circular no 159 of 16/09/1998). Although the R&D programmes are not strictly within the scope of the legislation, the increased focus on environmental behaviour and consequences in Denmark place increasing pressure on R&D programme administrators to assess the environmental consequences of their programmes.

Energinet.dk's work on environmental assessment is a voluntary approach motivated by the societal attention on environment, the company's CSR initiatives, and an interest in being proactive in terms of possible new legislative demands (Energinet.dk, 2010). The environmental assessment is a recent addition to the existing evaluation of the R&D applications in the ForskEL programme. The existing evaluation is an interdisciplinary blind expert peer-review, organised as workshops with the objective of prioritising the R&D applications in terms of technological and business potentials.

The visualisation of the ForskEL process and the EA in figure 1 emphasises that the primary role of the EA is to give input to the contract negotiation phase, which potentially can lead to improvement in the projects' environmental performance. The EA is not directly addressing the focus areas in the programme formation. Instead, the EA assesses the extent to which the projects fulfil the environmental intentions in the focus areas

(b). An aim of the assessment is to provide an empirical basis and assessment experiences that allow integration of environmental parameters in the existing procedure for evaluation and selection of applications (c). The assessment has both a formative character where the objective is "to provide programme staff with information useful in enhancing the management and implementation of the programme" (Hong and Boden, 2003, p. 28) (d) as well as a summative character (improve next year's assessment). The actual environmental performance in the project implementation is reported on by the projects in their final report. These reports constitute a basis for improving the EA (e) as well as the existing evaluation (f) and serve as the basis for programme formation (g). The figure furthermore emphasises the learning loops in terms of environmental consequences and potentials. The environmental assessment thus constitutes a "learning medium" (Kuhlmann, 2003, p. 141) throughout the R&D programming process.

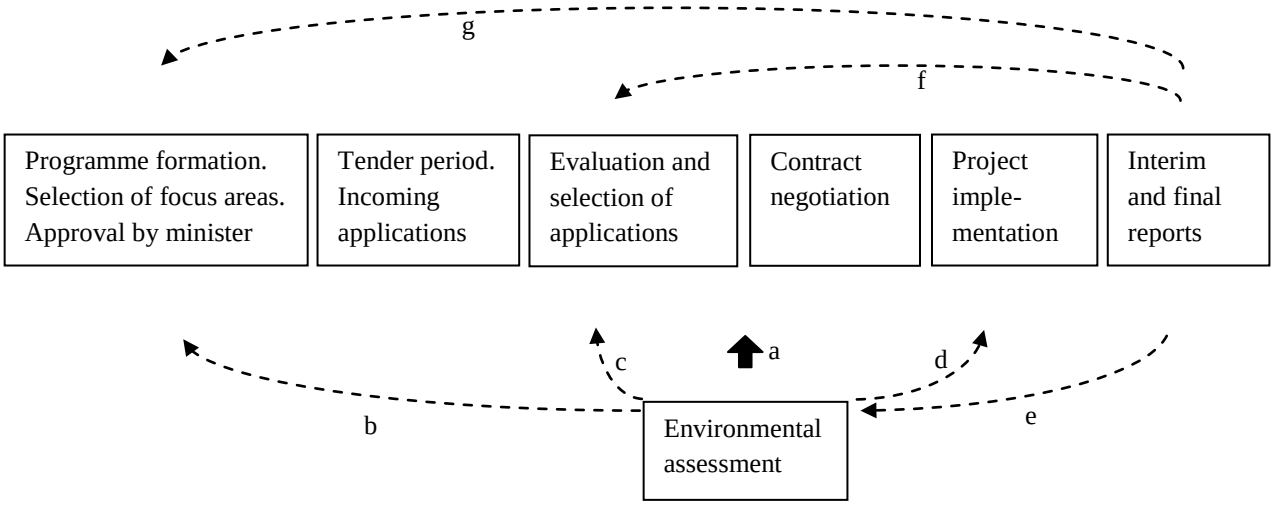

Figure 1: The ForskEL R&D programme process with specification of the interaction between the EA and the programme process. The arrows indicate the relations and the letters are referred to in the text.

In 2010, Energinet.dk started the development of an environmental assessment methodology inspired by life cycle analysis (LCA) methodology (Energinet.dk, 2010). The project applicants were asked to fill out questionnaires about technology potential, time horizon for implementation, and environmental impacts. The EA report then mapped the potential environmental effect of the supported types of renewable energy

technology. The uncertainty and vague knowledge about potential impacts led to the conclusion that it is "*not possible to conclude unambiguously whether [it] contributes to improving the environment"* (Energinet.dk, 2010, translated)

In 2011, Energinet.dk continued using the LCA-inspired model, but communicated the findings in a more complex design that emphasised specific aspects such as CO_2 savings (Energinet.dk, 2011). In the EA report, Energinet.dk concluded that "environmental assessment of not fully developed technologies is complicated. Partly because there are great differences in the attention paid to environment in the various projects and partly because it is often very difficult for project applicants to answer questions about production processes, which are not yet settled" (Energinet.dk, 2011, translated). Energinet.dk furthermore concluded that "there is a great goodwill to work with environment, and even at the R&D stage it is possible to estimate aspects concerning the environment, and this can be used as an integrated part of the development" (Energinet.dk, 2011, translated).

Based on experiences from the two years of conducting EA of R&D, Energinet.dk found a need to revise the EA methodology with the following objectives:

i. The assessment must be able to clarify whether the supported projects actually make or are able to make a difference in terms of the environment.

ii. The assessment should make the project participants more conscious about environmental aspects.

iii. The methodology should be designed so that Energinet.dk can perform the assessment without external assistance.

In the following analysis, the challenges and limitations of the existing work on environmental assessment in Energinet.dk are presented with proposals for ways to handle these. The proposals sum up to the environmental assessment methodology used for the 2012 tender.

3.1 Working group and basis for developing the methodology

The methodology is developed and tested in cooperation between The Danish Centre for Environmental Assessment and the Danish TSO, Energinet.dk. The cooperation has previously been characterised as a change agent way of doing research based on organisational autonomy and strategic interdependence (Kørnøv et al, 2010). The methodology was developed by the end of 2011 and applied in the beginning of 2012.

The methodology development is based on review of impacts in the questionnaires of the first two years of conducting environmental assessment of the ForskEL R&D programme. This amounts to more than 1.000 descriptions of environmental impacts in the supported projects. These descriptions have been used to get an overview of likely impacts from the portfolio of supported R&D projects.

The method developed and the results of the EA 2012 have been reviewed through discussions with R&D administrators, environmental assessment experts, and the experts that evaluate the applications.

4. Challenges and Solutions

The challenges of conducting a suitable environmental assessment of the ForskEL R&D programme widely relates to the diversity in technologies, activities in R&D, expected environmental impacts, awareness about environmental impacts, development stage, uncertainty about design, etc. The diversity causes a range of challenges in terms of data availability and quality, uncertainty, comparison, delimitations, etc. The main challenges are summarised in table 1.

With the previous experiences and objectives in mind, the basic structure of the environmental assessment methodology is that the project applicants complete questionnaires about their project's impacts and these responses are used to make an overview of the expected environmental impacts of the programme. The questionnaires are carefully designed to approach the challenges as described in table 1. The environmental assessment report is baseline oriented with detailed accounts of what types of impacts the programme is expected to cause, its significance, and the projects' goal achievement.

Table 1: Needs and challenges in existing practice exemplified with empirical quotes and proposals for an improved environmental assessment methodology.

Identified needs and problems in existing practice	**Example (if possible)**	**Proposals for an improved environmental assessment methodology**
When describing the impacts of the R&D project applicants often do not distinguish between their specific project's contribution and the overall RE technology,	A project about wave energy floaters describes a situation where "35 % of the Danish electricity generation is supplied by wave energy…"	Clear demarcation of direct (project period) and indirect (project's positive and negative impacts on the RE technology) in questionnaires to applicants
Applicants have a tendency to be selective in their comparison of impacts. Comparisons have to be transparent and controllable	"Demonstrations … have shown 10.000 times less emission of SO_x particles … compared to oil or coal power plants… "	'Significance' is made explicit and the determination of significance is based on applicants' statement of the actual impacts. The frame of reference is made explicit in the questionnaire.
Applicants refer to different political objectives in a selective way and there is a need to systematise and harmonise responses	-	Political objectives are emphasised in the questionnaire as applicants are required to give a score on their contribution to these objectives as well as an argument for this score.
Applicants often have a narrow understanding of the concept of environment	As an indication, only one project out of 32 reviewed considered occupational health and safety despite many projects working with hazardous chemicals, etc.	A broad concept of environment, similar to a scoping list, is added to the questionnaire (inspired by SEA methodology).
The previous EA of ForskEL has been descriptive but not action-oriented	-	A question about planned measures in cases of significant environmental impacts is

		added to the questionnaire
Due to the different character of the R&D projects, a uniform questionnaire will include many irrelevant impacts	Use of construction materials and visual impacts are not relevant for projects that only involve computer modelling	Projects are divided into different categories based on their characteristics. These are given different questionnaires. This makes the questionnaires more relevant and easier to complete.
Projects with great potential in MW tends to get more environmental credit compared to niche-technologies or system control projects, which indirectly can be of huge importance.	-	The use of political objectives and scores change potential from a number to a scale, which makes project potentials more equal.

A main concern about the approach is the trade-off between the benefits and disadvantages of the participatory approach, where the project applicants provide data and assessments of their project's impacts: On the positive side is the fact that the applicants have by far the highest insight into the project and how it is likely to interact with the environment. This insight is of a tacit nature and is time consuming if not impossible to access and control by other means. On the negative side is selectivity in terms of what is stated and how it is assessed as well as potential difficulties in getting thorough answers. In the case of ForskEL, the environmental assessment is made at a time, where the contracts are not negotiated and the project applicants have therefore been willing to cooperate.

The lists of impacts in the questionnaires are similar to screening lists used in EIA/SEA literature. Due to pragmatic reasons of not using too much of the applicants' time, it has been a priority to limit the list to impacts that are likely to be relevant. Relevancy is determined by a review of responses to open questionnaires about impacts in the previous year as well as a review of screening lists in EIA/SEA literature. The review thus comprised 98 completed responses and the impacts these included have been categorised. The review also formed the basis for grouping the types of projects into three categories: Larger physical constructions, minor units and non-physical projects.

The applicants accessed the questionnaire online, and when they marked environmental impacts from the screening lists relevant for their project, they were asked for more detailed information about the type/kind of impact; positive/negative nature; comprehensiveness/amount (if possible per installed production capacity); uncertainty [little-big]; significance [insignificant-significant-unknown]; frame of reference; and project measures to avoid, reduce, compensate or increase. The frame of reference is important in order to validate the applicants' assessment of significance. The detailed information makes the basis for the applicants' judgement of significance transparent without guaranteeing similarity in the level of significance across the applicants.

The goal achievement element is pragmatic: Since the main purpose of the R&D programme is to support R&D on environmentally friendly technologies for electricity generation, the goals included in the environmental assessment are national political renewable energy and climate targets. The projects are generally not sufficiently progressed in detail and design to consider goals such as biodiversity or landscape protection. Goal conflicts are primarily between cost and environmental-technical benefits of the R&D project and such conflicts are dealt with in the existing evaluation process.

The distinction between the projects' direct and indirect impacts on the technology that they do research and development within, helps to shed light on what happens and what can be done both within the project activities and within optimisation of the project to improve the way it can affect the technology. The indirect impacts were connected to the focus areas of the programme to make it possible to assess the environmental potentials of the programme. The distinction is not straightforward and can especially be ambiguous in cases where the R&D project is interrelated with a wide range of other R&D projects. In the cases of ambiguous distinctions, there is a risk of inconsistency in the assessment in terms of the delimitation made, which for instance may cause a difference in the projects' goal achievements.

The categorisation of the project types into three groups helped target the questionnaires and ease the applicants work load. The categorisation determined the type of impacts to be considered and it is therefore an important step in the process. For some types of projects, the distinction between 'minor units' and 'larger constructions' is ambiguous. Where the categorisation was initially intended to be performed by each applicant with the help of a guidance text, it ended up being made by a programme administrator with good insight into the projects.

5. Experiences from Testing and the Programme's Influence

The environmental assessment methodology was successful in a number of ways:

i. Due to the timing, all project applicants responded, apart from a few who were not able to due to illness and unavailability of the competent person within the period given.

ii. The screening list provided considerations to a wider range of environmental aspects compared to the previous years

iii. The required detailed data for the selected impact categories made the projects' assessment more transparent than previous years' assessments and made it possible to perform a guiding validation of the significance assessment

iv. The environmental assessment report presented in detail the expected negative effects of the programme as well as the projects contribution to the programme's focus areas and achievement of political goals (see Energinet.dk, 2012b)

In a range of aspects, the methodology and practice around the environmental assessment procedure need more work. The following aspects have been pointed out by the experts in the existing evaluation, by the environmental assessment working group, and in the comments made by the applicants:

i. More guidance is sought by the project applicants, e.g. on calculation of CO_2 or system delimitation. One project applicant complained in a provoking tone: "Impacts of drilling for rare materials in Greenland is too much to consider for us". Providing guidance would potentially streamline the responses, but taken the variety of projects into account, guidance risk being either very generic or inappropriate for some types of projects.

ii. The weighing between direct and indirect impacts should be carefully considered and communicated: How important are minor negative project-related impacts occurring in the coming years compared to comprehensive and positive improvements in technologies potentially emerging in 5 or 10 or 15 years?

This distinction becomes a central concern if it becomes a selection criterion, and in this case a transparent instruction for the weighing must be the basis for selection.

iii. The effort of making the assessment more action-oriented had a limited effect. Although the projects often described measures to avoid, reduce, compensate or increase effects, the measures were often passive in the sense that these often concerned actions that were legally required or taking place in related research initiatives. The limited actions may be due to the fact that the projects already have been designed in cooperation among project participants and the project manager therefore may have found it difficult to propose actions without consulting and redesigning with the entire group of participants.

iv. Due to the timing of the environmental assessment after the selection of projects, the environmental assessment did not include considerations of alternative technologies, but alternatives to project design. Therefore, the timing did not allow for articulation of strategic choices. On the other hand, the timing after the selection phase potentially reduced the selectivity of the projects as their incentive to hide significance negative impacts was reduced. Furthermore, the projects have an interest in a good cooperation with the programme administrators.

Despite these weaknesses, the environmental assessment presently influences the development – and in the long run deployment - of renewable energy technologies in several ways. It provides awareness-raising among the project participants in terms of direct and indirect environmental impacts. In this respect, the environmental assessment has an impact on several areas; it provides an opportunity for programme administrators to require changes in the projects' environmental performance as part of the contract negotiation; it provides input to the programme formation process about technology gaps seen from an environmental perspective; it will in time provide the basis for integration of environmental parameters in the existing evaluation and selection procedure, cf. figure 1. These influences range from technical changes in RE technology development to more strategic considerations towards environmental aspects, but all influences are enabled by the increased documentation and assessment of environmental impacts.

6. Conclusion and Future Developments

Assessment of environmental impacts of R&D activities is not straightforward and the limited international practice provides no appropriate methodology for assessment of detailed impacts of public R&D programmes. This paper has reported on challenges and solutions for an environmental assessment methodology on R&D activities with focus on the Danish ForskEL R&D programme. This methodology is based on experiences from two years of environmental assessment work, but as the described experiences indicate, the methodology needs to be further developed, e.g. in order to be more action-oriented.

The paper furthermore contributes to setting an agenda on ex ante environmental assessment of R&D programmes, which seems widely overlooked in theory and practice. The agenda should involve research into issues like the influence of the environmental assessment on projects and programmes, the variety of ways of making environmental assessment dealing with uncertainty, tacit knowledge, and other challenging characteristics of R&D activities. Research in these issues is needed to bring environmental assessment methodologies of R&D to the next level of appropriateness.

The case suggests a range of transferable lessons to be learned from experiences with the Danish ForskEL programme: The timing is important both in terms of getting valid information from the projects and for influencing the R&D programme; work load and selectivity should be central concerns when choosing a participatory approach; questionnaire design should be very alert on the institutional as well as technical context. A practical challenge is the identification and contact to the person(s) within the project's organisation with adequate insight in the project and knowledge about environmental consequences. In the case of ForskEL, the questionnaires are mostly completed by the project managers, who are not necessarily competent within or aware of environmental matters. The transfer of such lessons should take into account institutional and contextual differences as e.g. the timing of the R&D programme in the technology innovation process will most likely influence the type and uncertainty of data available.

Whereas the environmental assessment in itself constitutes possibilities for managing the environmental performance of the project, the aim of the environmental assessment work of developing a basis for integrating environmental issues in the selection phase, has a notable potential for affecting the environmental aspects of the development and deployment of renewable energy technology in Denmark. The early integration of environmental concerns and criteria could lead to changes in which projects are selected

and how applicants design their projects prior to submission. Ideally, such changes involve adjustments in material, design, production processes, or functions that can reduce negative or increase positive environmental impacts of the renewable energy technologies. With the introduction of environmental concerns in the selection phase, the described environmental assessment methodology will have to be reconsidered, as the role and potentials will be different.

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