PERCEPTIONS OF UNCERTAINTY ON THE SCIENCE-POLICY INTERFACE

EXAMINING A CASE OF DUTCH ENVIRONMENTAL POLICY ASSESSMENT

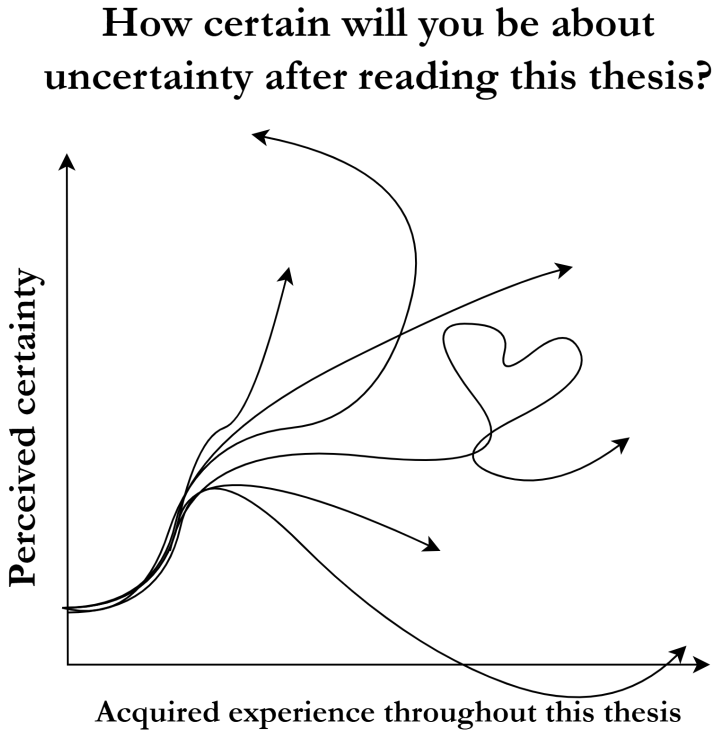

Figure 0: Projection of your perceived certainty about uncertainty, in different scenarios throughout the reading journey

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EXAMINING A CASE OF DUTCH ENVIRONMENTAL POLICY ASSESSMENT

Masters thesis submitted to Delft University of Technology in partial fulfillment of the requirements for the degree of

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in Engineering and Policy Analysis

by

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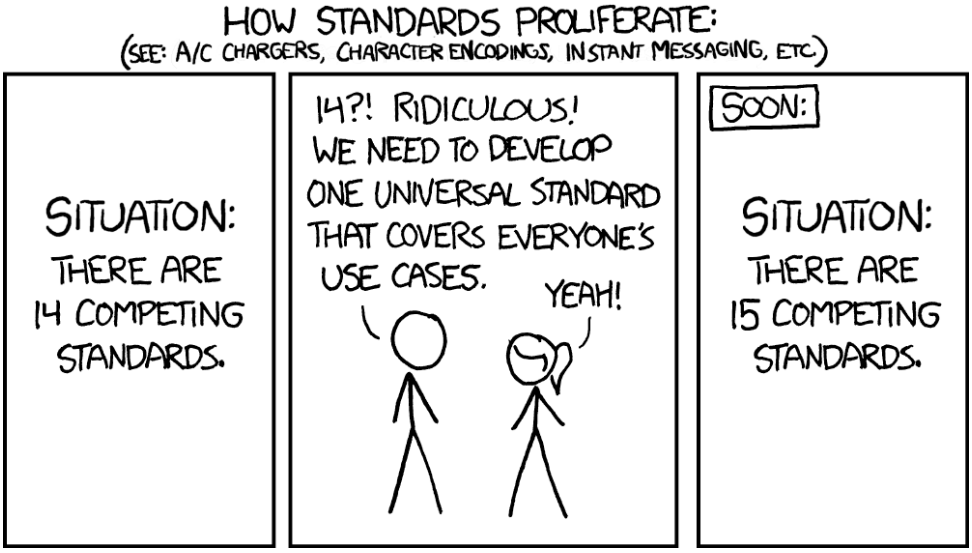

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PREFACE

During my other master's programme, Communication Design for Innovation (CDI), I became interested in critically reflecting on the role of science in society. But I wanted to learn more about tackling societal challenges. In the motivation letter to also apply to Engineering and Policy Analysis (EPA), I wrote about my interest in the impact of communication and use of model results for policy during the covid pandemic, for the case of the earthquakes in Groningen, and in the development of nitrogen policy.

At EPA, I learned more about the impact of my decisions as a modeller. In a mock debate during the course 'Model-based decision-making', my team (playing a stakeholder) used the model as a point of common-ground with the other stakeholders. Though the model was used to understand the possible outcomes, it mostly had to facilitate the discussion. In the end, a consensus was reached on an out-of-the-box solution.

Even since my bachelor's in mathematics, I've wanted to learn more about the actual practice of modelling for decision-making and the role of uncertainty. I am therefore so grateful I got to do both my master's thesis research projects on this topic. I've been enthusiastic from start to finish and have loved the research process.

Thank you Dr.ir. Floortje d'Hont and Dr. Lisa Scholten, my supervisors at TU Delft, for supporting my development as a researcher. During developing my idea into a full research plan, and eventually executing and reporting on these interesting results, I appreciated your help in making my thoughts concrete and your push-back during the occasional detour. You also responded kindly and encouragingly when I needed to hear I was doing well. I can now say I'm very proud of what I've learned and accomplished.

Also thanks to my external supervisors, Dr. Astrid Martens and Dr. Shruti Setty, for your time, expertise, and guidance at PBL. Fortunately for me, this project was exactly the topic of your interest. Though I'm still a student, even in our first discussion I felt like you were not holding back in asking for my opinion and posing critical questions. I hope you've had fun as well, because I certainly had a wonderful time and learned a lot.

Lastly, I want to thank my colleagues and friends for our time together next to my studies for the past 8 years. Laura for being interested in my thesis topic and getting me to become her colleague. The 'Hot Chocolate Gang' at EPA for finding each other on day one, and being just infinitely interesting and fun to hang out with. Student association 'De Bolk' and the friends I've made there for being 'prettig gestoord' and a constant source of support in a constantly challenging study landscape.

Cheers! Here's to finishing the first of two master's theses!

SUMMARY

This study explores perceptions of uncertainty and its effects on the policy-process on the science-policy interface in the Netherlands. Practitioners experience a misalignment, which leads to misunderstanding, decreased usefulness of policy assessments, and in the end affect policy design and investments.

Policy analysis can provide valuable information to understand what policy options are effective in complex policy problems, taking into account the uncertainty of human behaviour, economic development, and even weather changes. Previous studies have shown however that the applicability and relevance of uncertainty communication has been limited, specifically for policy-makers.

The case studied is the perception of uncertainty by researchers and policy officers that produce and use the Climate and Energy Outlook in the Netherlands, which presents projections of emissions and energy use with an uncertainty bandwidth.

A conceptual framework was developed to capture how uncertainty is understood in scientific literature: *Framing*, *Characterisation*, *Impact*, and methods of *Dealing with uncertainty*. Using an adapted mental model method, 9 researchers and 6 policy officers were interviewed, and their perceptions qualitatively coded (deductive and inductive) and compared.

It is concluded that two distinct perspectives were indicated on each aspect of uncertainty (definition, characterisation, and interpretation), shaped by values and institutional context. The differences were just more nuanced than a split between the participant groups. Probability statements helped align interpretation, but this may risk neglecting other important (qualitative) aspects of uncertainty. As uncertainty is also used strategically, there is a limitation to how much researchers can influence the impact of uncertainty information.

The observations help clarify the difference in uncertainty perception experienced on the science-policy interface, how they effect communication and policy-making, and suggest ways to improve alignment.

Though this case study focuses on a specific presentation of uncertainty in projections of greenhousegas emissions, the findings offer a new perspective on uncertainty perception in policy analysis.

SAMENVATTING

Deze studie onderzoekt de perceptie van onzekerheid en de effecten voor beleidsvorming op het raakvlak tussen wetenschap en beleid in Nederland. In de praktijk wordt een discrepantie ervaren, wat leidt tot misverstanden, een verminderde bruikbaarheid van beleidsbeoordelingen en is uiteindelijk van invloed op het ontwerp van beleid en investeringen.

Beleidsanalyse kan waardevolle informatie opleveren om te begrijpen welke beleidsopties effectief zijn bij complexe beleidsvraagstukken, rekening houdend met de onzekerheid van menselijk gedrag, economische ontwikkeling en zelfs weersveranderingen. Eerdere studies hebben echter aangetoond dat de toepasbaarheid en relevantie van communicatie over onzekerheid beperkt kan zijn, met name voor beleidsmakers.

De onderzochte casus betreft de perceptie van onzekerheid door onderzoekers en beleidsmedewerkers die de Klimaat- en Energieverkenning in Nederland opstellen en gebruiken, waarin ramingen worden gepresenteerd van emissies en energieverbruik met een onzekerheidsbandbreedte.

Er werd een conceptueel kader ontwikkeld om weer te geven hoe onzekerheid in wetenschappelijke literatuur wordt begrepen: *Framing, Karakterisering, Impact* en methoden om *met onzekerheid om te gaan.* Met behulp van een aangepaste mentale modelmethode werden 9 onderzoekers en 6 beleidsmedewerkers geïnterviewd en werden hun percepties kwalitatief gecodeerd (deductief en inductief) en vergeleken.

Geconcludeerd wordt dat er twee verschillende perspectieven waren op de meeste aspecten van onzekerheid (definitie, karakterisering en interpretatie), gevormd door waarden en institutionele context. De verschillen waren alleen genuanceerder dan een splitsing tussen de deelnemersgroepen. De interpretaties lijken meer op één lijn te liggen als naast een bandbreedte ook waarschijnlijkheid wordt uitgedrukt, maar dit kan het risico met zich meebrengen dat andere belangrijke (kwalitatieve) aspecten van onzekerheid worden verwaarloosd. Aangezien onzekerheid ook strategisch wordt gebruikt hebben onderzoekers maar beperkte invloed op de impact van onzekerheidsinformatie.

De observaties helpen het verschil in perceptie van onzekerheid op het raakvlak tussen wetenschap en beleid te verduidelijken, hoe deze de communicatie en beleidsvorming beïnvloeden, en suggereren manieren om de afstemming te verbeteren.

Hoewel deze casestudy zich richt op een specifieke presentatie van onzekerheid in ramingen van broeikasgasemissies, bieden de bevindingen een nieuw perspectief op de perceptie van onzekerheid in beleidsanalyse.

CONTENTS

1

INTRODUCTION

1.1. UNCERTAINTY ON THE SCIENCE-POLICY INTERFACE

Complex problems, like man-made climate change, loss of biodiversity, and large infrastructural projects, involve many stakeholders with different perspectives on the problem. Knowledge is disputed, problem definitions conflict, and many (conflicting) interests play a role (Enserink et al., 2022). On the science-policy interface, researchers and policymakers work together on these complex problems and try to identify, quantify and manage the uncertainty in the problem-solving process. Modelling and simulations can support exploring the potential impacts of policy by conceptualising the complex socio-technical-environmental system and simulating policy effects on that system (Amorocho-Daza et al., 2025).

However, actors on the science-policy interface experience a science-policy gap: a difference in the consensus, acceptance, and experienced usefulness of scientific findings, as well as divergent pereptions of uncertainty, (as discussed by Bradshaw and Borchers (2000), de Vries et al. (2010), Leung et al. (2016), and Wardekker et al. (2008)). Uncertainty perception plays an important role in the interpretation and confidence in scientific results, next to familiarity with scientific methods, pre-existing beliefs, cultural values, and political interests (Bradshaw & Borchers, 2000; Fischhoff & Davis, 2014; Mason-Renton et al., 2019). To address the relevance and acceptance of scientific findings on the science-policy interface, it is important to explore uncertainty perception and use of uncertainty information in the research and policy-making process.

UNCERTAINTY IN MODEL-BASED PROJECTIONS FOR DECISION-MAKING

Models are an abstraction of a part of reality, and can support decision-making by exploration of trade-offs, uncertainties and sensitivities. Model-based projections of policy effects inevitably involve uncertainty, specifically as systems are highly complex and often require incorporating several environmental, behavioural, and economic components. Such integrated models don't only involve quantifiable uncertainty (more frequent for well-defined problems) but also uncertainty in scientific agreement on the

model assumptions (for example the model structure or variation in input parameters, sometimes respectively defined as fundamental and operational uncertainty (Ragas et al., 1999)). These assumptions influence the uncertainty of the assessment results, not only because they are forecasts and the world can still change, but because the assumptions are subjective and therefore the outcomes can vary.

It is important to recognise that uncertainties are assessed in different ways (Matott et al., 2009). Fundamental uncertainties can be analysed by for example running the model with different structures using sensitivity analysis, or through expert judgement. Kloprogge et al. (2011) conclude fundamental assumptions are a source of uncertainty that's important to analyse and communicate to decision-makers, and suggests using a pedigree chart to that end. Other quantifiable uncertainties are often subject to for example a Monte Carlo analysis, where a density distribution is assigned to the possible values of the uncertain parameter, and forecasts are made for different combinations over all the uncertain parameters.

Communicating these distinctions in types of uncertainty, and how they are analysed, is a difficult task. Decisions must be made to select what information is most relevant to be transparent about the limitations of the research, but also what the user requires to interpret the results. Users may want to know what precautionary measures are effective, or whether there is time to take a wait-and-see approach. This shows it is important to examine what aspects are required to interpret the results and how uncertainty perception impacts decision-making.

UNCERTAINTY COMMUNICATION FOR POLICY-MAKING

Effective communication of uncertainty in policy assessments persists as a challenge, impacting interpretation and credibility. Tenney et al. (2006) found that Norwegian environmental impact assessments often lack accessible uncertainty information, making projections seem more certain than they are. Leung et al. (2016) surveyed Canadian actors about their perceptions of environmental assessments, revealing that while assessments are valued for informing policy, uncertainty is poorly disclosed and utilized, impacting credibility. Bostrom et al. (2016) identified gaps between hurricane forecasts and user needs in the USA, highlighting ineffective communication across professions, despite efforts to improve it.

The Intergovernmental Panel on Climate Change (IPCC) and the European Food and Safety Authority (EFSA) provide widely cited guidelines on uncertainty communication in environmental assessments. (European Food Safety Authority et al., 2019; Mastrandrea et al., 2011). These frameworks standardise the communication of uncertainty numerically and verbally using probability metrics, likelihood scales and confidence scores. However, studies show that such terms are often misinterpreted and shaped by framing (Budescu et al., 2012; Kause et al., 2019; Willems et al., 2020). Additionally, the interpretation of uncertainty is likely influenced by profession, experience, prior beliefs about science, and comfort with ambiguity (Bostrom et al., 2016; Kause et al., 2019; Kuonen et al., 2019; Leung et al., 2016; Rabinovich & Morton, 2012).

Critiques of these frameworks argue these approaches are of little relevance for policy-making, the scientists' judgements are value-laden, and there is limited guidance on how the uncertainty information is supposed to be applied in different contexts (Adler & Hirsch Hadorn, 2014; Jones, 2011; Swart et al., 2009). Though the IPCC has iterated on their uncertainty assessment and communication (Lempert et al., 2024), increasingly introducing concepts and methods to convey lower-confidence scientific information that is more policy-relevant for more complex and deeply-uncertain problems.

Though many many alternatives have been offered that emphasize risk, ambiguity, and consider policy- or model-relevant perspectives, there is no common language for communicating language as each case seems to require different approaches. (Arend, 2024; Bland & Schaefer, 2012; Brugnach et al., 2008; Gaudard & Romerio, 2020; Kwakkel et al., 2010; Maier et al., 2016; Marchau et al., 2019; Tannert et al., 2007; Walker et al., 2013; Walker et al., 2003). There is a need to better understand perceptions of uncertainty in different applications to create relevant frameworks for uncertainty communication in policy assessments.

POLICY-RELEVANCE OF UNCERTAINTY ANALYSIS

Policy-makers are likely short on time, money, and other resources. They must balance different policy goals and negotiate for their own policies. This may mean that there may not be resources to reach goals with 100% certainty, and have to deal with that uncertainty. Different levels of uncertainty also require different approaches in policy-making (Dewulf & Biesbroek, 2018; Kasperson, 2008; Marchau et al., 2019; Raadgever et al., 2011).

For policy-makers, uncertainty can be both a burden and an asset. In practice we can observe decision-makers prioritizing, ignoring, and reframing different types of uncertainty. Raadgever et al. (2011). Though the policy-making process seems to prefer certainty (de Vries et al., 2010), uncertainty information can also be used strategically, to delay action, or reduce responsibility (Dewulf & Biesbroek, 2018; Leonhardt et al., 2011; Moore, n.d.).

What information about uncertainty is relevant, depends on the phase of the policy-making and research process (Baustert et al., 2018). When the model is used for decision-support, the purpose of uncertainty analysis is to "quantify the confidence in a decision and the value of additional data collection". The decision-maker then can include the resulting information to evaluate "the risk associated with taking a decision based on the model's output".

The relevance of uncertainty information also depends on how well the decision-support model reflects the decision-making context. Advanced approaches to uncertainty to deep-uncertainty (like DMDU) are considered to rarely show consideration of individual, organisational and institutional contexts according to Roelich and Giesekam (2019) and Stanton and Roelich (2021). Without such contextualisation, it is hard for decision-makers to apply them in practice. Stanton and Roelich (2021) emphasize such methods should consider the stakeholders involved, their values and assumptions, and

their organisational context. Maxim and Van Der Sluijs (2011) conclude that researchers focus on the role of uncertainty analysis in highlighting gaps in knowledge, neglecting the role to improve the quality of decisions and its strategic use in the decision-making process.

This shows that steps can be taken to improve policy-relevance of uncertainty analysis methods by exploring personal and institutional context. Though policy-makers are sometimes considered uncertainty-averse, and scientists are considered not to provide 'useful' knowledge (Bradshaw & Borchers, 2000; de Vries et al., 2010), there is limited understanding of their institutional contexts shape their approach to and perception of uncertainty.

UNCERTAINTY IMPACT AND CREDIBILITY

Whether uncertainty decreases or supports scientific credibility has for a long time been a topic of discussion (Schneider et al., 2022; Shackley & Wynne, 1996). Some scientific experts believe communicating uncertainty leads to distrust in science, panic and confusion (Frewer et al., 2003). However, transparency about quantitative uncertainty has been shown to mostly have positive effects and no known negative effects (Gustafson & Rice, 2020), but this may differ with other types of uncertainty and types of audiences (Van Der Bles et al., 2019).

Though being transparant about uncertainty is likely positive for credibility, this does not mean that uncertainty is always welcome. As described previously, policy-makers may be uncertainty avoidant. And while evidence-based policy-making relies on scientific expertise, it can also "introduce more uncertainty on the methodological, social and philosophical level" (Hellström, 1996). The scientific community should beware it doesn't obscure uncertainty as it provides insight into the complexity of the problem, trust in and credibility of the research, and supports choosing an uncertainty management strategy (Bradshaw & Borchers, 2000; de Vries et al., 2010; Van Der Bles et al., 2019).

Though it is a hard task, scientists are increasingly making their values explicit and are communicating when uncertainty is irreducible, while also making sure results are policy-relevant (Funtowicz & Ravetz, 2019; Jebeile & Roussos, 2023; Kunseler et al., 2015; Stanton & Roelich, 2021). Therefore, to improve policy-relevant communication of uncertainty, there is a need to gain more insight into the (perceived) impact of uncertainty, especially in the policy-making process.

1.2. RESEARCH QUESTION FORMULATION

The aim of this research is to explore the experienced science-policy gap in the perception of uncertainty in the Netherlands. Therefore, the following explorative research question is formulated:

What are perceptions of uncertainty on the science-policy interface in the Netherlands perceive uncertainty, and what are the implications for the policy-making process?

First, to research uncertainty perception, it is important to look into what uncertainty is in theory and practice. A first sub-question is formulated:

SQ1: What is uncertainty?

Because uncertainty can be perceived differently based on personal background and institutional context, it is important to consider how different actors on the science-policy interface may perceive uncertainty differently. A second sub-question is formulated:

SQ2: What are different perceptions of uncertainty by policy-makers and researchers?

Effective and relevant communication of uncertainty can align perceptions of uncertainty. A third sub-question is formulated to address the implications of uncertainty perceptions for the policy-making process:

SQ3: How is uncertainty dealt with by policy-makers and researchers?

1.3. SCIENTIFIC AND SOCIETAL RELEVANCE

Policy assessments play an important role in policy-making. The uncertainty analysis can provide insight into more than just the reliability of the results. It can lead to more spending to take precautions for important policy goals, can lead to more monitoring to support adaptive policies, can lead to decreased action for more wait-and-see approaches, and can show what policy may be less effective due to the inherent uncertainties.

Uncertainty analysis and communication should therefore not be an afterthought, but an important part of the collaboration on the science-policy interface. This requires a shared understanding of uncertainty to support policy-relevant research and correct interpretation of assessment results.

A lack of consensus on terminology and interpretation of uncertainty indicates that there may not be a shared perception of uncertainty, making it harder to collaborate, especially across disciplines like policy-makers and researchers do. Instead of trying to align every perception in one all-encompassing theoretical framework, exploring these different perceptions in practice can provide a new direction for research. It would acknowledge that there is not one superior perspective, but support understanding the differences and address them case-by-case and how their contexts influence them.

Uncertainty analysis and policy problems evolve in practice. Exploring how different people perceive and deal with uncertainty in practice can help to understand the actual role of uncertainty in the policy-process. This in turn can empower policy-makers and researchers, in their collaboration, to effectively work with uncertainty in the face of vastly uncertain futures.

1.4. REPORT OUTLINE

The topic and research questions have been introduced in section 1. Next, the related concepts are examined and synthesised in a conceptual framework in section 2. The case study and methods for the uncertainty perception elicitation and analysis will be explained in section 3. The different perceptions of uncertainty are presented in section 4. How the personal and institutional context shapes these perceptions, and the limitations of this research, are discussed in section 5. Lastly, the report finishes by concluding what different perceptions of uncertainty are present on the Dutch science-policy interface, and recommendations for future research and practical application, in section 6.

1.5. DISCLAIMER AND POSITIONALITY

I declare that I performed this research as part of a paid internship at PBL Netherlands Environmental Assessment Agency and for my master thesis at Delft University of Technology. As the research was performed as part of an internship at PBL, I was more familiar with the perspective of the researchers than the policy-makers.

I'm a citizen of the Netherlands, where I studied Applied Mathematics (BSc.), Communication Design for Innovation (MSc.) and Engineering and Policy Analysis (MSc.). I'm interested in researching transdisciplinary collaboration on the science-policy interface, model-based decision-making, and the role of science in society.

2

CONCEPTUAL FRAMEWORK

This section helps to answer the first research question through a scoping literature review: *What is uncertainty?* Most papers touch on several approaches to explore uncertainty, as can be seen in the summary table in Appendix A. These different approaches will be discussed, as well as methods of elicitation of uncertainty perception.

2.1. FRAME

What uncertainty is can depend on the frame used by the author or the frame through which a reader interprets the information. This research uses the following generalised definition of framing: The *values and interests* that influence what information is considered important. It is also expressed as the *system boundaries* that are drawn (theoretical, social, political, economic perspectives) and personal *definitions* of, for example, uncertainty (from a risk, ambiguity or knowledge quality perspective). It is important to examine their relation to uncertainty perception.

VALUES AND INTERESTS

On a professional level, Höllermann and Evers (2017) pose that uncertainty is approached from different viewpoints for natural resource management: Scientists often focus on quantifying uncertainty, whereas decision-makers use a risk frame for uncertainty management in the decision-making process. They also note that process uncertainties are more relevant for strategic decision-making than those fundamental uncertainties that are often focused on by scientists.

SYSTEM BOUNDARY

Many authors cover the modeller's perspective on uncertainty in the decision-making process, where extensive typologies are developed to equip modeller's to address and treat uncertainty Kwakkel et al. (2010), Marchau et al. (2019), Ragas et al. (1999), Walker et al. (2013), and Walker et al. (2003). Though they recognise that uncertainty can be politicised in the policy-making arena, little attention is paid to the policy-maker's point

of view.

Policy-relevant perspectives of uncertainty are explored: strategic relationship to uncertainty, the institutional rules, and ethical rules that govern the policy-making process are considered relevant (Brugnach et al., 2008; Dewulf & Biesbroek, 2018; Tannert et al., 2007). They continue on the typology introduced by Walker et al. (2003). Later also Ongaro and Andreoletti (2022) who conclude that data-based decision-making can only consider empirical uncertainty whereas ethical uncertainty or deciding the boundaries of the problem are value-based uncertainties.

This discrepancy in applicability indicates different roles require different approaches to understanding uncertainty. Few articles attempt to reconcile the different perspectives by connecting steps of the policy-process in the framework (Arend, 2024; Maxim & Van Der Sluijs, 2011). That does not mean that the goal is to create one unified framework. A relevant typology for policy analysts may not be relevant for decision-makers.

DEFINITIONS

Uncertainty in everyday life is strongly related to risk and ambiguity, especially on a personal level and in communication (Alaszewski & Coxon, 2009; Van Der Bles et al., 2019). The terms are often used instead of one another. In literature, the terms are also tied, and have different definitions depending on the research domain (Kwakkel & Cunningham, 2008b). Considering that professional and personal understandings of uncertainty use different terminology and perspectives, the following exploratory list of definitions was established:

- Walker et al. (2003, p.1) adopt a general definition of uncertainty: "any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system."
- Brugnach et al. (2008, p.5) “Uncertainty refers to the situation in which there is not a unique and complete understanding of the system to be managed.”
- Maxim and Van Der Sluijs (2011) do not provide an explicit definition of uncertainty, but address dimensions of uncertainty related to the lack of (scientific) knowledge quality in decision-making.
- Brugnach and Ingram (2012) define ambiguity as a distinct type of uncertainty: "the presence of multiple possible interpretations of a situation". Therefore, explicitly not as a lack of knowledge.
- Höllermann and Evers (2017) advise scientists to present uncertainty from a risk frame. They define risk as “a product of the probability of occurrence of an event and its consequences.”

2.2. CHARACTERISATION

Most authors in this literature review identify multiple dimensions along which an uncertain factor can be differentiated from another. The most common dimensions, which

will be discussed here, are *location, nature, and level* based on Walker et al. (2003), but has often been expanded upon by other authors. Alternative perspectives are presented by Kloprogge et al. (2011) as a pedigree charts and by Gaudard and Romerio (2020) as an acuity scale.

Most authors address where the uncertain factor is “located” in the problem. There is a difference in the locations of interest from the modelling and from the policy perspective. Those papers focused on modelling extensively differentiate between different steps of the modelling process, from problem demarcation, input data, and model structure (Kwakkel et al., 2010; Walker et al., 2003). The policy perspective more extensively differentiates between different parts of the problem demarcation, the social/technical/environmental system, the strategic rules of the decision-making arena, and the different steps of the policy-making process (Brugnach & Ingram, 2012; Brugnach et al., 2008; Dewulf & Biesbroek, 2018; Höllermann & Evers, 2017; Maxim & Van Der Sluijs, 2011).

Another dimension that most of these authors comment on is the "nature" of the uncertainty. Both modellers and policymakers recognise that factors can be uncertain for different reasons, but the selected papers show this differentiation is rarely made in practice. The most common types are *lack of knowledge, variation, and presence of multiple frames* (Brugnach & Ingram, 2012; Brugnach et al., 2008; Kwakkel et al., 2010; Raadgever et al., 2011; Walker et al., 2003). Some papers expand on different types of variation, and few add an *ethical nature* (lack of moral rules) to the list (Ongaro & Andreoletti, 2022; Tannert et al., 2007), and one acknowledges that the quality of knowledge is impacted by *how it is communicated and interpreted* (Maxim & Van Der Sluijs, 2011). Lastly, Arend (2024) differentiate between *treatable and untreatable* uncertainties, and define a triage system to address policy-relevant aspects of uncerainty.

The last dimension is the "level" (Kwakkel et al., 2010; Walker et al., 2003) or intensity (Arend, 2024)] of uncertainty. It represents how much uncertainty there is. This dimension is not addressed in most papers. This dimension is useful for describing not only what is uncertain, but also what IS known. It can help to reflect on how the uncertainty can be reduced, or, if it will not be reduced, on what the effect will be on the model outcome or decision-making process.

2.3. IMPACT

There are few papers that represent the impact of uncertainty. From the accumulation and representation of uncertainty in model outcomes (Kwakkel et al., 2010; Walker et al., 2003), the uncertainty is interpreted and impacts feelings uncertain (worry), and (dis)trust in the modelling/decision-making process (Alaszewski & Coxon, 2009; Frewer et al., 2003; Maxim & Van Der Sluijs, 2011; Van Der Bles et al., 2019). Arend (2024) offers a typology that considers primary and secondary costs and benefits of uncertainty in the decision-making process.

2.4. DEALING WITH UNCERTAINTY

How decision-makers (can) deal with the uncertainty is rarely addressed, in contrast to how researchers analyse uncertainty. Raadgever et al. (2011) show uncertainty is dealt with in many different ways in (water management) practice, which they categorise under *Ignoring, Knowledge generation, Interaction, Coping strategies*. What strategy is chosen can depend on the nature of uncertainty, source/location, level, and whether it is managed individually or collectively (Dewulf & Biesbroek, 2018). It also differs per frame of uncertainty, and is often strategically chosen in the policy-making arena (Brugnach et al., 2008).

2.5. METHODS OF ELICITATION

To form an accurate representation of people's beliefs, a structured elicitation protocol is developed by Morgan et al. (2001). They use a mental model method to inform risk communication. A mental model is a structured set of beliefs (concepts and causal links) that is a personal abstraction of the real world. It influences what new beliefs and concepts will be added or changed based on whether they conflict with current concepts or causal beliefs.

The Morgan method for risk communication uses mental model interviews to build an understanding of how a target audience views a system and its risk, then compares it to an expert mental model to identify gaps in understanding that informs risk communications (Bostrom, 2017; Morgan et al., 2001). This includes both concepts and beliefs, but does not prescribe what this entails exactly.

The perceptions can be elicited through use of interviews, and can later corroborated by survey results of a larger population. The expert model can be formulated through a literature review or a focus-group. They summarise the elicited models in influence diagrams as an external representation, which includes the concepts (nodes) and influence pathways (arrows).

The mental model method has since been expanded to broader topics and using different techniques, as reviewed by Doyle et al. (2022). They define mental models as "people's psychological representation of 'how the world works'". Doyle et al. (2022) conclude in their review that mental models "can encompass an individual's understanding of physical systems, how we produce knowledge, as well as cultural, philosophical, socio-political, educational, and organisational influences on understanding. [...] Such mental models are a set of simplified causal beliefs and epistemic values people use to interpret events."

A limitation of the mental model method is that mental models are internal conceptualisations and can therefore not be analysed directly. There is also not one universal way of researching mental models and representing them. So far it has mostly been used as a method to examine how laypeople's "deficient" perception of a risk differs from an

expert model, to inform risk communication.

One study of interest does apply the mental model methods to perceived uncertainty. Doyle et al. (2023) interview 25 professionals with at least an undergraduate education about their perception of uncertainty related to natural hazards science, using a multi-stage mental model approach. They explored extensively the definitions and related sources of scientific uncertainty, but didn't look into how the uncertainty perception impacts decision-making.

2.6. WHAT IS UNCERTAINTY?

To conclude, uncertainty is defined and interpreted in literature using four different approaches, presented in Figure 2.1. The first is through *framing and definitions*. Next, most reviewed papers *characterize* and differentiate between different uncertainties, an example is included based on a common modeller's perspective: location, nature, level. Also, some papers comment on the interpretation and *impact* of uncertainty. Lastly, several case studies show how individuals and organisations *deal with uncertainty*.

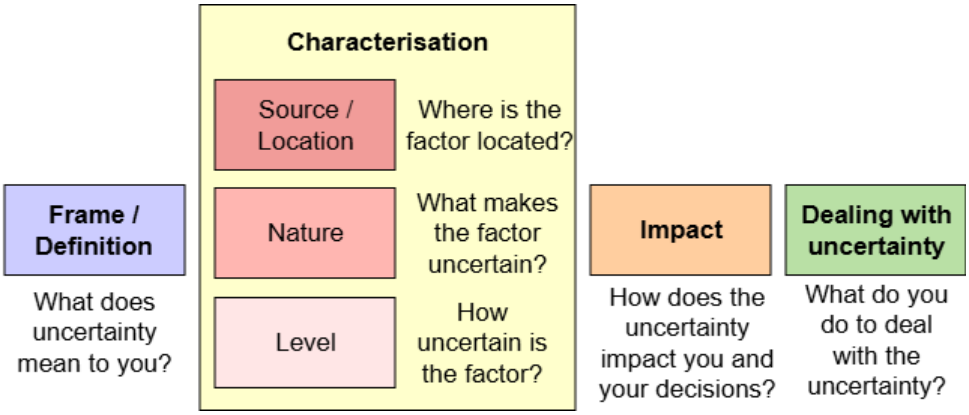

Figure 2.1: Conceptual framework describing different ways of perceiving uncertainty, based on a scoping literature review.

Important to observe is the variation in results across these approaches show. Therefore, it is not straight-forward to answer the sub-question: *What is uncertainty?* Additionally, there seem to be only few studies that address uncertainty characteristics from a policy-maker's perspective. Eliciting uncertainty perception using the mental model method can address this knowledge gap and provide insight into what uncertainty is, and how it is perceived, in newer contexts.

3

METHODOLOGY

3.1. RESEARCH APPROACH

This section will discuss the steps that are taken to explore the different perceptions of uncertainty: (grey) literature review of uncertainty to create a conceptual framework, identifying a case study, designing and testing an interview protocol, contacting participants and conducting the interviews, and lastly (iterative) coding and qualitative analysis. They are visualised in Figure 3.1.

It is important to note the general approach to this research is based on a constructivist point of view. It is assumed that there is not one true way of describing uncertainty, but there are meaningful ways that are subjectively constructed. It is also assumed that there is not one true expert in this case analysis, but there are different people who have their own perception and neither is superior to the other. This constructivist view is meaningful for this study because it allows to recognise a plurality of perceptions without labelling a party as having a 'wrong' perception.

3.2. CASE STUDY: THE DUTCH CLIMATE AND ENERGY OUTLOOK (SHORT: KEV)

To take a closer look at the practice of uncertainty perception, it is important to examine a real case where uncertainty is dealt with on the science-policy interface. Instead of examining the abstract concept of uncertainty, this will allow to elicit perceptions and impact of actual uncertainty, and take into account how the personal and institutional context shapes these perceptions. This section will present the policy problem that requires policy assessment, the methods of (uncertainty) analysis and communication, and the most important actors.

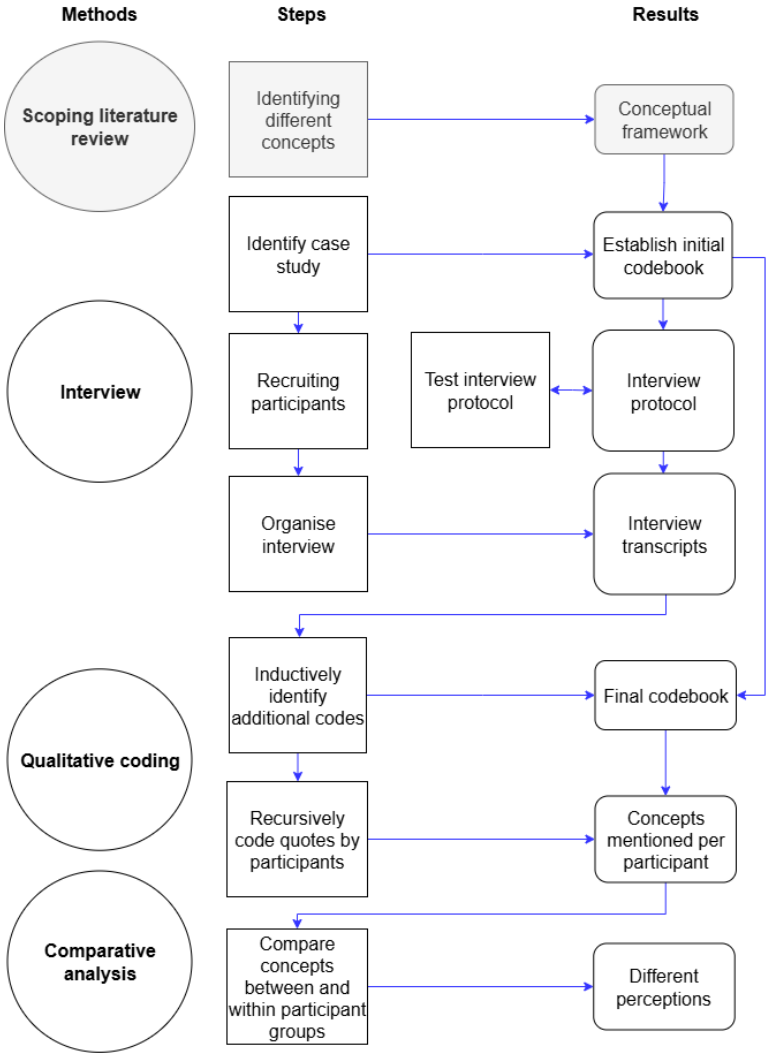

Figure 3.1: Research overview

3.2.1. TASK TO ASSESS CLIMATE POLICY

On the science-policy interface in the Netherlands, PBL Netherlands Environmental Assessment Agency (short: PBL) operates and assesses policy relevant to the environment (circular economy, energy use, climate impact, biodiversity, and more). Other organisations preceded PBL, and through mergers and new mandates PBL was formed in 2008.

In the climate law of the Netherlands, it is established that regular monitoring of climate policy is obligatory, PBL fulfills this task and publishes the Climate and Energy

Outlook yearly ("Klimaat- en Energieverkenning" in Dutch) (short: KEV) (PBL, 2024). PBL reports on the achieved and expected effects of climate and energy policy in relation to the european, national, and domain specific goals.

- The main binding objective, as noted in the Paris agreement, is to limit global temperature rise to well below 2 degrees Celsius, with the aim of limiting warming to 1.5 degrees Celsius.
- The main national climate goals are stated in the Dutch law, requiring a minimal reduction of greenhouse gas emissions of 55% compared to 1990 levels by 2030.
- Furthermore, the Netherlands must be climate neutral by 2050. Any greenhouse gases emitted by the Netherlands in 2050 are planned to be offset by carbon removal, resulting in net zero emissions.
- European emission target in the Effort Sharing Regulation (ESR) for the built environment, mobility, agriculture and small-scale industry defines a reduction of emissions on national level: For the Netherlands, this means a 48% reduction in greenhouse gas emissions (up from 36%) in 2030 compared to 2005.
- The European target for renewable energy for the Netherlands was significantly tightened from 27 percent in 2030 to 39 percent share of the gross final energy consumption.

3.2.2. ENVIRONMENTAL ASSESSMENT AND UNCERTAINTY ANALYSIS

To fulfil their task of assessing the climate and energy policy effects, a forecast of is made based on the relevant policy plans as submitted by the policy officers of the relevant ministries. The expected effects of those plans are modelled for several policy domains as defined in the agreements with the ministry in the Climate Law (Electricity, Industry, Built environment, Mobility, Agriculture, and Land use), which are based on the negotiation groups for that agreement.

The national goal and emissions forecast of KEV 2024 can be seen in Figure 3.2. Similar figures are generated for the relevant policy domains that were listed earlier. The forecast that is reported shows a calculated point-value every year, and a bandwidth in reference years (here 2030 and 2035) which is the result of an adapted Monte-Carlo analysis.

The factors that are taken into account in the Monte-Carlo analysis differ per domain, but they cover: uncertainty of policy execution and effect, model uncertainty, and a range of uncertain factors (energy- and CO2 pricing; economic, demographic, and technological developments; weather; relevant foreign policy). This bandwidth indicates a forecast-range, but not a complete theoretical range. Factors like future policy development, changing monitoring practice and definitions, extreme (not necessarily unlikely) events like war and disasters, and game-changing technologies are not taken into account.

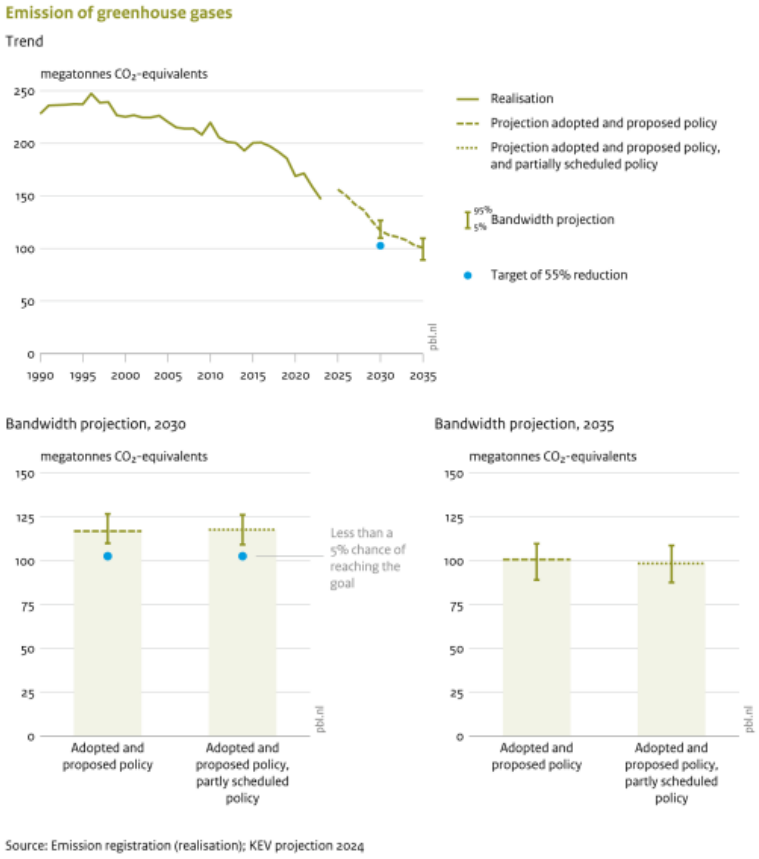

Figure 3.2: KEV 2024, pbl. National emissions forecast.

3.2.3. UNCERTAINTY COMMUNICATION

For PBL's predecessor MNP, uncertainty played an increasingly important role since 1999 (Petersen et al., 2011). The credibility of reports on the environment were challenged on the basis of the 'insufficient' uncertainty communication about inaccuracies of model results.

Since then, several iterations of guidelines on analysing and communicating uncertainty were published by PBL (and their predecessors and colleagues) (Janssen et al., 2005; Petersen et al., 2014), and in 2006 a conference about dealing with uncertainty in policy (assessments) was held (CPB/MNP/Rand Europe, 2007). Such events and guidelines do not only function to inform researchers on how they should deal with uncertainty, but also directly create transparency about the methods that are currently employed. The communication of probability (verbally and numerically) is comparable and based on related studies into uncertainty communication, like from IPCC (Mastrandrea et al., 2011).

PBL researched the interpretation of uncertainty information and its relevance for policymaking in 2007 together with CPB and Rand Europe (CPB/MNP/Rand Europe, 2007), with follow-up publications like in 2008 (Wardekker et al., 2008). The research consisted of several elaboration rounds, with policymakers and advisors, to understand policy-makers' view on uncertainty communication: how they interpret numerical descriptions of uncertainty, what they believe the role of science is for addressing uncertainty, what uncertainty information they require for decision-making and what they think about the way the uncertainty information is presented. This study considered mostly policymakers and policy advisors in different levels of government, and researchers. Their conclusions covered a broad range of suggestions for future consideration in the writing of the Environmental Balance (a precursor to the current KEV report). PBL has also published guidelines on uncertainty analysis, transparency and communication (Janssen et al., 2005).

3.2.4. RELATION BETWEEN POLICY ASSESSOR AND POLICY-MAKERS

These policy assessments have put topics on the political agenda (van Bergeijk & Kraan, 2024), and can instil confidence in the current policy plans (Kraan, 2023). Policy officers, politicians, industry actors, and others can evaluate how likely it is that energy and climate goals will be achieved, and what the biggest uncertainties and/or hurdles are to meeting the goals. The ministry of Climate Policy and Green Growth (Klimaat en Groene Groei in Dutch, referred to as Min. KGG), is the main contractor of the KEV report and is the ministry responsible for most of the relevant policy that is analysed in the KEV.

The KEV is a part of the policy-cycle at Min. KGG (Figure 3.3). The decision-making takes place in the political arena. In the cabinet, policy goals are designed which are voted on in parliament. Given the multitude of policy goals, the minister needs to negotiate and argue for specific policy measures that address their goals. They are supported by the policy officers at the ministry, who analyse several policy options and advise the minister how these options would require trade-offs between reaching a goal with certainty and the amount of resources it requires. At the same time, even one ministry has multiple and conflicting goals, which means trade-offs will always have to be made.

One of the most important documents that is used by the policy officers working on climate and energy policy is the KEV. They work closely with the researchers at PBL about what policies they are designing. Together with existing statistics, the effects of these policies are estimated and modelled at PBL. The results of the assessment (including a forecast and uncertainty analysis) are then used to gauge the progress to reaching the policy goal and informs new policy options, depending on whether the current progress is deemed good enough. This cycle is repeated each year.

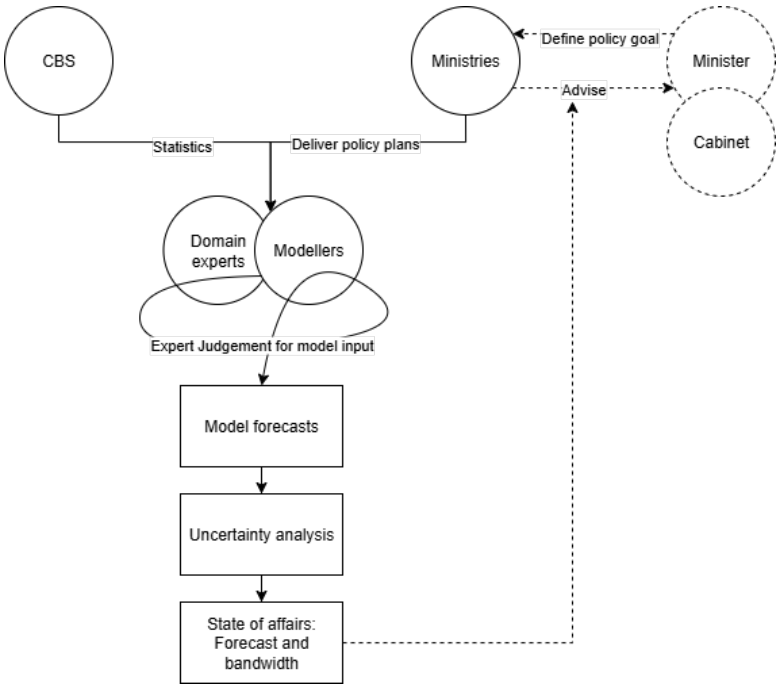

Figure 3.3: The connection between the modelling and policy-making cycles.

3.3. UNCERTAINTY PERCEPTION ELICITATION

This research adopts an altered mental model method. Through semi-structured interviews, both researchers' and policy-officers' perceptions of uncertainty are elicited. No participants' perception is considered superior. Instead of an expert model, a conceptual model is formulated based on theoretical and epistemic research. This conceptual model is summarised in Figure 2.1.

3.3.1. INTERVIEW QUESTIONS

This conceptual model shows what different ways there are of perceiving uncertainty. This helps to formulate interview questions by relating these topics to the research questions. 'Impact' is less explicitly considered in literature, and therefore hard to develop an initial codebook for. Separating 'interpretation' from other aspects of impact allows a distinct focus on that topic separately from secondary impacts on the research and decision-making process. The relation between the topics is presented in Figure 3.4.

The interview questions that are used in practice are in Dutch and can be found in Appendix C. Here they will be presented in the closest possible English interpretation, but some discrepancies in meaning may occur.

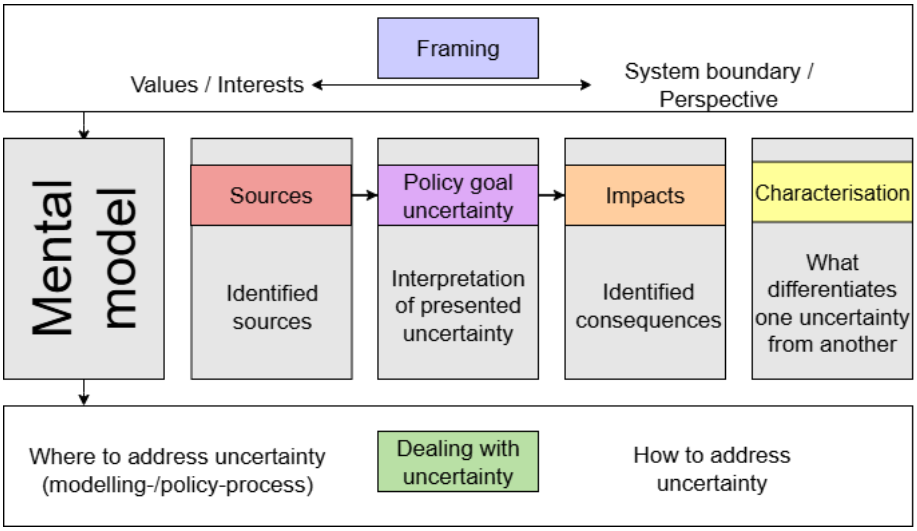

Figure 3.4: The connection between the different interview topics. In line with the conceptual framework in Figure 2.1 and in support of answering the research questions as defined in section 1. The arrows indicate an expected direction of influence. This will be discussed in section 5.

HOW UNCERTAINTY IS PERCEIVED

Answering this question can be supported by asking real policy officers and researchers to describe how they would interpret communication about uncertainty. Therefore this research will use a case study and present the participants with an excerpt of the Climate and Energy Outlook (KEV, in Dutch), which can be found in Appendix B.

- Is the information clear?
- How do you view the certainty with which the policy goals are reached?
- Could you give it a probability between 0-100%?
- What further conclusions could you base on this excerpt about a need for policy?
- How much certainty is enough?
- What do you think the largest sources of uncertainty are?

For comparison, participants will be presented with a second presentation of the uncertainty, where the probability will be specified, which can be found in Appendix C. The two excerpts will be based on the two styles of communication by PBL in the KEV 2023 and KEV 2024.

- Has the information in the excerpt changed according to you and how?
- What are the effects you would expect for the decisions that have to be made in the policy-making process?
- Do you think the change has an influence on how easy the information is to understand?

Reviewing how these interpretations are then influenced by personal perceptions, of uncertainty as a concept and the policy context, requires looking into the framing and characterisation of uncertainty.

- What do you think of when I mention the Climate and Energy Outlook?
- What comes to mind when thinking of uncertainty in the Climate and Energy outlook?
- If you had to define uncertainty in this context, how would you do so in your own words?
- What do you think is important when dealing with uncertainty in this policy-making context?
- Do you make distinctions in different types of uncertainty (in communication), and if so how?

DIFFERENT PERCEPTIONS OF POLICY-MAKERS AND RESEARCHERS

Though this can partially be addressed by how they frame uncertainty, the role the uncertainty plays in their process (the impact it has) can help explain why perceptions may differ.

- What impact does this uncertainty have on your job (direct and indirect)
- What impact does the change of presentation of uncertainty have for you?

DEALING WITH UNCERTAINTY

Lastly, understanding how people deal with uncertainty can be explained through understanding the consequences of uncertainty and how they frame uncertainty. Therefore, looking into all these aspects can support examining why uncertainty is dealt with in the way that it is. We already asked about what they think is important when dealing with uncertainty

- How does this uncertainty play a role in your job?
- How do you deal with that uncertainty?

To further examine how the policy case and institutional context plays a role in the uncertainty communication and perception the following additional questions are asked:

- How do you view the climate and energy policy context?
- What is your job in this process?
- What is policy-relevant information about uncertainty according to you?
- How do you assume other interpret the information?
- Why do you think there is a difference between how people should interpret uncertainty, and how they currently do?

INTERVIEW STYLE

Asking these questions in a funnel structure, in line with other mental model methods, allows participants to share their own beliefs with as little prompting by the interviewer as possible. Some questions iterate on previous questions with more specificity. Once a specific topic has not been touched upon more detailed questions are asked. A side-effect is that not all participants are asked exactly the same questions as some require less or more prompting.

A semi-structured format allows the flexibility to move on when participants had already covered their answer to one of the more specific questions. It also allows a conversational style when this makes participants more comfortable, and allows to dig deeper into topics that were previously not yet considered. However, questions may not all be asked in a similar manner.

3.3.2. RELIABILITY AND VALIDITY

The interview protocol follows the funnel-structure as designed in the mental model method by Morgan et al. (2001). First, more open general questions were asked, after which each topic was approached with increasingly specific questions. This hopefully prevents influencing the participants and steering them to take concepts into account that wouldn't interest them otherwise. That is important for eliciting their subjective perceptions.

The protocol was tested with three mock-participants, who were researchers at PBL. From their feedback, the following points were adopted in a new version of the protocol:

- It's nice that the interview feels like a conversation.
- Be specific with your word choice.
- Be clear what information you want to know from the participant. It is not nice to have to guess what the interviewer is looking for.
- There are many questions, but they also cover the same topic from different points of view. Therefore, prioritise the questions.
- It is nice that previous answers are acknowledged, and the following questions tie into them.

No mock-interviews were possible with policy officers due to the limited number of interested participants. However, after the first interviewee provided feedback, no changes were considered necessary.

3.4. PARTICIPANT SAMPLING AND RECRUITMENT

An initial purposive sample of potential participants is designed based on the requirements of the study: deeper insights into the practice of policy assessment can be found by interviewing the critical actors related to the case study: researchers and policy officers. Though politicians are also considered important actors, the strategic nature of their position is assumed to provide less insight into personal interpretation of uncertainty. They are also less conveniently available.

Researchers at PBL and policy-makers at the Ministry of KGG were naturally the most fitting potential participants. The KEV report plays an important role in the policy cycle at the ministry of KGG. Although other ministries, like Finance or Infrastructure and Water Management, also have interests in the KEV, narrowing on one ministry avoids problems with comparability of results.

The initial sample of participants is recruited through available contacts and grown through snowball sampling with the help of referrals. A point of saturation was reached when no new contacts were referred.

To reach saturation of responses but limit redundancy, the ideal size and diversity of the sample group would be 5-10 researchers at PBL and 5-10 policy officers at Min. KGG. A varied collection of roles and expertises helps to represent the cognitive diversity at these organisations. This led to 15 participants who were available in the spring of 2025, 9 from PBL and 6 from Min. KGG. To limit reidentification and protect the privacy of the participants, specific characteristics are not reported.

3.4.1. HUMAN RESOURCE ETHICS AND RISKS

To comply with human resource ethics guidelines, as established by the human resource ethics committee at the TU Delft, potential participants were fully informed about the study's purpose, methods, and their rights regarding withdrawal from the study. A copy of the informed consent form is attached in Appendix D. In that form, participants are also made aware of potential risks of participating. Measures were taken to minimise these risks:

- Risk of feeling obligated: As participants may potentially be referred by a superior which may lead to feelings of obligation, participants have the explicit opportunity to have their contributions deleted, even after the interview has finished.
- Risk of re-identification: Quotes are only presented anonymised and participants have the express opportunity to suggest changes to parts of the transcript that would otherwise lead to re-identification.
- Risk of reputational damage: Use of quotes requires express permission through the informed consent form. Anonymisation of contributions and limiting re-identification should mitigate risk of reputational damage. The interview transcripts are shared with the participants so they have insight into what data is used for the research.
- Risk of data breach and re-identification: Audio recordings are stored securely and deleted once the transcripts have been verified. Personal identifiable information is stored securely and deleted before the end of the research.

3.5. QUALITATIVE DATA ANALYSIS

3.5.1. RESOURCES

The interviews were transcribed and recorded using MS Teams. The audio-files were deleted after checking the transcriptions. The participants were sent the transcriptions and given the opportunity to suggest changes in case of mistakes or privacy-issues.

The transcriptions were coded using Atlas.ti. Using the code-document analysis functionality, frequency of codes per and across documents can be counted.

3.5.2. CODEBOOK DEVELOPMENT

In order to answer the research questions, the interview transcripts are analysed by coding concepts used by the participants. The deductive (theory-driven) codes are based on the theoretical and empirical research results covered in 2, and the resulting conceptual

framework (Figure 3.3) and interview topics (Figure 3.4).

Additionally, allowing inductive coding (data-driven) provides flexibility to learn about new concepts that were not established in the initial literature review and codebook. Codes are collected in code-groups that align with the level of detail necessary to answer the research questions. The final codebook can be found in section 3.5.5, where the deductive codes are given a colour to distinguish them from the inductive codes.

3.5.3. COMPARATIVE ANALYSIS

The coding results can be synthesised to comment on the number and similarity of perspectives across participants. Comparing what codes are mentioned by which participants allows to gain insight in not only the frequency of concepts used, but a collection of codes may present a distinct perspective, which can be shared or unique to certain individuals. What can be addressed, but won't be extensively analysed in this research, is whether individuals who share perspective on one topic share perspectives on another.

3.5.4. RELIABILITY AND VALIDITY

Coding both inductively as well as deductively, it was necessary to continuously compare earlier coded transcripts with the continuously developing codebook to ensure reliability of coding.

Because many terms are subject to interpretation, it cannot be guaranteed that the answer of one interviewee carries the same meaning when mentioned by a different interviewee. The researcher asked participants to define terms like 'uncertainty' 'policy-relevant' to safeguard validity.

Newly added codes were established based on participants' responses, but the number of codes had to be balanced with a useful level of generalisability. Because this research is performed by one researcher, no additional coders were present to validate the final codebook. The final tables with the tallied codes can be found in Appendix E.

3.5.5. FINAL CODEBOOK

Table 3.1: Resulting codebook part 1

Theme	Master Code	Subcode	Description
SYSTEM BOUNDARY			These aspects draw the boundaries around what parts of the complex system are considered by the participants in their perception of uncertainty
	Economic		Market dynamics and economic development
	EU		There are relevant rules and regulations in the EU that must be considered
	Industry practice		What is actually possible in practicy in the industry should be used to put theoretical results in perspective
	Job		The assessment and dealing with the uncertainty are closely tied to the job/profession
	Law		The legal basis of the assessment and policy goal
	Model		The model results and assumptions
	Multi-stakeholder		The perceptions and interests of other stakeholders
	Numerical check		The assessment is viewed as a shared numerical basis and important check of the policy progress
	Political		Political dynamics, interests and strategy
	Social		Social rules and relations
	Theoretical		Theoretical insights are contrasted to model results and knowledge from practice
VALUE			What the participants find important when dealing with uncertainty
	Avoid inaction		Uncertainty shouldn't lead to decision paralysis
	Clear Communication	Clear message	The message should not be misinterpreted
		Nuanced message	Uncertainty must be communicated and the results and numbers about specific years shouldn't be viewed as an absolute truth
		Transparency	All relevant information must be communicated
	Collaboration		The research process should be aligned with the interests of target audiences through collaboration
	Credibility		The credibility of the institutions should be ensured
		Science quality	The research should be of high scientific quality
		Independence	The independence of research institutes should be protected
		Political neutrality	Results must be communicated politically neutral and must not speculate.
		Standardisation	The process should be standardised for comparable results
	Focus on most important uncertainties		There are so many uncertainties. As we cannot deal with all of them we must focus on what we find most important
	Justice		It is important that decision-makers consider what is the right thing to do in relation to others
	Long-term perspective		To step out of short-term tunnelvision but keep an eye on long-term sustainability
	Policy-relevance		We must make sure of the policy-relevance of the research process and communciation of results
	Realism		That the results and/or assumptions are as realistic as possible.
	Relevance to societal debate		The results should be relevant and informative to societal debat
	Reproducible		The transparency of the process and replicability of the results
	Room for expert judgement		The reader should be given all the relevant information to make their own expert judgement
	Room for political interpretation		Policy goals leave room for value-based trade-offs with other political interests
DEFINITION			The definition of uncertainty provided by the participants, sometimes combining multiple of the following aspects.
	Ambiguity		The presence of multiple perspectives.
	Bandwidth policy goal		The uncertainty is represented by the bandwidth of the model outcome and how it relates to the policy goal.
	Complex system		The system is too complex to know everything.
	Expected possibilities		There are multiple realistically expectable values
	Lack of knowledge	Factors without certainty	All factors of which we cannot say for certain what their value will be.
		Unknown future	It is impossible to predict the future.
	Risk		Uncertainty is the cause of risk in decision-making.
	Undecided		The participant was unable to give a definition.
	Variance		There is an inherent variance in the value of the uncertain factor.

Table 3.2: Resulting codebook part 2

Theme	Master Code	Subcode	Description
INTERPRETATION			How participants would describe the uncertainty and how it should be interpreted in a specific case example.
	Ease of understanding	Could be misinterpreted	This participant sees how the results could easily be misinterpreted
		Easy	This participant already knows it well and proclaims it is therefore easy to understand
		Hard	This participant finds the results difficult to interpret
	Probability (0-100)%	(5-50)%	The probability the policy goal will be achieved.
		Can't read based on the excerpt	There is not enough information in the text and figure to conclude a specific probability
		(Not) achievable	The figure and text show the policy goal is (not) achievable
		(Very) small	The figure and text show the chance the goal will be achieved is (very) small
	Policy goal >(0-100)%	>(10-100)%	Policy-makers must do their utmost to achieve at least x percent probability, or they haven't put in enough effort
		As much as is in control	Policy-makers must do as much as is in their control to achieve the goals
		Change the goal	The current goal is unrealistic and should therefore be changed
		In the bandwidth	Policy-makers must at least aim for the goal to be in the expected bandwidth (5-95%)
		Up to judicial interpretation	How much effort is enough is up to interpretation by a judge
		Up to political interpretation	How much effort is enough is up to political interpretation
	Policy needed	Can't conclude based on this excerpt	There are more things to consider for whether or not policy is needed than the assessment presents (for example value-based judgements)
		Focus first on creating the right circumstances	Not just any policy is needed, first the right circumstances (infrastructure/jobs/etc.) must be created
		No that won't help for 2030	More policy will not help achieve the goals that are in the near future.
		Yes but focus on long-term	More policy is needed, but should be designed to be sustainable on the long-term
		Yes if you want a larger chance of reaching the goal	Should you want a larger chance of reaching the goal, more policy is needed
		Yes if you want to reach the goal	If you want to reach the policy goal at all, more policy is needed

Table 3.3: Resulting codebook part 3

Theme	Master Code	Subcode	Description
SOURCE			This factor is identified by the interviewee to be a source of uncertainty in the KEV
	Policy location	Monitoring	The quality of monitoring of policy execution
		Policy execution	How well policy can be executed, given technological limits, delays in infrastructure projects, available investments, purposefulness etc.
		Policy goal	It is unclear how the policy goal should be interpreted
		Policy-making process	Policies may be worded ambiguously, or maybe it is unclear whether the policy will be implemented at all
	Research location	Available knowledge	The availability of (historical) data about what you want to know
		Input data	The error in existing statistics and measurements
		Model location	How close the model and its results reflect reality
		Model outcome judgement	How close the interpretation of model results is to reality
		Policy judgement	How close the expected effect of policy is to reality
	STE location	Abroad	Policy effects and market dynamics abroad are unpredictable
		Crisis	It is unpredictable whether there will be a crisis, but we know it would influence the achievability of the policy goal
		Environment	Climate, weather, and nature development is unpredictable
		Human behaviour	Humans may act unpredictably and not respond to policy as intended
		Infrastructure	Infrastructure development is important for policy effect, but development timelines are unpredictable
		Market and economy	How supply and demand will develop and how well economies do influence the effectiveness of policy
		Private party choice	What private parties choose to invest in
		Production	It is unclear what volumes of production can realistically be expected in the future
		Technology	Technological development is unpredictable but is of influence
	Miscillaneous	External factors	Participants refer to 'external factors' as a concept and source of uncertainty
		Future	Across all factors, their future values are not truly predictable
		Probability distribution	It is unclear what the true probability distributions of factors are.
TYPOLOGY			What differentiates one uncertain factor from another
	Character		How the uncertainty expresses itself
	Controllability		Whether policy can have influence on the uncertain factor
	Distribution		The probability distribution
	Size	Effect size	How much the results vary when the underlying uncertain factor varies
		Uncertainty size	The possible values of the uncertain factor
	Location		Where' the uncertainty is (in the modelling/research process or environment)
	None		The participant does not explicitly differentiate between types of uncertainty.
	Present knowledge		The current amount of knowledge about an uncertain factor.
	Temporal		When the uncertain factor is of influence (which may not be all the time).
	Level	Shallow	Being able to enumerate multiple alternatives and provide probabilities (subjective or objective)
		Medium (ranked)	Being able to enumerate multiple alternatives and rank order the alternatives in terms of perceived likelihood. However, how much more likely or unlikely one alternative is compared to another cannot be specified
		Deep	Being able to enumerate multiple alternatives without being able to rank order the alternatives in terms of how likely or plausible they are judged to be
		Recognised Ignorance	Being unable to enumerate multiple alternatives, while admitting the possibility of being surprised
	Nature	Epistemic	The factor is deemed uncertain because of a lack of knowledge.
		Ontological	The factor is deemed uncertain because it naturally varies.
		Ambiguity	The factor is deemed uncertain because of the presence of multiple knowledge frames.
		Ethical	The factor is deemed uncertain because there is a lack of ethical rules on how to deal with it.
		Communication	The factor is deemed uncertain because of the imperfect communication.
		Treatable	The factor is deemed uncertain because of how addressable it is with policy

Table 3.4: Resulting codebook part 4

Theme	Master Code	Subcode	Description
IMPACT			How participants see the consequenes of uncertainty
	Acceptance		Uncertainty can influence how much the research results are accepted
	Comfort		The presence of uncertainty can influence how comfortable people feel making decisions
	Interpretation		The presence of uncertainty (and how it is communicated) influences the interpretation of research results
	Job at PBL	Careful Communication	The presence of uncertainty requires careful communication from the researchers
		Credibility	Uncertainty in the research can influence the trust other actors have in the research institute
		Job complexity	Uncertainty requires more analyses and effort to clearly show the nuance of the results
	Political decision-making process	(Effective) Decision space	The uncertainty influences what policy options are viewed as effective
		(Political) Discourse	The uncertainty (and how it is communicated) influence how people discuss the research results
		More policy effort	Uncertainty can influence how much effort is made, because it can show urgency but can also make policy goals seem unachievable
		Political decisions	It is observed that the decisions are made explicitly about uncertainty
DEALING WITH UNCERTAINTY			How participants use information of uncertainty or act in response to uncertainty
	Accepting uncertainty		As uncertainty is unavoidable, it is important to not accept it
	Avoiding uncertainty		Uncertainty can make decision-making more complicated people may opt to ignore it in favour of a strong message
	Avoiding ambiguity		People are inclined to avoid considering there are still multiple options possible
	Action	Communication	A common language and transparent communication are required
		Generating knowledge / quantifying	Uncertainty must be dealt with by gathering more knowledge
		Monitoring and adaptation	Policy effects must be monitored and policy must be adaptable to respond to unknown future changes
		Precaution	Precautions must be taken to account for unknown future setbacks
		Reducing uncertainty	Decision-making benefits from taking away as much uncertainty as possible
	Inaction	Postpoining choice	Uncertainty must be dealt with by postponing choice until there is more certainty
		Withholding ineffective action	Rather not spend resources that may be ineffective in some cases
		Withholding unnecessary action	Rather not spend resources that may not have been necessary in some cases
	Interpretation	Expert judgement	Because no one can be completely certain, it is important to judge results based on your own expertise
		Suggest goal adaptation	The policy goals must be designed with uncertainty in mind.
		Gut feeling / trust in relationships	Uncertainty must be dealt with by choosing to go with the options you trust.
		Political consideration	How to deal with uncertainty is a value-based decision
		Risk consideration	How to deal with uncertainty requires analysing the associated risks
		Collaborate on definition	Uncertainty must be dealt with by finding consensus with stakeholders
	Transforming	Simplify uncertainty	Uncertainty can mean a multitude of possibilities, so people may opt to for example take an average or only look at extremes to reduce the options
		Strategic reframing	Information about uncertainty can be used strategically depending on frame that people want to present

4

RESULTS

This section presents results of the qualitative analysis of the interviews with 9 researchers from PBL (R) and 6 policy officers from Min. KGG (P). They were qualitatively coded based on the conceptual framework presented in section 3. The tallied codes are collected per topic and presented in tables in Appendix E. Attention will be paid to what ideas are largely or minimally shared across and within groups, and whether there are distinct perspectives. [1]

The final codebook as a result of the interview is presented in Figures 3.1 through 3.4. Codes that are based on existing literature are coloured, highlighting the difference between what concepts were previously addressed, and what codes are new. Some new codes show potential to be generalised, whereas others are quite context-specific and only add new knowledge about this specific case. What can be learned from these new codes will be discussed in section 5.

4.1. PARTICIPANTS' FRAMING OF UNCERTAINTY IN THE KEV

[1] The anonymised transcripts are available for research and educational purposes at 4TU.ResearchData. DOI:10.4121/029eab40-d842-46b7-a2d4-f338a4315b80

4.1.1. SYSTEM BOUNDARY

Table 4.1: Framing - System boundary: summary of the number of participants that mention each concept.

Code	R (x/9)	P (x/6)
Numerical check	7	6
Model	3	1
Job	7	1
Multi-stakeholder	6	1
Political	7	5
Law	2	4
EU	1	3
Industry practice	2	1

Table 4.1 summarises the system boundaries of the participants. All concepts are mentioned by both groups, but not in equal frequency. Therefore, these results do not indicate a strict divide between the groups, but each group does tend to some concepts more than the other, as presented in Figure 4.1.

Largely, the participants look at the KEV as shared knowledge basis. It provides a numerical and factual basis on the progress to achieving the goals.

Interestingly, most researchers mention that the KEV is a product for many stakeholders, whereas only one policy officer mentions this. The policy assessment is also used by other ministries, NGO's, and available for the general public as it is commissioned by the government.

Most policy officers also mention the legal context (national and EU) the KEV relates to, as the Netherlands has established climate goals in the law. Surprisingly, only few of the researchers mention this in the interview.

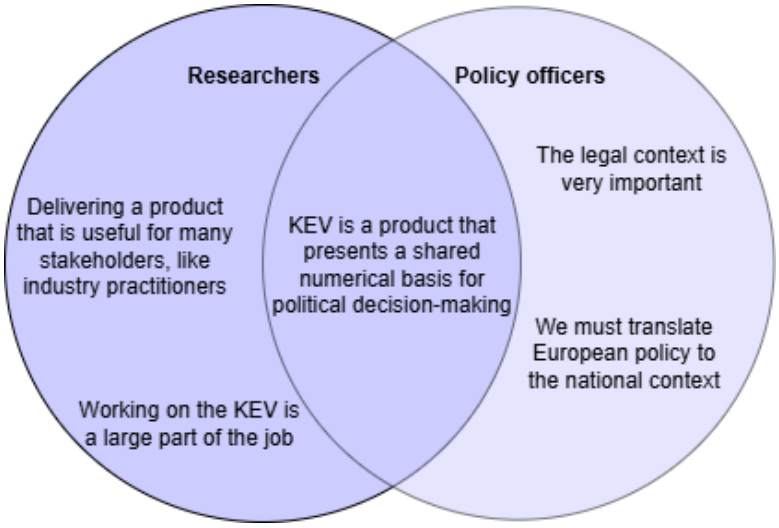

Figure 4.1: Topics that are considered relevant by the participants when thinking about uncertainty and the KEV. This is noted to form their system boundary. The topics presented are those that are most commonly shared or most separated across the participant groups.

4.1.2. VALUES

Table 4.2: Framing - Values: summary of the number of participants that mention each concept.

Code	R (x/9)	P (x/6)
Clear message	6	
Nuanced message	5	1
Transparency		4
Collaboration	2	
Credibility	2	1
Independence	2	
Science quality	7	1
Political neutrality		2
Standardisation		2
Reproducible	1	
Avoid inaction		1
Policy-relevance	6	2
Relevance to societal debate	3	
Realism	2	1
Focus on most important uncertainties	4	
Long-term perspective		1
Room for expert judgement	1	
Room for political interpretation		1
Justice		

Table 4.2 summarises what the participants value when dealing with uncertainty in the KEV. The groups present largely distinct perspectives. Yet, there are two values that ovelap, as presented in Figure 4.2.

First, most participants mention that clear communication is important to them. The researchers value a strong but also nuanced message, and they experience a trade-off between the two. Policy officers on the other hand mention that PBL must be transparent about the underlying assumptions and uncertainties and share as much information as available.

Next, though credibility was only mentioned specifically by three participants, several other values are strongly connected. Where researchers value independence of the research institute, scientific quality and the freedom to provide a nuanced message, policy officers focus on standardisation and political neutrality.

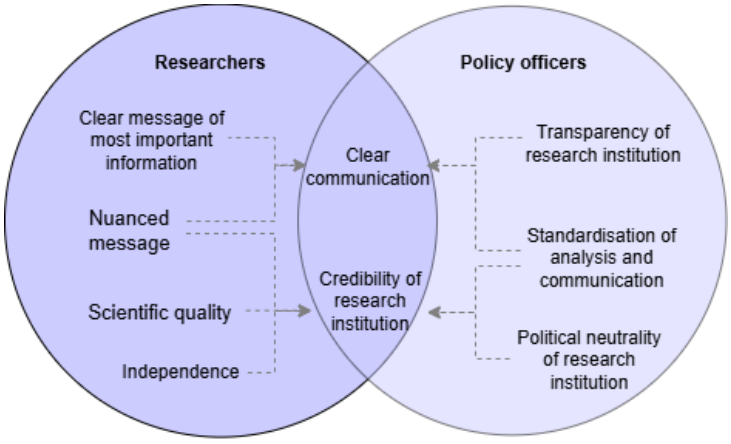

Figure 4.2: What participants value when dealing with uncertainty presented in the KEV. The concepts in this figure are those that are most commonly shared or most separated across the participant groups. The grey arrows indicate relations between the concepts.

4.1.3. DEFINITION OF UNCERTAINTY

Table 4.3: Framing - Definition: summary of the number of participants that mention each concept.

Code	R (x/9)	P (x/6)
Complex system	1	1
Bandwidth policy goal	3	4
Lack of knowledge: Factors without certainty	3	3
Lack of knowledge: Unknown future	5	3
Expected possibilities	2	2
Undecided	1	
Variance	1	
Ambiguity		
Risk		

Table 4.3 summarises what concepts participants used to define uncertainty in the context of the KEV. When asked for how they define uncertainty in this context, most participants didn't formulate a short definition. They often used *'uncertain'* in the definition, or said they were struggling to find the right words. The participants more easily brought up examples of sources of uncertainty, or characteristics of uncertainty, or referred directly to the bandwidth indicated in the KEV as *'that we do not know exactly where we'll end up'*. A popular term used was 'uncertain factors' that cause uncertainty. Notably, one researcher shared they could not define it.

Though there is not a strict divide between the participant groups, two perspectives are highlighted in Figure 4.3. On the one hand, there are participants (relatively more policy officers) who focused on the quantitative representation of the uncertainty, referring to the bandwidth *'a bandwidth around the goal due to uncertain factors'*, and *'a bandwidth that represents the expected possibilities'*. Next, there were participants (relatively more researchers) who defined uncertainty from a more general perspective, discussing the intrinsic unpredictability related to prognoses.

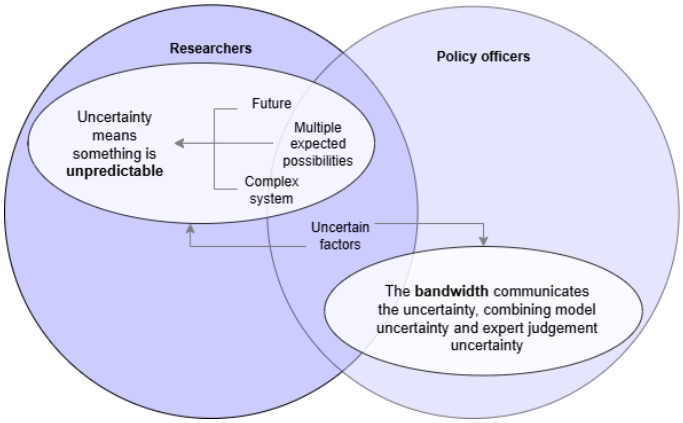

Figure 4.3: Definitions of uncertainty and the related concepts mentioned by participants can be divided in two groups: definitions focussing on the quantified representation of uncertainty, and definitions about the general unpredictability. The grey arrows indicate relations between the concepts.

4.2. PARTICIPANTS' INTERPRETATION AND MODEL OF UNCERTAINTY

4.2.1. PARTICIPANTS' INTERPRETATION OF THE KEV EXCERPT

Tables 4.4 and 4.5 summarise how the participants interpret the uncertainty as presented in the KEV. The participants were short in their answers and often explicitly said they would refrain from any personal views on the political implications. All participants were open to sharing their underlying thoughts for their interpretation of the uncertainty, often referring to how something in the graph or text led them to conclude something about the probability. However, all participants said that further interpretation was up to political decision-makers.

Table 4.4: Interpretation part 1: summary of the number of participants that mention each concept.

Code	R (x/9)	P (x/6)
Ease of understanding: Could be misinterpreted	4	1
Ease of understanding: Easy	9	6
Ease of understanding: Hard		
Probability: +-5%		1
Probability: +-10%		
Probability: +-15%		1
Probability: +-20%	1	
Probability: +-25%	1	
Probability: +-50%		1
Probability: Can't read based on the excerpt	6	2
Probability: Not achievable	1	1
Probability: Possible to achieve	2	1
Probability: Small	3	2
Probability: Very small	2	

The results do not indicate a specific divide between the participant groups. All participants shared that they think the text and figures in the KEV were easy for them to interpret. Some shared that it could be misinterpreted by people who were less trained in working with statistics. However, when examining what the participants share about their interpretations, different perspectives can be observed and these are presented in Figure 4.5.

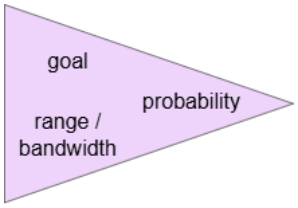

Figure 4.4: Concepts used by participants when reasoning about uncertainty of achieving the policy goal.

When interpreting the certainty of reaching the policy goal, about half of the participants answered that they cannot conclude anything about the probability from the excerpt, saying *"it seems possible"*, or *"the text states it is only possible if all goes well, and that never happens"*. The rest of the participants mentioned they could conclude something about the probability, concluding as little as 5% or as much as 50%. One policy officer didn't want to share.

When examining the reasoning of the participants, they use the concepts presented in Figure 4.4. Participants combine information on the goal and the range of the bandwidth, and compare their relative locations to estimate a probability. Say the bandwidth would run from 49 to 59, then 50 or lower would have a 10% chance.

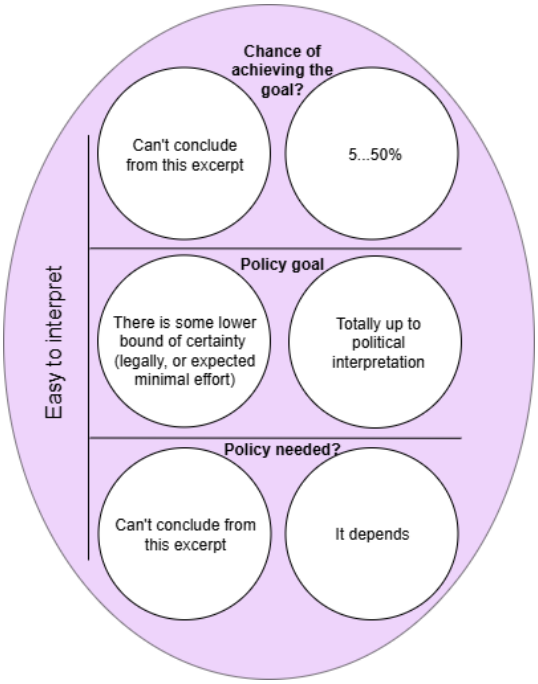

Figure 4.5: Though all participants mention the uncertainty is easy to interpret, the participants can be divided into distinct perspectives on several topics.

Table 4.5: Interpretation part 2: summary of the number of participants that mention each concept.

Code	R (x/9)	P (x/6)
Policy goal: >10%	1	
Policy goal: >25%	1	
Policy goal: >50%	2	2
Policy goal: >80%	1	
Policy goal: >90%	1	
Policy goal: >95%		
Policy goal: 100%	2	
Policy goal: As much as is in control	1	
Policy goal: Change the goal		
Policy goal: In the bandwidth (>5%)		
Policy goal: Up to judicial interpretation	1	2
Policy goal: Up to political interpretation	6	6
Policy needed: Can't conclude from this excerpt	2	1
Policy needed: Focus on creating the right circumstances	2	2
Policy needed: No that won't help for 2030	1	1
Policy needed: Yes but focus on long-term	2	1
Policy needed: Yes if you want a larger chance of reaching the goal	4	
Policy needed: Yes if you want to reach the goal	3	2

Multiple participants share the sentiment that they cannot conclude more policy is needed. It depends on other factors like the infrastructure and worker availability. There

are also participants who mention that the timeframe is important for the interpretation.

"we are so close to the deadline of 2030, that only with immense political will the goal be reached"

"let's not take crazy steps to achieve the 2030 goal, it is better to create long-term policy that is widely supported and reach the goal a little later".

Interestingly, all participants mentioned that t is impossible to reach 100 percent certainty due to inherent uncertainties. Yet, some participants observe some lower bound (because of legal reasons or an expected minimal/best effort), and others say that it is completely up to political interpretation.

4.2.2. SOURCES OF UNCERTAINTY

Table 4.6: Sources: summary of the number of participants that mention each concept.

Code	R (x/9)	P (x/6)
External factors	3	4
Future	5	2
Policy location: Monitoring	1	
Policy location: Policy execution	6	5
Policy location: Policy goal	2	1
Policy location: Policy-making process	5	2
Probability distribution	1	
Research location: Available knowledge	1	
Research location: Input data	1	
Research location: Model location	5	3
Research location: Model outcome judgement		1
Research location: Policy Judgement	4	3
STE location: Abroad	4	5
STE location: Crisis	2	1
STE location: Environment	6	4
STE location: Human Behaviour	4	3
STE location: Infrastructure	2	
STE location: Market and economy	6	5
STE location: Private party choice	3	1
STE location: Production	3	
STE location: Technology	3	1

Table 4.6 summarises what participants perceive as the most important sources of uncertainty of achieving the policy goals as presented in the KEV. All participants could name several different sources by heart. Often they cut themselves off because the list was so long. There is no clear indication for different perspectives, but the responses naturally differed a bit between participants of different domain backgrounds (electricity, industry, etc.).

From the responses, three broad categories of sources can be observed: *external socio/ technical/ environmental factors*, *policy-process*, and factors related to steps in *research or modelling*.

All participants name multiple social, technical or environmental factors that are a source of uncertainty: production volumes, the weather, market prices, technological progress, investment behaviour, and more. Most mentioned factors related to the policy process as sources of uncertainty, but participants also recognised sources of uncertainty in the research process.

4.2.3. TYPOLOGY OF UNCERTAINTY

Table 4.7: Typology: summary of the number of participants that mention each concept.

Code	R (x/9)	P (x/6)	R relevant	P relevant
Character	1			
Controllability	8	6	9	6
Distribution	1			
Uncertainty size	3	1	3	3
Effect size	4		4	
Location	2	1	3	3
None	2			
Present knowledge	4	1		
Temporal	1			
Level				
Nature	0			

Many participants don't explicitly differentiate between types of uncertainty. But when prompted, most of them mentioned that they do make implicit distinctions. Table 4.7 summarises what the participants think differentiates one uncertainty from another. It also shows which characteristics participants found most policy-relevant. Two different perspectives can be observed, which are presented in Figure 4.6.

Researchers mostly use many different characteristics to precisely characterise uncertainty. Policy officers (and some researchers) on the other hand indicate they try to focus on what the most important characteristics are for the policy case at hand.

Almost all participants shared that they (would like to) distinguish between uncertainties that the policy can influence (controllability) and sizes of uncertainty. Some researchers indicate that influential factors that are highly uncertain do not automatically lead to large uncertainty in the output, as this depends on interactive effects. This makes it hard to precisely indicate uncertainty size.

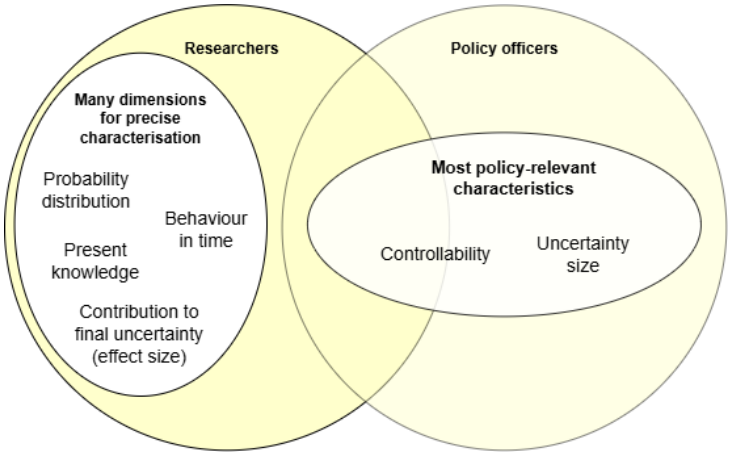

Figure 4.6: There are two perspectives on characterising uncertainty, but not restricted to a specific participant group.

4.2.4. IMPACT OF UNCERTAINTY

Table 4.8: Impact: summary of the number of participants that mention each concept.

Code	R (x/9)	P (x/6)
Acceptance	2	1
Comfort	6	2
Interpretation	4	2
Job at PBL: (Careful) Communication	3	2
Job at PBL: Credibility	2	2
Job at PBL: Job complexity	3	
Political decision making process: (Effective) Decision space	5	2
Political decision making process: (Political) discourse	8	4
Political decision making process: More policy effort	5	
Political decision making process: Political decisions	2	

Table 4.8 summarises the impact of uncertainty (communication) that participants experience. Though there were not specific distinct perspectives, the participants share some interesting observations.

Most commonly mentioned is the impact the presentation of uncertainty can have on the political discourse. Previously, policy officers would focus on the boundaries of the bandwidth (is the goal in the bandwidth or not):

"Now we have a whole array of options and can aim for specific chances."

The uncertainty is also perceived to provide clarity about the decision space, with participants saying:

"The information on the uncertainty also provides a clearer view of what are and are not effective policy options to increase the chance of reaching the goal."

Not only is the uncertainty perceived to have impact on the political discourse, it also has impact on the work of the researchers:

"Because there is uncertainty, the researchers must take care to communicate carefully, or the message may not land".

It is mentioned by some policy officers that the way uncertainty is presented can influence interpretation, but also the credibility of the research institution. It can be experienced as positive:

"Communicating about the uncertainty is more honest"

But is can also be experienced as negative:

"It is also vulnerable for the researchers if they are more transparent about uncertainty and assumptions, and results are substantiated less certainly substantiated than they seemed."

4.3. DEALING WITH UNCERTAINTY PRESENTED IN THE KEV

4.3.1. HOW PARTICIPANTS DEAL WITH UNCERTAINTY

Table 4.9: Dealing with uncertainty

Code	R (x/9)	P (x/6)
Accepting uncertainty	4	5
Avoiding uncertainty	1	2
Action: Communicating	6	1
Action: Generating knowledge / quantifying	5	2
Action: Monitoring and adaptation		
Action: Precaution		3
Action: Reducing uncertainty		2
Inaction: Postponing choice		1
Inaction: Withholding ineffective action	1	2
Inaction: Withholding unnecessary action		2
Interpretation: Expert Judgement	3	1
Interpretation: Suggest goal adaptation	1	2
Interpretation: Trust in relationships		1
Interpretation: Political consideration	3	6
Interpretation: Risk consideration		3
Interpretation: Collaborate on definition	1	
Transforming: Simplify uncertainty	1	2
Transforming: Strategic reframing	1	4

Table 4.9 summarises ways in which participants deal with uncertainty. Due to the nature of their roles, mostly the policy officers shared how they deal with uncertainty.

In general, 4 ways of dealing with uncertainty can be observed, as presented in Table 4.9: *action*, *inaction*, *interpretation*, and *transforming*. These do not directly lead to different perspectives, as participants use a combination of these different methods depending on the situation.

Uncertainty can notably lead to inaction. Policy officers mention that the uncertainty means that politicians do not want to take unnecessary actions (rather not overspend to reach a high certainty) or ineffective actions (due to the large uncertainties, it is unclear how much more certainty can be gained with policy actions). It can also lead to a more wait-and-see approach, due to for example decision-paralysis.

Many participants recognise, in line with their earlier responses, that in the end it is up to politicians how the uncertainty is acted upon. These political decision-makers are perceived to prefer a show of certainty. Because many participants (both policy officers and researchers) are concerned about the clarity of the intended message to decision-makers, extra effort for careful communication and sometimes simplification of uncertainty are notable ways uncertainty is dealt with. In extreme cases uncertainty may even be avoided, for example, by choosing to focusing on only one point (for example the mean) instead of the whole bandwidth.

Though there does not seem to be a strict divide between groups, one specific perspective can be highlighted, which is presented in Figure 4.7: dealing with uncertainty in a political environment. In this value-laden decision arena, politicians would rather present certainty (or avoid uncertainty if it suits them), and uncertainty is strategically reframed to fit their own arguments. In this perspective, the risks associated with un-

certainty (like political and legal risks) are important to analyse. Participants share that when dealing with uncertainty, it is important to be aware of this perspective, and that it may influence how they must deal with uncertainty in their own job.

Figure 4.7: Methods of dealing with uncertainty. One perspective is highlighted where participants more actively consider how the politicians deal with uncertainty.

4.3.2. PARTICIPANTS' ASSUMPTIONS OF HOW UNCERTAINTY IS DEALT WITH

Most researchers say they experienced that the information about uncertainty is strategically reframed to fit political causes.

"The coalition will say they are doing well, and the opposition will say more needs to be done. Based on the same information."

This is elaborated on by two policy officers. Some researchers also experience that politicians and policy officers avoid uncertainty in some ways:

"In my experience, they choose to focus on one value, even if we only provide a bandwidth."

Other shared experiences were that policy-officers are well-informed about the uncertainty and what is realistically achievable, whereas some researchers experienced that some policy-officers misinterpret the uncertainty . Some individual assumptions were that policy does change policy based on the KEV, policy officers do accept it if the forecast does not provide a point-value, and policy officers want to score well in the KEV.

Policy officers experience that researchers shape their communication to avoid misinterpretation. Policy officers also experience that the researchers communicate well about the present uncertainty. However, some experience that researchers focus too

much on the probability and not enough on the variance and that researchers are conservative in their policy judgement (rather under-estimate than over-estimate).

Participants mention that the policy-making process cannot extensively take uncertainty and the full picture into account. For example, they mention that decision-making can happen on a micro-level details despite the uncertainty. Policy officers also want their own policy to be chosen and will probably present it too positively and may be prone to ignore key uncertainties.

4.3.3. HOW TO DEAL WITH UNCERTAINTY ACCORDING TO PARTICIPANTS

As not everything can be planned, some participants suggest that the way policy goals in general are formulated should be revisited:

"The goals are ambitious but not realistic, it creates uncertainty and inaction."

"The uncertainty varies a lot from year to year and sector to sector, taking an average over a few years would be more logical."

"Policy makers should determine with how much certainty they want to reach their goal, depending on their priorities."

Other arguments were that policy should look at what prerequisites are necessary for effective policy (like good infrastructure) instead of creating new policy, and policy officers should not ignore uncertainty but consider how policy can take the extremes of the bandwidth into account.

Most policy officers mentioned that it would be nice if researchers could provide more information about uncertainty to support decision-making. The type of information could be: what uncertainty is controllable, explanation of decisions made through expert judgement, and explanation of methods like how the uncertainty is calculated. Policy officers also mentioned that researchers should stay politically neutral when working with uncertainty, mostly in their expert judgement of policy effects. It is perceived as important that researchers consider how their communication of uncertainty impacts the policy-making process. Lastly, one policy officer reflected that dealing with uncertainty is very hard for goals that are in the very near future and would like to be supported in looking further into the future.

4.3.4. IMPACT OF UNCERTAINTY PRESENTATION

Researchers indicated that they think introducing a probability statement to communicate uncertainty, next to the standard graph with bandwidth, makes the results easier to interpret, especially for readers who are less versed in reading such graphs. They think it makes the chance more explicit, it makes the discussion less binary as it adds more nuance within the bandwidth. Now the reader can more easily discuss how much certainty is enough. Therefore, they expect and notice a change in the (political) discourse.

The policy officers indicated the specified probability is added information, and does make the discourse less binary. However, it may be unclear where the specific probability comes from, and it should not overshadow the variance and distance to the goal. Those who specifically liked one figure over another said: 'I liked the older image better because the distance to the goal is clear', and 'I liked how the new image has a clearer middle of the bandwidth'. Mostly, participants favoured visualisations they are used to, with some preferring the new figure because it looks more like how other studies visualise uncertainty.

5

DISCUSSION

This study set out to explore the perceptions of uncertainty on the science-policy interface, in order to improve uncertainty analysis and communication in support of policymakers. The interview data analysis showed that though participants generally say they are accepting of uncertainty and find the communication of uncertainty in the KEV easy to interpret, there are distinct perspectives on definition, characterisation, and interpretation of uncertainty. There is more nuance to the perspective than a divide between policy officers and researchers, but the values and ways of dealing with uncertainty are more contained to each group. The results show participants experience the impact of uncertainty (communication) in the way the political discourse is conducted, but also in the perceived credibility of the research institution.

These findings provide important insights into how uncertainty can be perceived differently depending on professional and institutional context, and they highlight new policy-relevant perspectives on uncertainty that deviate from previous bodies of work.

5.1. FRAME OF UNCERTAINTY PERCEPTION OF THE KEV

5.1.1. FOCUS ON QUANTIFIED UNCERTAINTY

The interviews with the policy officers show they largely share a perspective where they define and associate uncertainty in the KEV with its representation as the bandwidth. This association would indicate the uncertainty perceived by the policy officers is reduced to all uncertainties that are taken into account in the uncertainty analysis.

However, in practice, the participants seem to be interested in more sources of uncertainty than are quantified and communicated. The participants consider the changing political climate (and therewith future policy changes) and war abroad to be relevant, whereas PBL has communicated they will not take such uncertainties into account. Additionally, policy officers are interested in the uncertainty resulting from expert judgement, but this is not communicated precisely.

The focus on quantitative aspects and presentation of uncertainty by the participants of this study could partially be explained by the roles of the institutions and the participants. Quantified uncertainty could be perceived as more exact and easy to deal with, and qualitative statements as more value-laden, which would be less appreciated by actors who value political-neutrality in research and want a solid numerical standard of information. These results may be reflected in other research cases where users of the results want to use exact quantitative results, but where some results are hard to quantify.

However, some sources of uncertainty are hard to take into account in uncertainty analysis, so qualitative statements would be more suitable. If qualitative aspects of uncertainty are taken into account less in general, this would mean that important less-quantifiable aspects of uncertainty play too little of a role in the decision-making process.

Several studies have advocated for more inclusion of qualitative aspects of uncertainty, specifically also as deep uncertainties are hard to quantify (Funtowicz & Ravetz, 2019; Mastrandrea et al., 2011; Padilla et al., 2021; Stainforth et al., 2007; Van Der Sluijs et al., 2005; Wardekker et al., 2008). For example, Maxim and Van Der Sluijs (2011) and Wardekker et al. (2008) elaborate that qualitative aspects of uncertainty (like value-ladenness of assumptions and level-of-knowledge) cannot easily be quantified. The policy advisors surveyed in that study prefer solid quantitative information, but at the same time wanted more communication about these qualitative aspects to put them into perspective.

Researchers are trying to tackle this conflicting task. Funtowicz and Ravetz (2019) and Van Der Sluijs et al. (2005) suggest a pedigree system to providing more attention to qualitative aspects of uncertainty, like hard to quantify aspects like value-ladenness and confidence, which could promote a reflexive practice and collective learning. However, it can be unclear where the qualitative metrics come from and how they should be used (Adler & Hirsch Hadorn, 2014).

So, qualitative presentation of uncertainty could be viewed as indicative of more value-laden research. But, research cannot be performed completely value-free. The openness about qualitative aspects of uncertainty therefore provides the reader the ability to scrutinize also those aspects of the research. This is important for a healthy research environment. Understanding the role of uncertainty in the policy process could then also support development of easy-to-use qualitative statements about uncertainty.

5.1.2. CHARACTERISING UNCERTAINTY TO SUPPORT DEFINITION

Participants lacked a shared definition and often struggled to articulate one, reflecting the many sources of uncertainty and the complexity of the policy context (Doyle et al., 2024). Similar difficulties appear in other domains (Doyle et al., 2023). Uncertainty definitions vary by field and author (Kwakkel & Cunningham, 2008a), and is often linked to related concepts such as ambiguity and risk (Alaszewski & Coxon, 2009; Gaudard &

Romerio, 2020; Jansen et al., 2019; Jenkins-Smith & Bassett, 1994; Leonhardt et al., 2011).

Characteristics helped participants to express their understanding of uncertainty, though some of the participants mention they do not often do so explicitly. Two perspectives were identified, where some focus on the most policy-relevant aspects of uncertainty, modellers at PBL also make other model-relevant distinctions. When pressed, participants consider uncertainty 'size' and 'controllability' to be most relevant in the context of the KEV. This is elaborated by their value of policy- and discourse-relevance.

It is note-worthy that PBL has published a guideline on communicating and dealing with uncertainty, wherein they share how uncertainty can be described (Petersen et al., 2014). Based on the typology by Walker et al. (2003), they expand the framework with 'value-ladenness' as an important characteristic of uncertainty. The framework does not explicitly include 'controllability' or related terms like 'reducibility' or 'treatability'.

The disconnect between theoretical guidelines and practice of uncertainty typologies in this case can have several explanations. Such theoretical frameworks could be rarely used in practice because they are too extensive or unknown; Participants didn't consider theoretical typologies to be relevant to mention in the interview, but they are used; or participants may have learned about such guidelines but only use them implicitly. This disconnect could however be a common problem in other areas of uncertainty communication where senders and receivers of uncertainty information have different roles and interests.

It is important to note that more decision-relevant typologies, like those preferred by the users of the KEV, are suggested for example by Arend, 2024; Matott et al., 2009, who both suggest moving away from other typologies and build extensive frameworks around treatability of uncertainty. Though this seems promising, the semantics of 'treatability', 'controllability' and 'reducibility' is important to consider. In hindsight, this difference wasn't always clear in the responses that were analysed. Though policy officers may want to have control, this can also be done by taking measures that work without treating the uncertainty.

Though characterisation schemes can support defining and communicating uncertainties, unifying all schemes to unify communication is a challenge (Arend, 2024; Bland & Schaefer, 2012; Brugnach et al., 2008; Dewulf & Biesbroek, 2018; Doyle et al., 2019; Gaudard & Romerio, 2020; Kwakkel et al., 2010; Packard et al., 2017; Patt, 2007; Walker et al., 2003). The results of this study imply that exhaustive typologies could be less useful and applicable in practice when dealing with many uncertain factors for policy-making as not all characteristics are relevant. Therefore, it seems that guidelines on distinguishing uncertainties should be context-dependent for relevant and useful descriptions (Doyle et al., 2019).

5.2. INTERPRETATION OF UNCERTAINTY IN THE KEV

5.2.1. UNCERTAINTY AS PROBABILITY

When presented with the research results in the KEV, the interpretations of uncertainty as a bandwidth varied, from impossible to possible and very small to larger probabilities. Participants generally used the same approach to interpretation, gauging the relative position of the bandwidth to the policy goal.

There was a general divide in two perspectives: Where some participants could very specifically deduce probability from the graphs and text, others kept their interpretation more vague, mostly because they considered there to be too little information to make further conclusions (for example the absence of a probability distribution). Though there are different perspectives, there is no clear divide between the participant groups.

Previous studies have shown uncertainty is easily misinterpreted, when represented verbally or in a graph (Padilla et al., 2021; Wardekker et al., 2008; Willems et al., 2020). Misinterpretation could explain the variance in the interpretations. Where one person may think the goal is very close to 5% certainty in the bandwidth, another using the same method may come to a different conclusion.

However, when confronted with the exact probability there is less variance in the conclusions drawn by the participants. The combination of verbal and numerical presentation has been indicated to decrease the variation in interpretations (Budescu et al., 2012). Therefore, it seems that without additional information about the probability distribution, more detailed interpretations are not possible, as some participants also suggested, leading to varying interpretations.

This would imply that communicating a more specific probability (distribution) would reduce the ambiguity when uncertainty is represented by a bandwidth. However, this only applies to similar cases where uncertainty is represented quantitatively and with a bandwidth. This does not cover decreasing ambiguity of qualitative aspects of uncertainty. An additional challenge is that communicating a probability distribution requires such a probability distribution is feasibly knowable.

5.2.2. POLICY-RELEVANT RISK AS THE EFFECT OF UNCERTAINTIES

One specific perspective that is identified is when participants actively consider how politicians deal with uncertainty. Specifically, the policy officers consider the political and legal risks that are related to the inherent uncertainty of reaching the legal climate and energy goals. The risk is posed by having to balance limited resources with the consequences of not reaching the goal. There is a legal aspect as the goals are established by law. The policy landscape is also ruled by other (political) goals that also require resources, leaving the decision-makers (or the policy officers in their stead) to make value-based judgements on what risk they are willing to take.

A possible explanation of the interest of the policy officers in this study to relate risk

to uncertainty is the decision-making context. Uncertainty in itself is not a bad or a good thing. Instead, the consequences may be valued as (un)desirable. Therefore, the relevant risks in connection to the uncertainty must be defined in the decision-making process.

In contrast, the lack of consideration of risk by the researchers can be explained by their position as a more politically-neutral party and provider of information. They are viewed as a party that should be politically-sensitive in how they present the policy options and consequences, but it is not their job to take into account all risks that are relevant to the policy officers.

Interestingly, the relation between uncertainty and risk is not new, and several studies have addressed how they are perceived (Alaszewski & Coxon, 2009; Asselt, 2000; Bostrom et al., 2016; Doyle et al., 2023; Gaudard & Romerio, 2020; Höllermann & Evers, 2017, 2019; Smithson & Bammer, 2012). Some consider the two concepts as subcategories, others as risk being a consequence of uncertainty, and others consider them independent but related concepts. These different definitions imply that the relation may be subjective or context-dependent and differ between personal or institutional context Alaszewski and Coxon (2009) and Doyle et al. (2023)

These results suggest that in some cases risk interpretation can be considered more relevant to the decision-maker than only uncertainty. This can help explain why actors experience uncertainty differently, and why interpretation of a message about uncertainty may seem to be misinterpreted. Though the role of PBL in this case study is only to report on the projection and uncertainty, in other cases analysing and communicating risks related to the uncertainty may connect more with the reader.

5.2.3. IMPACT: POLICY DISCOURSE AND CREDIBILITY

The researchers at PBL experience a trade-off, considering the strength of a message, credibility, and possibility of strategic use of the information. Participants generally accept uncertainty as it's unavoidable. The presentation of uncertainty information is perceived to significantly influences policy discourse, both positively and negatively.

The perception of these impacts as positive or negative may depend on the roles and values of the participants. All participants generally value strong credibility from researchers to establish a shared knowledge base. However, researchers value conveying a strong message, while politicians may seek greater uncertainty to allow for strategic interpretation. These observations confirm the assumptions of the participants that uncertainty information is used strategically.

There is evidence that there is both positive and negative impact of uncertainty communication on credibility (Lammers et al., 2024; Padilla et al., 2021; Van Der Bles et al., 2019), but decision-makers may be more comfortable with uncertainty than researchers assume and appreciate transparency (Doyle et al., 2023; Gustafson & Rice, 2020; Udovyk & Gilek, 2013). A possible explanation is that the manner in which the uncertainty is communicated may be of more importance to the credibility than the actual amount of

uncertainty.

These findings can resonate in other cases of science communication with multiple perspectives on uncertainty. Working with scientific research requires an amount of trust in the methods and the institution. Transparency can support this trust. Additionally, the degree to which uncertainty is quantified and communicated affects the credibility and impact of the message. Insights can also be gained for uncertainty communication specifically for policy. Uncertainty can lead to decision-paralysis. The format of uncertainty information, such as bandwidth and probability, can also shape the course of political discourse. Strategic use of uncertainty likely cannot be avoided.

5.3. DEALING WITH UNCERTAINTY IN POLICY-MAKING

Participants deal with uncertainty is many ways, and this research groups them in four main categories: action, inaction, interpretation, and transformation. The results suggest some new methods of uncertainty management that seem to have received limited attention (see Appendix A).

The institutional context may shape how uncertainty is dealt with. Considering the wealth of information that must be considered by a minister, it is not strange if policy officers are required to condense information about uncertainty. Uncertainty is however also used strategically, to delay decision-making or avoid responsibility (Höllermann & Evers, 2017; Leonhardt et al., 2011).

An important note by participants is that the current policy arena makes it hard to take uncertainties into account: policy decisions can happen at micro-scale about specific numbers in individual policies, financially and politically short-term wins are valued more which makes necessary late-interventions more expensive, and the siloed nature of policy domains makes it difficult to design system-wide interventions that take uncertainties across domains into account.

However, all participants agreed that the selection of uncertainty management methods is up to the politicians. The experience of the participants shows this depends on the extent that a political party favours one goal over another, and whether they are in the opposition or not. Additionally, if only very drastic measures can guarantee complete certainty, participants see policy-makers would rather not spend all resources on a single goal but also want to invest in other goals. Participants also recognise that policy-makers want to avoid unnecessary and ineffective spending.

How much certainty is preferred is a resource allocation, as well as a legal and ethical question in this case study. The policy-makers at Min. KGG seem to manage risk, but these results imply that moral and rule uncertainty are also relevant to consider (Tannert et al., 2007). It seems that the rules of the game are not clear: Is there a certain percentage that is certain enough? It also seems the morel rules are not clear: What freedom for value-based decisions do policy-makers have when they do not have enough resources to achieve all goals but some are established in the law? Some participants also want

the political freedom to focus more on long-term policy-making and feel limited by the strictness of the goals.

Yet, some participants considered some lower bound of certainty necessary to take the effort seriously. One could also interpret the law such that the goals have to be met no matter the circumstances. Therefore, the actual minimal certainty may be up to legal interpretation. Currently participants deem 100 percent certainty not possible, but there are very concrete steps (though extreme) that could help reaching the goal no matter what (stop travelling, shutting down industry). These steps may not be preferable when considering other goals, but they illustrate that in theory the national climate goals can be reached with complete certainty.

Several participants indicate that the goals will probably not be met, and some vouch for formulating new more long term goals. However, in general, the setting of specific goals and targets is preferred for clear communication to practitioners, the media, and the broader public to hold politics accountable (Moore, n.d.). Specific short-term goals can lead to tunnel-vision (committing to a goal in a specific year no matter what happens) and maybe disproportional legal repercussions (if there is no difference between reaching the goal in one year or the next). However, less short term and less specific goals make it harder to keep policy-makers responsible.

These findings are relevant to understand uncertainty perception in other decision-making contexts. Similar dynamics are likely present in other organisational and individual contexts where decision-makers are required to balance different values, goals, and resources. There, uncertainty management is probably not a strict rational process but depends on values and strategy. Moral and legal rules may also be relevant in guiding the interpretation of goals and deciding on uncertainty management strategies in other political decision-making cases.

5.4. RESEARCH LIMITATIONS

RELEVANT PARTICIPANTS

Relevant decision-makers that may be considered as a missing party in this research are politicians, or ministers. However, they were not included in this study for several reasons.

First, the environmental assessments are usually read and analysed by policy officers/advisors/consultants who distil the information in concrete advice. Ministers don't have the time to read all the reports, nor possibly all the required background-knowledge. This means however that the most misinterpretation can also happen at this point, where the decisions are made, which is not directly captured in this research.

Secondly, as politicians will likely present a particular frame as 'the correct frame', and not their personal interpretation. This means that the answers in this hypothetical interview would risk being little insightful when it comes to the individuals' true percep-

tion is. Therefore, though this research may run the risk of missing the perspective of key decision-makers, it focuses on the role of the advisors by including policy officers.

INTERVIEW STRUCTURE

The structure of the interview (half-strucutred) meant that it cannot be guaranteed that all participants were asked exactly the same question, which can lead to semantic and comparability problems. However, this was managed as much as possible through a strict coding scheme.

Another drawback of the interview structure was not letting participants construct their own representations of the concepts and causal relations that are part of their beliefs. This means this research also depends more on the interpretation of the researcher than other mental model researches do. This choice was made in consideration of a more broad exploration of different topics, instead of diving into a specific topic more extensively, as well as for the practical consideration of how time-intensive an extensive mental-model method is.

The influence of the interpretation was limited as much as possible by firstly communicating clearly in this report what judgements were made, and secondly by providing the participants the opportunity to read and adjust the transcripts in case of misrepresentation of their ideas.

CODING ASSUMPTIONS

The half-open coding and mental model approach allowed divergent responses. This requires an additional layer or interpretation by the researcher to address the comparability of the results, in comparison to letting participants pick from a pre-made list. This is however preferred as a pre-made list steers participants to provide socially desirable answers that may actually be less relevant to their individual interests.

QUALITY OF RESPONSES

Some interviewees were very short in their answers, and other elaborated a lot on their answers. Sometimes this meant that people were direct or even already answered other questions, but other times this meant that the interviewees didn't cover the topics of the discussion.

The risk of missing their perception on certain topics was mitigated as much as possible by coming back to earlier questions at a later moment when the interview had more momentum, and by more concretely asking for an explanation about a specific topic. This however runs the risk of steering the interviewee too much.

SOCIAL PRESSURE IN INTERVIEW CONTRIBUTIONS

This research focuses on a politically sensitive topic in the Netherlands. This can lead participants to want to give a 'politically correct' answer. At the same time, the interviewer seemed to be considered to be party to PBL, or at least in their role as a researcher to belong to 'people who are researchers'. As the research focuses on differences between

researchers and policy officers, this can lead participants to give 'socially acceptable' answers depending on whether they saw the interviewer as belonging to their in- or outgroup.

The first risk was mitigated as much as possible by informing the participants their answers would be collected and processed anonymously. The second risk could hardly be mitigated, especially as the research is performed as part of an internship at PBL.

PERSONAL AND INSTITUTIONAL CONTEXT

This research set out to explore uncertainty perception considering the personal and institutional context as this would enrich an understanding of why perceptions may differ. In the end, this case study provided less insights into how the personal context influences uncertainty perception as the participants were holding back in personal opinions and focused on sharing their professional experience.

Though the personal context wasn't explored well, the results still provide valuable insights into the variation of interpretation of uncertainty, even in similar institutional contexts.

5.5. COMMUNICATION DESIGN FOR INNOVATION: REFLECTION ON EXPERT JUDGEMENT OF UNCERTAINTY

This research was performed in parallel to a second research project at PBL on expert judgement of uncertain factors. This section will discuss the role of expert judgement in uncertainty perception, as well as the relevance and the implications of the results for developing expert judgement methods.

Participants share they require enough information for their own expert judgement, to interpret and act on the uncertainty. This includes underlying assumptions of the research. On the one hand, researchers need to apply expert judgement in their analysis of policy effects, and policy officers on the other hand apply their expert judgement in their interpretation of research results, methods, and assumptions.

Most participants find it important that the KEV has a clear message, and for some that means that there should maybe be less focus on the uncertainty to get that message across. However, considering the credibility of the researchers and room for expert judgement that the reader has a right to, the transparency about assumptions and uncertainty is also appreciated.

Expert judgement is an important part of the modelling and uncertainty analysis process. Using available statistics, stakeholder engagement, and other studies, modellers make a assumptions for parameters that cannot feasibly (with the given time, budget and data) be quantified (Colson & Cooke, 2018). They are required to estimate a 5-95% bandwidth of probable values. Additionally, expert judgement is required to estimate effects of policy plans that are shared by the policy officers of Min. KGG.

Expert judgement is not limited to only scientific expertise. In the environmental modelling literature, "expert knowledge", "expert judgement" and "expert opinion" seem to be used interchangeably (Krueger et al., 2012). One could also say it should not be applied when there is a lack of relevant expertise. However, the definition of expertise is a question of debate (Hanea et al., 2022a). Democratisation of expertise requires accountability and inclusion of different expertises, (Hanea et al., 2022b; Krueger et al., 2012).

The results suggest several points of attention in the development of expert judgement methods:

- Collaboration between policy officers and researchers about the policy intentions and the model assumptions, requiring transparency from both parties to share information and to ensure a policy-relevant and scientific process;
- Credibility of the scientific process, requiring a scientifically based expert judgement process that takes into account multiple expertises and is traceable;
- The individual skill and courage to make assumptions, requiring safeguards against false certainty while trusting that making an assumption will improve the relevance of the results to the policy-making process.

6

Conclusion

This research aimed to address the question: *"What are perceptions of uncertainty on the science-policy interface in the Netherlands perceive uncertainty, and what are the implications for the policy-making process?"* This involved developing a conceptual framework of uncertainty and interviewing producers and users of the Climate and Energy Outlook (short: KEV) in the Netherlands as a case study.

What is uncertainty?

In literature, uncertainty definitions differ across authors and domains. Those addressed in this study examine uncertainty from four perspectives: How uncertainty is *framed*, *its characteristics*, *the impact*, and *how it is dealt with*. In practice, characterising uncertainty can help to understand and communicate it more clearly.

What are different perceptions of uncertainty of policy-makers and researchers?

Generally, two different perspectives were identified for uncertainty definition, characterisation, and interpretation, but they do not mirror the participant groups. As similar approaches to interpretation were used, likely not all information is present to come to similar conclusions. Supporting the projection with a probability statement seems to align interpretations, but it may distract from other qualitative aspects of uncertainty (variance, controllability, and value-ladenness). What characteristics of uncertainty are considered relevant for interpretation may depend on the modelling or policy context.

How is uncertainty dealt with by policy-makers and researchers?

In general, uncertainty is dealt with in multiple different (and potentially strategic) ways. In this case study they can be categorised in four groups: *action*, *inaction*, *interpretation*, and *transforming*. The chosen options appear to largely depend on the perceived implications for credibility and related political and legal risks. Relatedly, participants experience uncertainty creates a trade-off between a nuanced and a strong message. The presentation of uncertainty also influences the political discourse: for example, presenting a bandwidth or a probability in the KEV influence the policy options under consideration and make the debate less binary.

General conclusion

Overall, these findings show that the differences in perceptions of uncertainty in the KEV at the science-policy interface are more nuanced than a strict divide between the participant groups. This could be expected as the groups are heterogeneous (domain expertises, roles). The decisions that are made by researchers about how to present what information of uncertainty impacts how policy-makers interpret and deal with uncertainty. However, researchers can only influence the interpretation to a certain extent, as uncertainty is also used strategically in the political arena. These different values and contexts possibly explains the experience of a gap in perceptions of uncertainty by researchers and policy-makers.

Though interpretations differ, participants across groups agree that uncertainty analysis and communication can be policy-relevant when communicating the distance to the policy goal, what uncertainties are the largest and what lies within the control of the government. However, these aspects present a challenge as they are not easily quantifiable due to the complicated interactions of policy and external factors.

These findings provide a new perspective on uncertainty perception in the policy-making process. Understanding how uncertainty is perceived and dealt with in different ways on the science-policy interface is essential to develop policy-relevant and effective communication of research results. In turn, this may improve support of policy-makers in dealing with uncertainty, as they might decide on precautionary measures or decide to leave out less effective measures.

Recommendations

To examine whether these results can be generalised, similar studies can be performed for other cases of policy analysis. As this study provided some ideas for why perceptions differ based on the heterogeneity of the participant sample, future research can look into the impact of different domain expertise (e.g. elektricity vs mobility, Kwakkel and Cunningham (2008a)), job function (modeller vs coordinator), and personal beliefs about the policy problem (concerned vs unconcerned, Kause et al. (2019)). Interpretation of uncertainty seemed to not only depend on the relation of the bandwidth to the policy goal. Important aspects for future studies, that were indicated to be relevant, are the distance in time to the goal (Doyle et al., 2019), perceived risks, or feelings of control. Lastly, this study examines a specific expression of uncertainty in a study that quantitatively projects expected policy effects in the near future. Uncertainty is however relevant in other types of research for policy (e.g. scenario studies), and other studies can examine how uncertainty is perceived and dealt with in those policy-research cycles.

The results of this study can also be applied in practice on the science-policy interface. The re-occuring need to (re)define uncertainty implies there is not one definition that fits every single context and can seem subjective. Research into unifying the definition and characterisation therefore can be limited. This will just create more conflicting standards. It is therefore important for researchers to check whether uncertainty is interpreted in the way it is intended, also in different case studies. This requires investigating

what information is needed for interpretation (perhaps presenting a probability distribution is required). This also requires openness about what uncertainties were left out of the research all-together, maybe because they were hard to quantify, and instruct the reader on how they can use their own expert judgement to put the results into perspective.

To address the need for policy-relevance, attention must clearly be paid to what is known, and to what lies in control, in addition to the uncertainty. For example, by highlighting what policy options are effective despite the uncertainty. While protecting political-neutrality, researchers can recognise that risk perception is relevant and can draw inspiration from risk communication for their own communication design. To avoid decision-paralysis, research into how policy-makers can be supported in managing uncertainty despite the hurdles of the institutional context would be really valuable to overcome them (Akse, 2024; Kasperson, 2008; Maas et al., 2022).

Though research mostly shows positive impact of transparency, the impact on credibility is still a concern in communication design. An important, and probably constant, dialogue is required to make transparency about uncertainty a part of a healthy science-policy relationship. Researchers should not doubt to communicate uncertainty, and policy-makers can trust the message that is conveyed when the assumptions are clear to put the uncertainty into perspective. An important step can be collaboration, or at least stakeholder consultation in the case of independent research, for project assumptions and expert judgement of policy effects. In the case of the KEV, the main assumptions were established years ago in the first iteration of the report. However, policy effects must be judged every year in a very tight schedule. For the KEV this suggestion may lie beyond the tasks and available resources of PBL and the Min. KGG, but if policy officers can openly share their expectations and assumptions, researchers can reply to those openly as well, creating a transparent dialogue.

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A

OVERVIEW OF LITERATURE FOR CONCEPTUAL FRAMEWORK

Author/**typology**	**Source/Location**												
Ragas et al. (1999)							Model: Fundamental				Model: Operational		
Walker et al. (2003)	Context						Model structure			Model software/ technical	Input: System data	Input: external driving forces	
Kwakkel et al. (2010)	System boundary						Conceptual model	Model structure	Parameters inside the model		Input parameters to the model	Input data	Model implementation
Brugnach et al. (2008)	Natural	Technical	Social										
Brugnach & Ingram (2012)													
Raadgever et al. (2011)	Natural	Technical	Social										
Höllermann & Evers (2017)	Fundamental/ environmental			Policy-making process									
Tannert et al. (2007)													
Dewulf & Biesbroek (2018)	Substantive			Strategic		Institutional							
Ongaro & Andreoletti (2022)	State space uncertainty												
Arend (2024)				Steps of policy making process									
Maxim & Van Der Sluijs (2011)	Substantive ++			Contextual ++		Procedural ++							
Frewer et al. (2003)	Scientific												
Alaszewski & Coxon (2009)			Human behaviour										
Van Der Bles et al. (2019)													

Figure A.1: The different locations of uncertainty (sources) as observed in a limited literature review.

Author/**typology**	**Nature**						**Level**			
Ragas et al. (1999)										
Walker et al. (2003)	Epistemic	Variability (ontological): Behavioural, societal, randomness					Statistical	Scenario		Recognised ignorance
Kwakkel et al. (2010)	Epistemology	Ontology	Ambiguity				Shallow	Medium (ranked)	Deep	Recognised ignorance
Brugnach et al. (2008)	Incomplete Knowledge	Unpredictable	Multiple knowledge frames							
Brugnach & Ingram (2012)										
Raadgever et al. (2011)	Incomplete Knowledge	Unpredictable	Multiple knowledge frames							
Höllermann & Evers (2017)										
Tannert et al. (2007)	Objective Undertainty			Subjective Uncertainty						
	Epistemological	Ontological		Moral uncertainty	Rule uncertainty					
Dewulf & Biesbroek (2018)										
Ongaro & Andreoletti (2022)	Epistemic uncertainty			Ethical uncertainty						
Arend (2024)	Treatable	Untreatable					Intensity characteristics, etc.			
Maxim & Van Der Sluijs (2011)	Epistemology	Ontology	Expert Subjectivity	Communication						
Frewer et al. (2003)										
Alaszewski & Coxon (2009)										
Van Der Bles et al. (2019)	Epistemic	Aleatoric								

Figure A.2: The different natures and levels of uncertainty as observed in a limited literature review.

Author/**typology**	**Impact**				**Dealing with uncertainty**			
Ragas et al. (1999)								
Walker et al. (2003)	Model outcome							
Kwakkel et al. (2010)	Processed output data							
Brugnach et al. (2008)					Data gathering	Monitoring and adaptation	Strategic change	Shared definition
Brugnach & Ingram (2012)								
Raadgever et al. (2011)					Knowledge generation	Coping	Interaction	Ignoring
Höllermann & Evers (2017)		Decision process			Quantifying			
					Risk management			
Tannert et al. (2007)								
Dewulf & Biesbroek (2018)					Go-alone			
					Concerted			
Ongaro & Andreoletti (2022)								
Arend (2024)	Costs and benefits, etc.							
Maxim & Van Der Sluijs (2011)	Precision /Quality	Transparency	Credibility	Confidence				
Frewer et al. (2003)			Trust	Worry				
Alaszewski & Coxon (2009)			Trust		Risk management, gathering knowledge (organisations)			
					Heuristics, relationships (personal)			
Van Der Bles et al. (2019)	Cognition		Trust	Emotion	postponing choice, precaution, withholding unnecessary action			

Figure A.3: The different consequences (impact) of uncertainty and ways of dealing with uncertainty as observed in a limited literature review.

B

KEV EXCERPT FOR INTERVIEW

Klimaat- en Energieverkenning 2023 (26 oktober 2023)

Ramingen van broeikasgasemissies, hernieuwbare energie en energiebesparing op hoofdlijnen

De jaarlijkse Klimaat- en Energieverkenning wordt voorgeschreven door de Klimaatwet en is een verantwoordings- en monitoringsinstrument voor het Nederlandse klimaat- en energiebeleid. De broeikasgasuitstoot in Nederland daalt mogelijk met 46 tot 57 procent in 2030 ten opzichte van 1990. Daarmee is het wettelijke klimaatdoel van 55 procent reductie voor het eerst in zicht.

Klimaatdoel 2030 voor het eerst in zicht; snelle en ambitieuze uitwerking plannen cruciaal
Met de plannen in de Voorjaarsnota Klimaat zet het inmiddels demissionaire kabinet een belangrijke stap vooruit op weg naar realisatie van 55 procent minder broeikasgasuitstoot in 2030, vergeleken met 1990. Nederlandse en Europese plannen die concreet genoeg zijn voor een effectschatting zorgen voor 5 procentpunt extra emissiereductie ten opzichte van de raming van vorig jaar. Zo is een reductie van 46 tot 57 procent mogelijk. Maar om de bovenkant van deze bandbreedte aan te tikken en dus het doel te halen moet alles meezitten, ook niet-stuurbare factoren zoals weer en elektriciteitsimport.

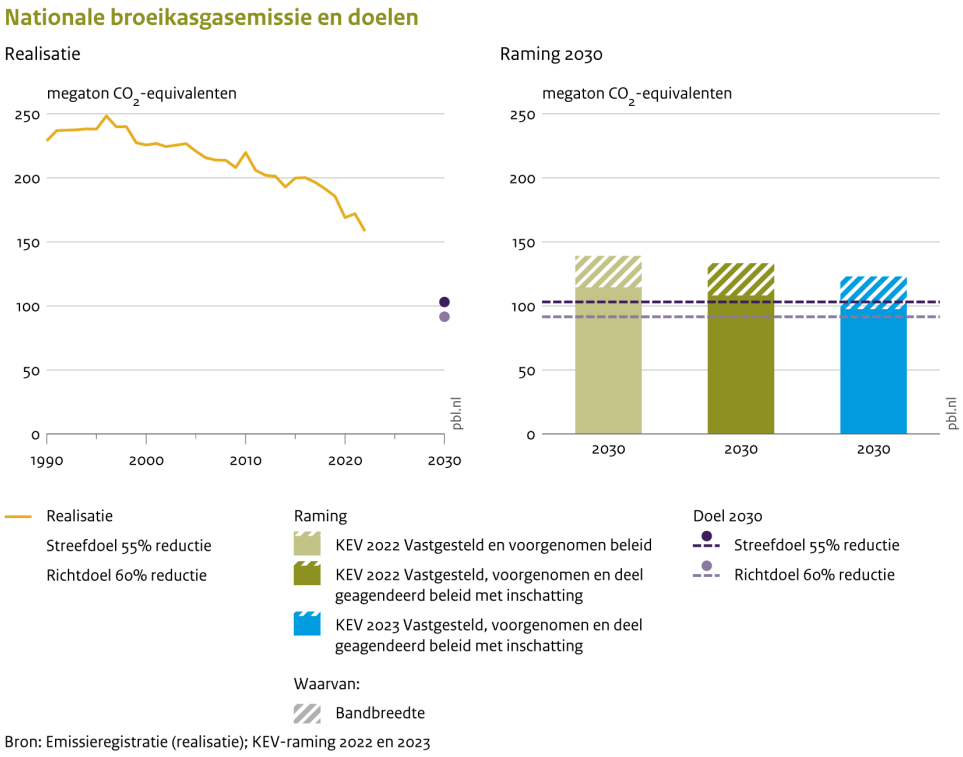
Zonder concretisering geen effect
Van de klimaatplannen die niet concreet genoeg zijn voor een effectinschatting verwachtte het kabinet in de Voorjaarsnota 10 megaton CO2-equivalenten (ruim 4 procentpunt) extra emissiereductie. Als ook deze plannen op tijd, concreet en maximaal worden uitgewerkt komt het klimaatdoel van 55 procent emissiereductie in 2030 met meer zekerheid binnen bereik. De speelruimte tot 2030 is zeer beperkt. Voor veel maatregelen moeten ook de juiste randvoorwaarden worden geschapen. Daarvoor is flankerend beleid nodig:

aanpassing van wet- en regelgeving en handhaving daarvan, en snellere vergunningverlening voor de aanleg van de benodigde energie-infrastructuur die al gepland is. Ook moet er voldoende geschoold personeel zijn voor de uitvoering van plannen.

B

Energiebesparing vraagt extra inzet; aandeel hernieuwbare energie stijgt flink
Nederland ligt nog niet op koers om in 2030 alle eerder dit jaar aangescherpte Europese doelen voor energiebesparing te halen. Tegelijk stijgt door de plannen in de Voorjaarsnota Klimaat het aandeel hernieuwbare energie in het finale energieverbruik flink. Daardoor komt het eveneens aangescherpte doel voor hernieuwbare energie in zicht.

Bron: PBL. (2023). *Klimaat- en Energieverkenning 2023.* Planbureau Voor De Leefomgeving. Bezocht April 22, 2025, op https://www.pbl.nl/publicaties/klimaat-en-energieverkenning-2023



Bron: Emissieregistratie (realisatie); KEV-raming 2022 en 2023

C

INTERVIEW PROTOCOL

C.1. INTERVIEW PROTOCOL – RESEARCHER

SURFACE-LEVEL – 10 MIN

Als ik de Klimaat- en Energie Verkenning noem, wat roept dat bij u op?
Kunt u wat vertellen over hoe u kijkt naar de beleidscontext?

- Kunt u me vertellen over uw eigen taken in dit beleidsproces?
- Wat is voor u belangrijk in dit beleidsproces?

Waar denkt u aan bij onzekerheid in de Klimaat- en Energie Verkenning?

- U noemt daar X Y Z. Als u onzekerheid breder zou moeten definiëren, hoe zou u dat in uw eigen woorden doen?
- Hoe speelt die onzekerheid een rol in uw werk? En hoe gaat u daarmee om?
- Wat vind u belangrijk voor het omgaan met deze onzekerheid in deze beleidscontext?

VERSLAG INTERPRETATIE – 20 MIN

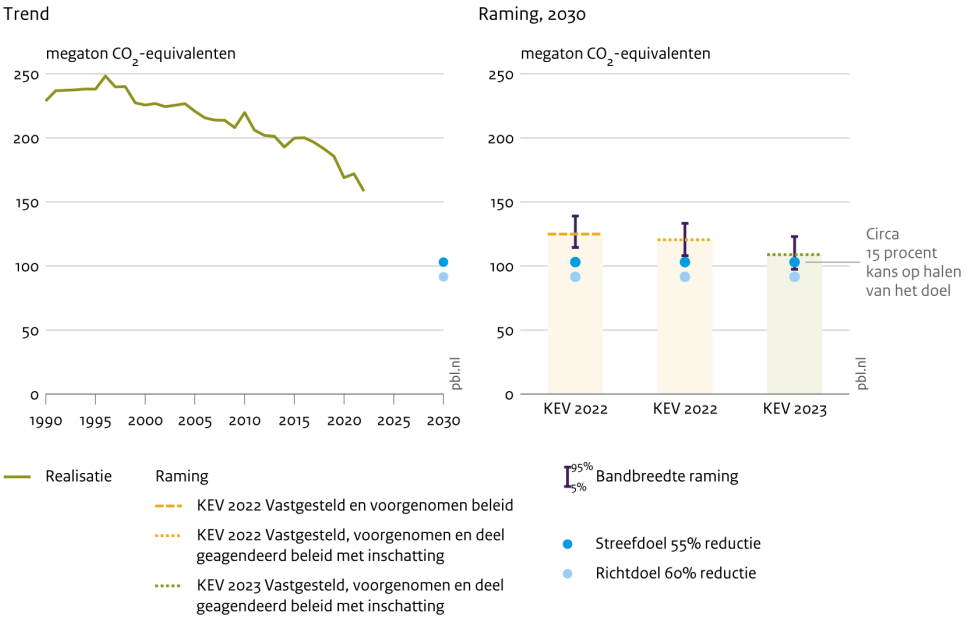
U heeft van tevoren een kort verslag van de KEV 2023 gelezen. Hier is een kopie.
Hoe begrijpelijk is de informatie voor u?
Hoe kijkt u aan tegen de haalbaarheid van de beleidsdoelen?

- Welke kans zou u het geven tussen 0 en 100 % ?
- Zou u hier concluderen dat er een beleidstekort is?
- Hoeveel procent kans van haalbaarheid van de beleidsdoelen is genoeg volgens u? Aan wie is dat om te bepalen?
- Denkt u dat er meer moet gebeuren om de haalbaarheid van de doelen te verbeteren?

Wat vind u van de relevantie van de gegeven informatie voor beleidmakers?

Er is een nieuwe versie van het figuur.

Nationale broeikasgasemissie en doelen



Bron: Emissieregistratie (realisatie); KEV-raming 2022 en 2023

Is de informatie volgens u verandert en hoe?

- Wat is het effect daarvan voor de keuzes die gemaakt moeten worden voor beleid?
- Wat is het effect daarvan op de begrijpelijkheid?

In de KEV wordt de haalbaarheid van beleidsdoelen aangegeven met een kans of bandbreedte en niet een ja of een nee.
Waarom is dit volgens u? Hoe komt dat dan?

Hoe voelt u zich erbij dat in de uitkomst de haalbaarheid van de beleidsdoelen onzeker is?

- Wat is de impact van deze onzekerheid op uw werk? +Direct/Indirect
- Wat denkt u dat de impact is voor de keuzes die beleidsmakers moeten maken?

OMGAAN MET ONZEKERHEID – 15 MIN

U vertelde over [uw takenpakket] en de rol van onzekerheid. Maakt u [in uw taken] verschil tussen soorten onzekerheid?
Hoe kiest u welke informatie over onzekerheid belangrijk is om te delen met beleidsmakers bij KGG?

- Wat is volgens u beleidsrelevante informatie over onzekerheid?
- Maakt u voor communicatie naar beleidsmakers verschil tussen soorten onzekerheid?

Wat is uw ervaring met wat beleidsmakers, bij het ministerie KGG die werken met de KEV, doen met de resultaten van de KEV?

- Wat zijn uw aannames over hoe beleidsmakers om gaan met de informatie over onzekerheid die in de KEV gepresenteerd wordt?
- Wat zouden beleidsmakers moeten doen met de informatie over onzekerheid?
- Waarom is er, volgens u, een verschil tussen de hoe de beleidsmakers met onzekerheid om moeten gaan en hoe ze dat nu doen?

C.2. INTERVIEW PROTOCOL – POLICY OFFICER

SURFACE-LEVEL – 10 MIN

Als ik de Klimaat- en Energie Verkenning noem, wat roept dat bij u op?
Kunt u wat vertellen over hoe u kijkt naar de beleidscontext?

- Kunt u me vertellen over uw eigen taken in dit beleidsproces?
- Kunt u me vertellen over de rol van de Klimaat- en Energie Verkenning in uw taken?
- Wat is voor u belangrijk in dit beleidsproces?

Waar denkt u aan bij onzekerheid in de Klimaat- en Energie Verkenning?

- U noemt daar X Y Z. Als u onzekerheid breder zou moeten definiëren, hoe zou u dat in uw eigen woorden doen?
- Hoe speelt die onzekerheid een rol in uw werk? En hoe gaat u daarmee om?
- Wat vind u belangrijk voor het omgaan met deze onzekerheid in deze beleidscontext?

VERSLAG INTERPRETATIE – 20 MIN

U heeft van tevoren een kort verslag van de KEV 2023 gelezen. Hier is een kopie.
Hoe begrijpelijk is de informatie voor u?
Hoe kijkt u aan tegen de haalbaarheid van de beleidsdoelen?

- Welke kans zou u het geven tussen 0 en 100 % ?
- Zou u hier concluderen dat er een beleidstekort is?
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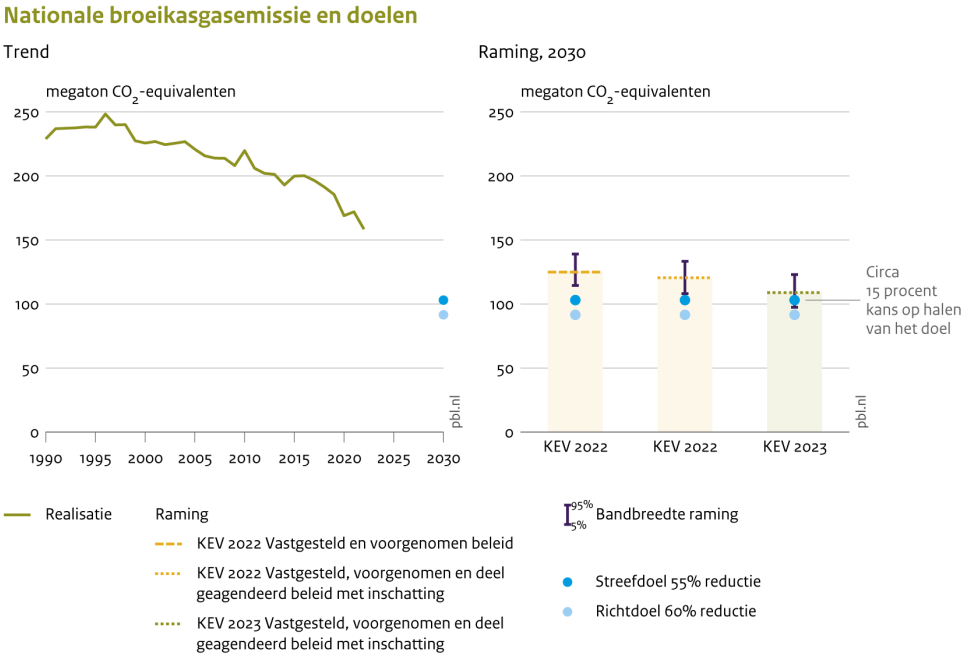
Wat vind u van de relevantie van de gegeven informatie voor beleidmakers?

Er is een nieuwe versie van het figuur.



Bron: Emissieregistratie (realisatie); KEV-raming 2022 en 2023

Is de informatie volgens u verandert en hoe?

- Wat is het effect daarvan voor de keuzes die gemaakt moeten worden voor beleid?
- Wat is het effect daarvan op de begrijpelijkheid?

In de KEV wordt de haalbaarheid van beleidsdoelen aangegeven met een kans of bandbreedte en niet een ja of een nee.
Waarom is dit volgens u? Hoe komt dat dan?

Hoe voelt u zich erbij dat in de uitkomst de haalbaarheid van de beleidsdoelen onzeker is?

- Wat is de impact van deze onzekerheid op uw werk? +Direct/Indirect
- Wat vind u relevant voor de makers van de KEV om te weten over deze impact?

OMGAAN MET ONZEKERHEID – 15 MIN

U vertelde over [uw takenpakket] en de rol van onzekerheid zoals die in de KEV gepresenteerd wordt. Maakt u [in uw taken] verschil tussen soorten onzekerheid?
Welke informatie over onzekerheid is volgens u beleidsrelevant?

- Maakt u daarvoor verschil tussen soorten onzekerheid?

Wat is uw ervaring met hoe de onderzoekers bij PBL omgaan met onzekerheid tijdens hun onderzoek?

- Wat zijn uw aannames over hoe onderzoekers bij PBL omgaan met onzekerheid in de KEV?
- Hoe zouden de onderzoekers met de onzekerheid om moeten gaan?
- Waarom is er, volgens u, een verschil tussen de hoe de onderzoekers met onzekerheid om moeten gaan en hoe ze dat nu doen?

D

INFORMED CONSENT FORM

Toestemmingsformulier

Onderzoek: Onzekerheid in Milieuramingen

U wordt uitgenodigd om deel te nemen aan een onderzoek getiteld “Onzekerheid in Milieuramingen”. Dit onderzoek wordt gedaan door Thirza Bolhuis van de TU Delft met begeleiders Lisa Scholten en Floortje d'Hont (TU Delft). Het onderzoek is onderdeel van een stage bij PBL (Planbureau voor de Leefomgeving) met als begeleiders Shruti Setty en Astrid Martens.

Het doel van dit onderzoek is om percepties van onzekerheid in ramingsprocessen te onderzoeken en te vergelijken. Het interview kost ongeveer 45 minuten. We vragen u om in te gaan op uw persoonlijke ideeën over onzekerheid in ramingen, uw persoonlijke waarden met betrekking tot onzekerheid in de ramingen en hoe u inhoudelijk omgaat met deze onzekerheid in uw werk.

Uw antwoorden worden opgenomen en getranscribeerd. De geluidsopname wordt verwijderd nadat de transcriptie is gecontroleerd. Alle gegevens worden gedeïdentificeerd en opgeslagen op de TU Delft One Drive. De onderzoeker en de eerder genoemde begeleiders van de TU Delft hebben toegang tot de gedeïdentificeerde gegevens, alleen de onderzoeker heeft toegang tot het sleuteldocument met persoonlijke informatie voor identificatie. De persoonlijke informatie omvat uw naam, functie en contactgegevens.

Zoals bij elke online activiteit is het risico van een inbreuk altijd mogelijk. Uw antwoorden in dit onderzoek zullen naar ons beste vermogen vertrouwelijk blijven. We minimaliseren eventuele risico's door uw persoonlijke informatie en eventuele opnames van het interview (schriftelijk of audio) op een met een wachtwoord beveiligde locatie op te slaan voor maximaal de duur van het onderzoek. Alleen de onderzoeker en begeleiders hebben toegang tot deze gegevens, zoals eerder vermeld.

Uw antwoorden zullen worden gebruikt voor een masterscriptieverslag, dat openbaar beschikbaar zal zijn in het universiteitsdepot van de TU Delft. In het rapport zullen alleen geanonimiseerde (en geaggregeerde) gegevens worden gebruikt, vergezeld van een beschrijving van de expertise van de geïnterviewden. Hieronder kunt u toestemming geven voor het gebruik van alleen geaggregeerde gegevens of ook geanonimiseerde citaten in het rapport.

De transcripties worden voor maximaal 10 jaar bewaard op de TU Delft. De data kan worden gebruikt voor onderzoek en lesactiviteiten op het onderwerp onzekerheid in model-based decision-making. De contactgegevens en het sleuteldocument worden uiterlijk aan het einde van het onderzoek, ongeveer in oktober 2025, verwijderd, waardoor al het verdere gebruik van de onderzoeksdata anoniem is.

U moet zich ervan bewust zijn dat er een risico van heridentificatie mogelijk is omdat a) er slechts een laag aantal geïnterviewden is, b) u bij een bekend partnerbedrijf van PBL werkt, of c) u een specialist in het veld bent. In het geval van heridentificatie kunnen er persoonlijke risico's ontstaan, zoals reputatierisico's, omdat u informatie verstrekt op basis van uw deskundige oordeel. Om heridentificatie te voorkomen zullen resultaten alleen anoniem gepubliceerd worden, en zal specifieke informatie in uw bijdrage dat tot heridentificatie kan leiden zo veel mogelijk weggelaten worden. Tevens zal het sleuteldocument met uw naam en contactgegevens verwijdert worden.

Uw deelname aan dit onderzoek is geheel vrijwillig en u kunt zich tot een maand na het interview terugtrekken, maar niet na afloop van dit onderzoek. Het staat u vrij om vragen achterwege te laten. U krijgt een kopie van het transcript van het interview ter inzage en u kunt wijzigingen voorstellen. Als u zich terugtrekt, worden de transcripties van het interview verwijderd en zullen we ons best doen uw antwoorden uit het onderzoek en de publicatie weg te laten.

Contactpersoon: Thirza Bolhuis – t.k.bolhuis@student.tudelft.nl

Verantwoordelijke onderzoekers: Associate professor Lisa Scholten – L.Scholten@tudelft.nl; Assistant professor Floortje d'Hont – f.m.dHont@tudelft.nl

VINK DE JUISTE VAKJES AAN	Ja	Nee
1. Ik geef toestemming voor het opnemen en verwerken van de gegevens die in dit interview worden verstrekt, zoals hierboven beschreven.	☐	☐
2. Daarnaast geef ik toestemming voor het vermelden van anonieme citaten uit dit interview.	☐	☐

Door dit formulier te ondertekenen, stemt u in met het bovenstaande.

Handtekeningen

_____ _____ _____

Naam van deelnemer Handtekening Datum

Ik, als onderzoeker, heb het informatieblad nauwkeurig voorgelezen aan de potentiële deelnemer en, naar mijn beste vermogen, ervoor gezorgd dat de deelnemer begrijpt waarmee hij/zij vrijwillig instemt.

Thirza Bolhuis _____ _____

Naam van onderzoeker Handtekening Datum

Contactgegevens voor meer informatie:

Thirza Bolhuis

t.k.bolhuis@student.tudelft.nl

E

CODING RESULTS IN TABLE FORMAT

Table E.1: Framing - System boundary

Code (number of quotes)	R1	R2	R3	R4	R5	R6	R11	R13	R14	P7	P8	P9	P10	P12	P15	Total participants
Economic																0
EU				1							1	1			1	4
Industry practice		1	1									1				3
Job	1	1		1	1	1	1	1						1		8
Law				2				1			1	1	1	1		6
Model	1						1	1						1		4
Multi-stakeholder	2		3		1	1		1	2						1	7
Numerical check	1	1	1	1	1	1			1	2	2	1	1	1	1	13
Political	2	2	1	4		1		2	1	1	2	2		1	1	12
Social																0
Theoretical																0
Total # different codes	5	4	4	5	3	4	2	5	3	2	4	5	2	5	4	

Table E.2: Framing - Values

Code (number of quotes)	R1	R2	R3	R4	R5	R6	R11	R13	R14	P7	P8	P9	P10	P12	P15	Total participants
Avoid inaction															1	1
Clear communication: Clear Message	1			1	1	2	1	1								10
Clear communication: Nuanced message	1		1	1		1			1		2					6
Clear communication: Transparent Communication										1			2	1	1	10
Collaboration							1	1								2
Credibility								1	1					1		3
Credibility: Independence					1				1							2
Credibility: Political neutrality													1		1	2
Credibility: Science quality	1	2		1	2	2		2	1						1	8
Credibility: Standardisation										1		1				2
Focus on most important uncertainties			1			1	1		1							4
Justice																
Long-term perspective											2					1
Policy-relevance			2	1	1	1	2	1		3	1					8
Realism		2			1							1				3
Relevance to societal debate	1	1	1													3
Reproducible								1								1
Room for expert judgement		1														1
Room for political interpretation											1					1
Total # different codes	4	4	4	4	5	5	4	6	5	3	4	2	2	2	4	

Table E.3: Framing - Definition

Code (number of quotes)	R1	R2	R3	R4	R5	R6	R11	R13	R14	P7	P8	P9	P10	P12	P15	Total participants
Ambiguity																
Bandwidth policy goal			1					1	1	1	1	1		1		6
Complex system		2													1	2
Expected possibilities			1		1							1	1			4
Lack of knowledge: Factors without certainty						1		1	1	1			1	1		6
Lack of knowledge: Unknown future	1	1	1	1	2							1	1		1	6
Risk																
Undecided							1									1
Variance								1								1
Total # different codes	1	2	2	1	2	1	1	2	2	2	1	3	2	2	2	

Table E.4: Interpretation

Code (number of quotes)	R1	R2	R3	R4	R5	R6	R11	R13	R14	P7	P8	P9	P10	P12	P15	Total participants
Ease of understanding: Could be misinterpreted		1		1		1	2			1						5
Ease of understanding: Easy	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
Ease of understanding: Hard																
Probability: +-10																
Probability: +-15											2					1
Probability: +-20					1											1
Probability: +-25%							1									1
Probability: +-5												2				1
Probability: +-50														1		1
Probability: Can't read based on the excerpt	1	1	1			1		1	1				1		1	8
Probability: Not achievable						1					1					2
Probability: Possible to achieve		1				1									1	3
Probability: Small	1			2					1	1	1					5
Probability: Very small	1					1										2
Policy goal: >10%					1											1
Policy goal: >25%		1														1
Policy goal: >50%		1			1						1		1			4
Policy goal: >80%									1							1
Policy goal: >90%		1														1
Policy goal: >95%																
Policy goal: 100%						1	1									2
Policy goal: As much as is in control					1											1
Policy goal: Change the goal																
Policy goal: In the bandwidth (>5%)																
Policy goal: Up to judicial interpretation						1						2		1		3
Policy goal: Up to political interpretation	2	1		2	2	1		1		2	2	2	1	3	2	12
Policy needed: Can't conclude from this excerpt							1	1							1	3
Policy needed: Focus on creating the right circumstances		1		1						1				1		4
Policy needed: No that won't help for 2030					1						1					2
Policy needed: Yes but focus on long-term						1			1		1					3
Policy needed: Yes if you want a larger chance of reaching the goal			1	1				1	1							4
Policy needed: Yes if you want to reach the goal	2	1			1					1		1				5
Total # different codes	6	10	3	6	8	10	5	5	6	6	8	5	4	5	5	

Table E.5: Interpretation-Source

Code (number of quotes)	R1	R2	R3	R4	R5	R6	R11	R13	R14	P7	P8	P9	P10	P12	P15	Total participants
External factors	2		2							1	1	1	1	1		7
Future	1	2		1	1	3					2	1				7
Policy location: Monitoring			1													1
Policy location: Policy execution	1	1		2	1	2		1		2	1	2	1	1		11
Policy location: Policy goal		1		1									1			3
Policy location: Policy-making process		4	1			2		1	1	1			1			7
Probability distribution		1														1
Research location	5	4	1	1		2	1	1		3	1		1	2		11
Research location: Available knowledge						1										1
Research location: Input data							1									1
Research location: Model location	4	4	1			1			1	1	1			1		8
Research location: Model outcome judgement										1						1
Research location: Policy Judgement	1	1		1				1		1			1	1		7
STE location: Abroad	2	3	1					1		1		1	1	1	1	9
STE location: Crisis		1						1			1					3
STE location: Environment	2	1			1	1	1	1		2	1		3	1		10
STE location: Human Behaviour				1		1		2	1		2	1			1	7
STE location: Infrastructure			1	1												2
STE location: Market and economy	2		2		1	1		2	1	3	2		1	1	1	11
STE location: Private party choice				3		2		1				2				4
STE location: Productie		1	1	2												3
STE location: Technology		2			1				1			2				4
Total # different codes	9	13	9	9	5	10	3	10	5	10	9	7	9	8	3	

Table E.6: Interpretation-Typology

Code (number of quotes)	R1	R2	R3	R4	R5	R6	R11	R13	R14	P7	P8	P9	P10	P12	P15	Total participants
Character	1															1
Controllability	2	2	2	2	1	1	1	1		2	2	1	1	1	1	14
Distribution	1															1
Effect size		1	1	1					1							4
Location	3							1			1					3
None				1			1									2
Present knowledge	1	1			1	2									1	5
Temporal			1													1
Typology - Level																
Typology - Nature																
Uncertainty size		1	1						1			1				4
Total # different codes	5	4	4	3	2	2	2	2	2	1	2	2	1	1	2	

Table E.7: Interpretation-Impact

Code (number of quotes)	R1	R2	R3	R4	R5	R6	R11	R13	R14	P7	P8	P9	P10	P12	P15	Total participants
Acceptance		1				1				1						3
Comfort	1	2		2	2		2		2		1				2	8
Interpretation	1				6	1	2			5	1					6
Job at PBL: (Careful) Communication		1			3			1		2			1			5
Job at PBL: Credibility	1								1	1	2					4
Job at PBL: Job complexity	1						1		1							3
Political decision making process: (Effective) Decision space		1	1	1	1			1		4		1				7
Political decision making process: (Political) discourse	2	2	3	3	2		1	1	1		1		2	1	1	12
Political decision making process: More policy effort		1	2		1	1			1							5
Political decision making process: Political decisions		2	2													2
Total # different codes	5	7	4	3	6	3	4	3	5	5	4	1	2	1	2	

Table E.8: Dealing with uncertainty

Code (number of quotes)	R1	R2	R3	R4	R5	R6	R11	R13	R14	P7	P8	P9	P10	P12	P15	Total participants
Accepting uncertainty	1		1			1	1			2	1		2	1	1	9
Action: Communicating	2		1	1		1		1	1			1				7
Action: Generating knowledge / quantifying	2	4	1					1	1	2		1				7
Action: Monitoring and adaptation																
Action: Precaution												1	3		1	3
Action: Reducing uncertainty										3			2			2
Avoiding uncertainty					1								1		1	3
Inaction: Postpoining choice															1	1
Inaction: Withholding ineffective action		1									1	2				3
Inaction: Withholding unnecessary action											1		2			2
Interpretation: Expert Judgement	1			1				1				2				4
Interpretation: Goal adaptation				1							3			1		3
Interpretation: Gut feeling / trust in relationships												1				1
Interpretation: Political consideration	1		1	2						5	4	3	1	2	1	9
Interpretation: Risk consideration												2		4	1	3
Interpretation: Collaborate on definition			1													1
Transforming: Simplify uncertainty							1						1		1	3
Transforming: Strategic reframing									1	2		1		1	1	4
Total # different codes	5	2	5	4	1	2	2	3	3	5	5	9	7	5	7	

Table E.9: Assumptions

Code (number of quotes)	R1	R2	R3	R4	R5	R6	R11	R13	R14	P7	P8	P9	P10	P12	P15	Total participants
PBL does: communicate strategically										1		1	1			3
PBL does: communicate well about uncertainty											1	2	1		1	4
PBL does: focus too much on probability										1						1
PBL does: take caution														1		1
PBL should: consider the impact of their communication														1	2	2
PBL should: have more long-term perspective											1					1
PBL should: should provide more information										6	1		1	1		4
PBL should: stay politically neutral													1	1		2
Policy does: accept uncertainty	1															1
Policy does: avoid uncertainty	1	4	2	2	3				2					1		7
Policy does: change the policy goals			1													1
Policy does: keep well-informed		1	1			2			1							4
Policy does: Not everyone is well-versed in statistics		1		1				1								3
Policy does: not have the design to take uncertainty and the full picture into account		1		1	1	1	1		2				1	1		8
Policy does: strategically reframe the uncertainty	1	1	1	1		2	2			1			1			8
Policy does: want more info than the KEV provides					1				1							2
Policy does: want to score well					1											1
Policy should: beware of tunnel-vision				1			1		1							3
Policy should: create the right circumstances for effective policy				1												1
Policy should: monitor and adapt		1							1							2
Policy should: revisit how goals are set	1	1		1				1								4
Policy should: take ends of bandwidth into account			1						1							2
Policy should: take uncertainty into account more	1	1	2		1	2	2		1							7
Total # different codes	5	8	6	7	5	4	4	2	8	4	3	2	6	6	2	