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Inclusion of Uncertainty in Environmental Impact Assessment in Greenland

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Abstract: Uncertainty is an inherent part of impact assessment (IA), and can vary in type and source. However, according to previous research, uncertainty is rarely explicitly acknowledged and handled in IA, indicating that it is a challenging issue in practice. This paper adds to the current research body a study of EIA in Greenland, which includes a document study of EIA reports as well as white papers and summaries from public hearings. The study findings are in line with previous results, finding a limited explicit acknowledgement of uncertainty, although uncertainty is indicated through implicit language use. The study also finds that various tools are applied, which could be used for handling uncertainty, including sensitivity analysis, monitoring and worst-case estimates. However, often these tools are not used systematically, and it is not transparent whether they are targeted at handling uncertainty. Regarding the examination of materials from hearing processes, there is little evidence that uncertainty is part of the discussions. These results initiate discussions of how choices of whether and how to acknowledge and handle uncertainty are made, and how consciously participants in the process make these choices.

1 Introduction: Impact Assessment as a tool for integrating uncertainty in decision-making

Impact Assessment (IA) can be defined as "*the process of identifying the future consequences of a current or proposed action*" (IAIA, 2009 p. 1). The purpose of IA is to promote sustainable development by providing science-based information on the possible impacts of a proposed action to decision-makers as well as the public. Thus, mitigation and monitoring of impacts and promoting transparency and participation in the process are important parts of IA. (IAIA, 2009) As indicated by the definition cited above, IA aims to predict "*future expected consequences of possible decision*" (IAIA, 2009, p. 1). This focus on the process before a potential activity is approved and implemented means that uncertainty is an inherent part of the IA process, and one that warrants attention in research and practice (see e.g. Tennøy, Kværner and Gjerstad, 2006; European Commission, 2013; Leung et al., 2015; Bond et al., 2015) The fact that uncertainty challenges science-based instruments, such as IA, is stressed by the understanding put forward among others by Funtowicz and Ravetz (1990; 2005) that "*in many contemporary complex science-related policy issues, uncertainty significantly limits the degree to which science can provide objective, valid and reliable knowledge*"(Wardekker et al., 2008, 630).

1.1 Uncertainty in impact assessment

Uncertainty has been associated with various parts of the IA process including the baseline, impact prediction, cumulative impacts, impact mitigation and impact management. This has been derived both from empirical studies of EIA practice as well as legal provisions or guidance for dealing with uncertainty (European Commission, 2013; Lees et al., 2016; Pavlyuk et al., 2017).

The nature of uncertainty encountered in IA can be described in many ways. For instance, Zhu et al. (2011) in their study of uncertainty in SEA, distinguishes between internal uncertainty related to the plan or project assessed and external uncertainty related to the surrounding natural and social environment. Walker et al. (2003) in relation to decision support tools, such as IA, distinguishes between epistemic uncertainty related to a lack of knowledge, and variability uncertainty related to inherent variability. An

important distinction is that uncertainty in IA can be related not only to knowledge but also to values, emphasising the human and societal dimension which is changeable (Walker et al., 2003; De Jongh, 2000). The nature of uncertainty is important for practice because depending on the nature of uncertainty, different approaches for handling it in IA will be relevant. For example, epistemic uncertainty might be minimised by gathering more knowledge, while variability uncertainty often will not.

Another relevant dimension of uncertainty in IA is the sources of uncertainty. Walker et al. (2003) conceptualise locations of uncertainty in model-based decision support, context uncertainty, model uncertainty, input uncertainty, parameter uncertainty and model outcome uncertainty. Tennøy, Kværner and Gjerstad (2006) based on empirical studies of EIA find that sources of uncertainty are model errors, errors in baseline data, input data and assumptions. Also, based on an empirical study of EIA, Larsen (2014) identified sources of uncertainty as shown in Table 1.

Source	**Description**
Design and technology	Uncertainty about the final project design and the choice of technology
Construction	Uncertainty about timelines and methods for construction
Data	Uncertainty about data used as a basis for calculations, prediction and assessments e.g. because of questionable data collection or natural variability
Calculations and models	Uncertainty about the specific methodology, assumptions etc. for models and calculations of impacts
Causal mechanisms	Uncertainty about what the derived consequences of predicted impacts are
Values	Uncertainty about society's values e.g. expressed through attitudes, classifications or goals
Related activities	Uncertainty about the status of related projects, plans and activities etc.

Table 1 Sources of uncertainty in EIA (Larsen, 2014)

As exemplified by the brief review presented here, both on location, nature and source of uncertainty in IA, there is no common framework for research and practice in IA. This lack of a common framework, e.g. common typologies and terminology, has been highlighted as problematic and a worthwhile aspect of a future agenda for research and practice (see Leung et al., 2015; Lees et al., 2016).

1.2 Dealing with uncertainty in impact assessment

IA can potentially provide information about uncertainties for use in decision-making. However, as suggested by Larsen, Kørnøv and Driscoll (2013), there are multiple possible pathways for dealing with uncertainty, including first whether uncertainty is (implicitly or explicitly) acknowledged or not by actors in the process. Second, if uncertainty is acknowledged, there is a question of whether uncertainty is actively handled or not (Larsen, Kørnøv and Driscoll 2013). To handle uncertainty in IA, various tools have been suggested and documented, including scenarios, monitoring, adaptive management, applying likelihoods and the precautionary principle (De Jongh, 2000; European Commission, 2013; Azcárate et al., 2013; Bond et al., 2015; Lees et al., 2016).

Studies of practice have shown that acknowledging and handling uncertainty is a major challenge for IA and that uncertainty is most often not explicitly acknowledged and handled in IA reports (see e.g. Tennøy, Kværner and Gjerstad, 2006; Larsen, Kørnøv and Driscoll, 2013; Lees et al. 2016). As an example of the implications of this, a study of IA of hydrocarbon activities in the Disco Bay, Greenland found "*that environmental change has been insufficiently analyzed in planning processes, leading stakeholders to endorsing hydrocarbon development based on information that may underreport uncertainty and the extent of potential harm"* (McDowell and Ford, 2014). As the quote highlights, if uncertainty is not explicitly acknowledged, impact predictions appear more certain than they are, which may influence decisions and

impede the ability of stakeholders to identify and demand resilient solutions (see also Wardekker et al., 2008). It also indicates another possible pathway for dealing with uncertainty, namely analysis, the benefits of which are pointed out by Walker et al. (2003, p. 6) stating that "*uncertainty is a fact of life, and a better understanding of the different dimensions of uncertainty and their implications for policy choices would be likely to lead to more trust in scientists providing decision support, and ultimately to better policies.*"

Based on the above, three main possibilities for dealing with uncertainty can be put forward:

- Acknowledging uncertainty - basically stating its existence
- Analysing uncertainty – analysing uncertainty e.g. through applying predetermined scales or performing sensitivity analysis
- Handling uncertainty – actively doing something about uncertainty e.g. reducing uncertainty, improving resilience or securing robustness

The acknowledgement of uncertainty can be either explicit, using direct wording of uncertainty, or more implicit, e.g. as suggested by Funtowicz and Ravetz (1990) presenting a range of results, characterising the methodological acceptability of results, or acknowledging ignorance about the system studied.

1.1 Problem statement

The relevance of uncertainty for IA and the expedience of attention to uncertainty in IA research is also reflected in the fact that recent years have seen the amount of published research focussed on uncertainty in IA increase (Leung et al., 2015). There has been a variety of studies published concerning uncertainty and IA (Leung et al., 2015), however, as stated by Lees et al. (2016), relatively few studies exist that examine the actual IA practice of acknowledging and handling uncertainty. This paper aims to contribute to this field by adding a study of IA practice in the Arctic.

A search in the Scopus database for the search terms 'Impact Assessment' OR 'Environmental Assessment' AND 'Arctic' AND 'Uncertainty' yielded only a few studies that touch upon uncertainty in IA in the Arctic (see e.g. McDowell and Ford, 2014; Azcárate et al., 2013), leaving the topic relatively unexplored. The relevance of adding knowledge about uncertainty in EIA in the Arctic is emphasised by the fact that the Arctic is facing possible significant changes, e.g., due to:

- Climate change, which alters the natural environment and entails both challenges and possibilities
- Developments in the global economy and market conditions e.g. related to minerals and hydrocarbons

Such issues render the Arctic environmental, economic and social development as changing and uncertain (see e.g. Nakashima, 2012; Emmerson and Lahn, 2012; Koivurova and Lesser, 2016; Larsen et al., 2019). The changing context has implications e.g. on different extractive industries and tourism, and as a consequence, on large-scale developments, such as resource extraction activities and infrastructure construction. When working and assessing such developments in an uncertain context, it is expedient to acknowledge and work with uncertainty, striving to understand complex systems, to build communities that are thriving and resilient regardless of the development in external drivers (see e.g. Hansen and Larsen, 2014; Arctic Council, 2016).

Across the Arctic, EIA is a pivotal tool used to support decision-making, although the specific regulations vary (Koivurova and Lesser, 2016; Hansen and Larsen, 2016). EIA is used as part of planning large-scale projects with severe impacts on their surroundings, such as mining and infrastructure projects (Hansen, Larsen and Noble, 2017). The focus of this paper is EIA of large-scale projects in Greenland to shed light on

EIA practice in an Arctic nation and add experiences from this region to the building of knowledge on uncertainty in IA. Greenland has two separate sets of legislation for EIA, one for projects under the law on mineral resources, such as mining and oil and gas projects, the other broadly covers remaining projects (Koivurova and Lesser, 2016).

Two specific issues will be explored in this paper through general discussions and examining how these are reflected in EIA practice in Greenland:

- Is uncertainty acknowledged in EIA processes and how?
- Which tools and approaches are used to deal with uncertainty in EIA processes?

Regarding the EIA process, this study entails looking at the practice reflected in the EIA report, as well as what input the involved parties provided in the hearing process. As stated in section 1.1, there is a lack of and a need for a common framework for research and practice in IA, e.g. common typologies and terminology on uncertainty (see Leung et al., 2015; Lees et al., 2016). This study aims to contribute to this issue through a partly inductive approach suggesting a typology for sources of uncertainty based on the empirical study results guided by the research questions above.

The paper is structured as follows: the methodology is provided in section 2, the results are presented, structured by the two research questions, in sections 3 and 4, with section 5 discussing and drawing the conclusions.

2 Methodology

In order to contribute to exploring the questions posed above, three Greenlandic EIA processes (Table 2) were selected based on the following criteria:

- Geography: securing cases from different geographical areas of Greenland while focusing on areas with a local population
- Status: securing cases in different stages of the project process from preparation to operation
- Legislation: securing at least one case which has been processed according to each of the two sets of EIA legislation in Greenland

Name (based on the location of the project)	***Killavaat Alannguat***	***Ilulissat***	***Aappaluttoq***
Project type	Mine	Airport	Mine
Year of publication of EIA report	2013	2018	2014
Status	Awaiting approval	Under construction	In operation
Region	South Greenland	Northwest Greenland	West Greenland

Table 2 EIA processes selected for the study

The mine at Killavaat Alannguat will produce concentrates of various minerals and rare earth elements but after the EIA process in 2013, the application for a production licence was rejected due to lack of documentation. Since then, the mining company Tanbreez Mining Greenland A/S has gathered additional documentation, and according to an update in March 2020, there are plans for a renewed EIA process and negotiations (Government of Greenland, 2020). The ruby mine at Aappaluttoq started operation in 2017 after receiving its licence in 2016 (Greenland Ruby n.d.). The airport in Ilulissat is part of a larger plan for the renewal of airports in Greenland, the construction of which started in January 2020 (Kalaallit Airports, 2020). For each of these EIA processes, a document study was conducted as described in the following section.

2.1 Document study

The following documents were studied for each of the three EIA processes:

- The EIA report
- Responses sent in by various participants during the public hearing
- Minutes from public meetings held during the public hearing

It should be noted that for the airport in Ilulissat, only one response was received during the hearing, and there are no minutes available from the public meeting held, thus, there is very little material available concerning the public hearing of this EIA process. The project in Ilulissat falls under the broad Greenlandic legislation on EIA in the Environmental Protection Act. The legislation demands a hearing period of 8 weeks when the EIA is published, during which, the public should have access to comment and respond to the project. After the hearing, the Minister of Environment and Nature can demand changes to the project. There are no legal demands for responding to the hearing, but a white paper is published for some projects. For EIA under the legislation for mineral extraction projects a white paper is mandatory.

Each EIA report and document from the public hearings were reviewed by first looking for acknowledgement of uncertainty. For the hearing documents, this takes the form of looking for instances where the participants address uncertainty e.g. by pointing it out or asking for it to be handled. Lees et al. (2016) point out the challenges of data collection and analysis of information on uncertainty from IA documents because of the lack of consistent terminology, thus, a search for specific words to find uncertainty is not deemed expedient, rather, the whole document is examined. Furthermore, for each occurrence of uncertainty, the issues stated in Table 3 have been recorded. The data gathered for each EIA process was then analysed, summarised and compared to determine various categories which are described later in the paper.

Document	***EIA reports***	***Hearing documents***
Issues recorded	Whether the uncertainty is acknowledged explicitly or implicitly	Whether the uncertainty is acknowledged explicitly or implicitly
	The source of uncertainty	The source of uncertainty
	Whether the uncertainty is assessed or analysed (as opposed to merely mentioned)	Whether there are demands for assessment or analysis of uncertainty
	Whether any tools are used to handle the uncertainty	Whether there are demands for handling uncertainty

Table 3 Issues recorded for each occurrence of uncertainty in the documents studied

3 Uncertainty in the EIA process

In the following subsections, the results concerning whether and how uncertainty is acknowledged in the EIA reports and hearings are presented, in accordance with the first research question.

3.1 Uncertainty in the EIA reports

First, regarding the EIA reports, the report from Ilulissat contains an explicit acknowledgement of uncertainty, for example: "*Possibly the noise limits should be lowered to 50 dB in areas with vulnerable species, because higher noise levels can have a negative influence. However, there is uncertainty concerning the effect in different habitats, since some species show a high degree of tolerance to noise*" (Kalaallit Airports A/S, 2018, p. 65; emphasis added by author). More often though, explicit acknowledgement of uncertainty is not phrased in those words, rather in another form, for example: "*To what extent the low*

water flow in Lakseelv during mid-winter will cause the concentration of lead to exceed the GWQG value after 3-5 years of operation is unknown" (Tanbreez, 2013, p. 80; emphasis added by author).

The report from Aappaluttoq does not contain any explicit acknowledgements of uncertainty. However, this report as well as the other two contain examples where uncertainty is not acknowledged but there are implicit indications of uncertainty, for example: "*The mine infrastructure seems to be able to avoid any conflicts with the cultural heritage sites*" (True North Gems, 2014A, p. 5; emphasis added by author).

These findings, as well as inspiration from Tennøy, Kværner and Gjerstad (2006), Pavlyuk et al. (2017) and Lees et al. (2016), leads to dividing the findings of uncertainty in the documents into three categories:

A) The explicit acknowledgement of uncertainty using the word 'uncertainty' or variations e.g. 'uncertain' or 'not certain'
B) Explicit acknowledgement of uncertainty not using the word 'uncertainty' or variations, but using other words such as 'unknown' or 'unclear'
C) Implicit indication of uncertainty using words such as e.g. 'seems', 'probably', 'expected' or 'typically'.

The results are summarised in Table 4, presenting the categories of acknowledgement found, and how many occurrences have been registered for category A and B. For category C, there are too many and too varied occurrences for quantification.

EIA process	***Killavaat Alannguat***	***Ilulissat***	***Aappaluttoq***
A) Explicit acknowledgement of uncertainty phrased as 'uncertainty'	No (0)	Yes (2)	No (0)
B) Explicit acknowledgement of uncertainty not phrased as 'uncertainty'	Yes (3)	Yes (10)	No (0)
C) Implicitly indicated uncertainty	Yes	Yes	Yes

Table 4 Whether and how uncertainty is acknowledged in EIA reports from the three EIA processes

Direct comparison with results from Lees et al. (2016) and Tennøy, Kværner and Gjerstad (2006) is difficult since the frameworks or typologies differ. The analytical frameworks of both previous studies have categories that are a mix of the issue of implicit/explicit acknowledgement and the quality or depth of describing and analysing uncertainty, whereas the typology presented here has implicit/explicit acknowledgement as a separate issue and adds category C implicitly indicated uncertainty, which is also found by Lees et al. (2016) although it is not part of their analytical framework.

Compared with the results from Lees et al. (2016), who found an equal amount of explicit (corresponding to category A) and implicit (corresponding to category B and C) uncertainties, this study clearly found fewer occurrences of category A explicit acknowledgements. The results of Tennøy, Kværner and Gjerstad (2006) are more similar to those presented here, as most EIA reports studied either did not mention uncertainty or did not refer to it specifically as uncertainty. It is interesting to note this difference, and it leads to several questions; if the practice of acknowledging uncertainty differs significantly between countries, then which factors influences this practice? Is it factors such as e.g. different legislation, culture or planning systems?

In the reports from Killavaat Alannguat and Ilulissat, uncertainty is acknowledged in relation to setting the baseline as well as the assessment of impacts. This echoes the findings of Lees et al. (2016), who found that most of the disclosed uncertainty was associated with impact prediction.

In the EIA reports, the uncertainties explicitly acknowledged have different discernible sources (referring to Table 1) as reported in Table 5.

EIA process	***Killavaat Alannguat***	***Ilulissat***	***Aappaluttoq***
Design and technology	X	X	X
Construction		X	
Data	X	X	X
Calculations and models	X		X
Causal mechanisms	X	X	X
Values	X		
Related activities		X	

Table 5 The sources of the uncertainties acknowledged in the EIA reports

Based on the data and analysis, the typology is adjusted and another category is added; implementation, meaning whether the project and mitigation measures are implemented in the way it has been presupposed in the assessment. The issue of not knowing whether implementation will be entirely as assumed is pointed out as a source of uncertainty in the EIA reports and hearing documents.

3.3 Uncertainty in the hearing

Looking at the material from the hearings, only one of the participants explicitly points to uncertainty (category A). In the written hearing for the mine at Killavaat Alannguat, uncertainty concerning wind data wind is pointed out: "*If the measurements are compared to the nearest official climate stations for the period and the last 10 years…the measurements look sensible but based on our long-time experience with wind measurements in Greenland, I know that this type of measurements is subject to major uncertainties*" (Jakobsen, 2013, p. 3; emphasis added by author).

In both Killavaat Alannguat and Aappaluttoq, uncertainty is indicated by asking for more information and further studies. For example, from Aappaluttoq: "*Before an actual approval is given, it should be examined whether there are problematic substances and compounds in the rock*" (True North Gems, 2014B, p. 179). Also, "*In this regard, NEKA want a quantification of how large a part of the water flow comes from Fostersø in the winter period, since this has a great effect on the magnitude of the lead concentration the trout are exposed to*" (Department of Nature, Environment and Climate, p. 1).

In Killavaat Alannguat, participants also questioned the data and data collection, asked for documentation for claims and transparency regarding the premises. For example, *"…in general there is a lack of access to the background data and calculations in the form of technical appendices, giving independent experts and NGOs the possibility to access the conclusions of the report*" (KANUKOKA, 2013, p. 1-2).

Unfortunately, only one hearing response was available for Ilullissat Airport (as stated in section 2.1), in this response, mainly factual mistakes are corrected.

4 Handling uncertainty in the EIA process

In the following subsections, the results concerning whether and how uncertainty handled in the EIA reports and hearings are presented to address the second research question.

4.1 Handling uncertainty in the EIA reports

First, as to whether uncertainty is actively assessed or analysed, the report from Killavaat Alannguat contains a systematic declaration of the confidence level for the assessment of each impact, focussed on whether or not there is confidence in the data which forms the basis for assessment. A set scale was used as described in Table 6.

Levels on the scale	***Description of level***	***No. of instances where the confidence is assessed as on the specific level of the scale***
Low	Data is weak	0
Medium	Data from Greenland or other parts of the Arctic (in particular Canada) points to conclusion	3
High	Data from the study area or neighbouring parts of South Greenland are conclusive	15

Table 6 Description of the scale used to declare the confidence level in data in the Killavaat Alannguat EIA process

It is not clear which actions, if any, medium confidence in the data prompts. Findings from Lees et al (2016) show examples of similar practice with various assessments of confidence in data, but no further discussion or handling of any of the results. The EIA process of Killavaat Alannguat also includes an assessment of the probability/likelihood that the impact will occur using a scale: improbable, possible, probable and definite. However, it is not very clear how this assessment was conducted and how the levels on the scale were defined.

In Killavaat Alannguat and Aappaluttoq, various methods to try to analyse and reduce the sensitivity of results to uncertainty were used. For example, two different methods were used for an estimation, in order to determine whether they match and consolidate the results in Aappaluttoq: "*The water balance of the lake has been calculated by two different methods…the two methods are in good agreement*" (True North Gems, 2014A, p. 28-9), and three sets of limit values from the EU, Norway and Canada were used to assess the significance of the impact from dust in Killavaat Alannguat.

Regarding whether any tools were used to handle uncertainty, a monitoring programme was applied in both Killavaat Alannguat and Aappaluttoq. For Aappaluttoq, "*A comprehensive environmental management plan and monitoring program ensure the emerging and unforeseen problem will be handled in a timely and appropriate manner*" (True North Gems, 2014A, p. 59). In general, there are no clear links between uncertainty and the use of monitoring, as also found by Lees et al. (2016). For example, none of the three issues with medium confidence in data (see Table 6) were covered by the monitoring programme in Killavaat Alannguat. An exception is that in Killavaat Alannguat, where mitigation measures were suggested, in case monitoring showed that specific limit values for the water environment were exceeded, an issue which was highlighted as uncertain (True North Gems, 2014A, p. 80).

Examples are found of working with a worst-case estimate of impacts, implicity in Killavaat Alannguat and explicitly in Ilulissat. Regarding Ilulissat, "*The assessments are based on the available information concerning the project and its activities in the construction and operation phases, and the assessments of environmental impacts are worst-case assessments. In the detailed planning of the project, the design and activities will be specified, and thus the real environmental impacts may prove to be less than assessed in the present report*" (Kalallit Airports, A/S 2018, p. 48).

One example shows a mix of reducing uncertainty via further studies and applying the precautionary principle until the results are available: "*Until further studies prove it environmentally safe to dispose of the remains in local landfills or sewer systems, the waste will be shipped for further processing and disposal outside Greenland*" (True North Gems, 2014A, p. 5).

The results found here, echo the results from Lees at al. (2016), who also find the application of precautionary approaches, conservative estimates, sensitivity analysis and additional studies.

4.2 Handling uncertainty in the hearing

Concerning analysis of uncertainty, one participant in the EIA process of Killavaat Alannguat explicitly points to a lack of documentation for the validity of results and assessment of the uncertainties: "*There seems to be a lack of documentation for the validity of results or as a minimum an assessment of the anticipated uncertainties*" (Jakobsen, 2013, p. 4; emphasis added by author).

Looking at handling uncertainty, participants in the hearing of Killavaat Alannguat called for the application of conservative limit values, the precautionary principle and a worst-case approach. The latter is also articulated by a participant in the hearing regarding Aappaluttoq: "*WWF further comments that a worst-case scenario should be described, where there is both a naturally high discharge due to high precipitation and an extra discharge due to the project. What will the consequences of this be for the area, and which mitigation measures could be applied to limit the negative impacts?* (True North Gems, 2014B, p. 144). Also, in Aappaluttoq, participants suggest corrections and additions to monitoring and management, for example: "*WWF recommends that a monitoring programme is prepared as part of the plan for closure, for example, a five-year programme, securing monitoring of the areas nature and environment in a period after the closure and implementation of rehabilitation*" (True North Gems, 2014B, p. 148). It is interesting to note that in Killavaat Alannguat, several participants questioned the use of monitoring and control mechanisms; whether it works in practice with the anticipated effect. For example, in relation to the water environment: "*A planned monitoring programme can only give information that something has gone wrong – not remove an already occurred pollution*" (KANUKOKA, 2013, p. 3). Several participants also ask for clarification of the distribution of responsibility if something turns out differently (worse) than expected, for example: "*If those that have a licence to an area start polluting and threatening the surroundings – what happens then? Who will be responsible for the pollution?*" (Tittussen, 2013). Thus, the participants questioned the outcomes of these tool meant to handle uncertainty by following the development and acting if needed in the future when more is known.

5 Conclusion and discussion

In the following sections, conclusions are drawn and discussed, structured according to the two research questions:

- Is uncertainty acknowledged in EIA processes and how is it acknowledged?
- Are tools and approaches used to deal with uncertainty in EIA processes, and which tools and approaches are used?

5.1 Acknowledgement of uncertainty in EIA processes

One of the studied EIA reports contains explicit acknowledgement of uncertainty phrased as 'uncertainty' (type A), and two of them contain explicit acknowledgement of uncertainty not phrased as 'uncertainty' (type B), while all of them implicitly indicated uncertainty (type C). One participant in the hearings explicitly raised issues of uncertainty, while in two of the EIA processes, participants indicated uncertainty by asking for more information and studies, questioning facts and data, and asking for transparency concerning premises.

The fact that only one of the EIA reports have explicit disclosure of uncertainty of type A and only two of type B indicates a low occurrence of acknowledgement given the uncertain trends in the Arctic described in section 1. Several studies have found that there is a lack of disclosure of uncertainty in IA reports (e.g.

Tennøy, Kværner and Gjerstad, 2006; Larsen, Kørnøv and Driscoll, 2013; Lees, 2016). The approach taken in this study of counting the number of times uncertainty is disclosed cannot answer the question of whether it is disclosed often enough. However, the fact that all three EIA reports contain many indications of uncertainty that are not addressed explicitly may indicate that something is missing.

Nonetheless, as stated in section 1, there is inherent uncertainty associated with all assessment of future impacts, and it may not be possible or expedient to deal with all uncertainty at the same level. Thus, there is a relevant question of what uncertainty should be made explicit, what should be handled actively and what should be left as mere indications: How do practitioners of IA decide how to treat uncertainty, and how conscious are they of this choice? Also, as stated in section 3, what are the factors that influence these decisions? e.g. legislation, culture, planning system.

When deciding on whether and to what extent to explicitly acknowledge uncertainty, it is relevant to consider how the other participants in the IA process receive such information. Previous studies indicate that there are limits to the amount of information on the uncertainty that decision-makers can use. According to Wardekker et al. (2008, p. 631), "*policymakers expressed that assessment reports, such as the Annual Environmental Balance, should not contain every nuance of uncertainty, but put forward only the most relevant messages*". Drawbacks of too much uncertainty disclosure include unnecessary discussion, delay in action and the risk of the information being misused selectively and strategically (Wardekker et al., 2008; Duncan, 2013). However, Wardekker et al. (2008, p. 637) also acknowledge that "*nuances in information may be obvious to scientists, but not to policy-makers and, therefore, need to be made explicit*".

One issue of distinguishing between different levels of uncertainty is that of wording, whether to phrase uncertainty in those words or not or whether to use 'unlikely', 'probable', 'typical' etc. For example, the EU guidance on climate change suggests that uncertainty can be communicated using terms such as 'strongly suspected' and 'suspected' etc. and stresses the importance of defining the wording, for example, using probability intervals (European Commission, 2013).

Taken together, this suggests more research is necessary concerning how the choice of acknowledgement and wording is made by IA practitioners as well as how it is perceived by the other involved actors.

There is not much evidence that uncertainty is an explicit part of the discussions in the EIA process in the hearing documents studied. This may be problematic following the argument by Duncan (2013, p. 153-54) that there is a need for opportunities for "*deliberation and negotiation of fundamental assumptions and parameters before they become embedded in predictive models and obscured from view*". The present study, however, does not answer questions of whether such discussions take place internally within the team preparing the EIA.

Several findings of the present study support the call from other authors for the development of typologies and terminology for working with uncertainty in IA. As a contribution to this end, an updated framework of general sources of uncertainty in IA (see Table 1) is proposed in Table 7.

Source	***Description***
Design and technology	Uncertainty about the final project design and the choice of technology
Construction	Uncertainty about timelines and methods for construction
Data	Uncertainty about data used as a basis for calculations, prediction and assessments e.g. because of questionable data collection, natural variability or human behaviour
Calculations and models	Uncertainty about the specific methodology for models, assumptions and calculations of impacts

Causal mechanisms	Uncertainty about what the derived consequences of predicted impacts are
Values	Uncertainty about society's values e.g. expressed through attitudes, classifications or goals
Related activities	Uncertainty about the status of related projects, plans and activities etc.
Implementation	Whether or not the project and mitigation measures are implemented as presupposed in the assessment process

Table 7 Sources of uncertainty in EIA

5.2 Handling uncertainty in EIA processes

Various approaches are taken in the EIA reports, which can be part of analysing and handling uncertainty, namely sensitivity analysis, monitoring and worst-case estimates. However, it is not clear in the EIA reports whether and how the use of these approaches is linked to uncertainty. Only in one instance is uncertainty handled systematically, through disclosing levels of confidence in the data used for assessment. Looking to the hearings, one participant calls directly for the handling of uncertainty, while others more indirectly call for handling uncertainty through the use of conservative limit values, the precautionary principle, and worst-case approaches and monitoring. There are also expressions of concern over the usefulness of monitoring. Research has also found that there are various methodological problems and poor practice concerning monitoring in IA, also in the Arctic (see e.g. Azcárate et al., 2013).

Previous studies showing a lacking disclosure of uncertainty in IA reports emphasise that the degree of treatment of uncertainties is low (e.g. Tennøy, Kværner and Gjerstad, 2006; Larsen, Kørnøv and Driscoll, 2013; Lees, 2016). This study finds multiple examples of the application of approaches that can be used to handle uncertainty, but little evidence that these are used for that purpose. This again raises questions of how these choices of whether and how to handle uncertainty are made.

Generally, it is important to note that it is not necessarily expedient to consider uncertainty as an added issue that can make IA processes and reports longer and more resource consuming. However, as evident from the results of this as well as previous studies, it may be the case that many of the puzzle pieces needed to better acknowledge and handle uncertainty are already present in the process, and what is lacking is a more systematic, conscious, transparent and precise use of these pieces.

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