Policy-relevance of emission scenarios: Policymakers require simpler communicated scenarios, including national detail and actions

Abstract

Abstract: Since 1990, scientific information has not been transformed into effective climate mitigation policies. Integrated Assessment Models (IAMs) and emission scenarios represent a critical scientific tool for analyzing future climate change and the effect of the Paris Agreement. Scientifically, IAMs are considered essential for informing policymakers to avoid future catastrophes. This paper survey delegates of the United Nations Framework Convention on Climate Change (UNFCCC), presenting a timely contribution to ongoing debates about the role of emission scenarios in policymaking. The scenario literature reveals that scientists focus on the quality of scenario content and methods, assessing policy relevance from a scientific perspective. In contrast, we show that policymakers focus on understanding and using scientific tools for negotiations and national policy. Too little attention has been paid to the needs and views of scenario users in discussions about how to develop "policy-relevant" scenarios. We show a contradictory policymaker request for simpler scenario communication and more national detail and clear-cut understandings of efficient century-long mitigation and adaptation actions. We suggest communicating scenario series (and scientific knowledge) separately and in non-technical terms for policymakers with clear links for policy implementation. Modelers need to be selective in the communicated scenario information. To meet the policymaker demand for "national detail", we recommend short-term scenarios to support national policy designs by providing plausible national roadmaps, comparing national targets and global goals. Furthermore, we suggest long-term scenarios to support UNFCCC negotiations with examples of specific global climate policy roadmaps fulfilling the Paris agreement.

Non-technical abstract: Emission scenarios are descriptions of different possible futures. They can all happen, but since they show different outcomes, the realized future may look like one of the scenarios. They show how the global society can develop in terms of energy use, economic growth, population, lifestyles, political ambition, and focus (e.g., on economic growth or sustainable development). These describe the future levels of greenhouse gas emissions by 2100 and how warm the planet may get. The scenarios are created via words (storyline descriptions of the global society and political foci) and numbers (mathematical calculations and translations of the storylines). Scenarios are the only existing tool to track the progress of the Paris Agreement (the short-term policy scenarios analyzing national targets for the Paris Agreement). Other emission scenarios represent the backbone of future climate research (long-term emission scenarios informing the Intergovernmental Panel on Climate Change, used as input for climate scenarios). The latter is used as input for impact scenarios (assessing future damage to nature and human societies and how they are vulnerable to changes in the climate, e.g., more extreme and frequent droughts and storms). The survey informing the paper included 57 UNFCCC delegates. The research shows that scenario developers need to better support policymakers, e.g., more uncomplicated communication of scenarios, more national detail about mitigation actions, their effects and costs, and specific distribution of relevant data and descriptions to non-scientific scenario users. Those policymakers request scenarios that can inform and support national policies to a higher degree.

Keywords: Emission scenarios; policy relevance; science-policy communication; scenario improvements; climate mitigation policy; United Nations Framework Convention on Climate Change (UNFCCC)

1 Introduction

Producing policy-relevant knowledge is challenging (Watson, 2005). Future climate change science aims to support mitigation policy analysis (Moss et al., 2010; van Beek et al., 2020) and is deeply embedded in scenario-based assessments (CAT, 2021a; Kriegler et al., 2014; UNEP, 2021). Emission scenarios are agenda-setting and have been evaluated and criticized by media, politicians (Economist, 2003; McGrath, 2020), and scientists for the past three decades (J. T. S. Pedersen et al., 2022). They are fundamental for

scientifical analyses of future climate change, informing climate and impact scenarios (IPCC, 2022a, 2022b). Historically, emission scenarios and their policy relevance have mainly been evaluated scientifically (J. T. S. Pedersen et al., 2022).
Seen from a policymaker perspective, are emission scenarios relevant for policy, and how can their policy relevance be improved? This paper analyses UNFCCC focal point delegates' perceptions of the policy relevance of emission scenarios and how to adjust them to increase their usability. The postponement of COP26 from 2020 to 2021 caused by the Covid-19 pandemic created an opportunity to survey the often-busy policymakers.

The Science-Policy Interface and the linkages between climate science and policy are based on the increasing need for information (Gluckman, 2016) from the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Environmental Programme (UNEP) (IPCC, 2005d) to provide evidence-based national policies (Chen, 2022; Huitema et al., 2011) and facilitate negotiations toward international climate treaties under the United Nations Framework Convention on Climate Change (UNFCCC) (UNFCCC, 2021). The UNFCCC Conferences of the Parties (COPs) include national delegates with experience as either policy advisors or policy enablers (leading or coordinating policies) (J. T. Pedersen, 2022; UNFCCC, 2020a). Emission scenarios and integrated assessment models (IAMs) aim to inform both science and policymaking (van Beek et al., 2020), while policymakers and UNFCCC COP delegates also request scenarios for policy design (Kriegler et al., 2017). Thus, scenarios and their projected emissions ranges have been interpreted as plausible boundary objects (IPCC, 2018b; UNFCCC, 2020b), bridging science and policymaking. Boundary objects often have different localized meanings and usages, but still, enough shared meaning and coherence to act as a bridge between different groups (Guston, 2001, 1999; Spee and Jarzabkowski, 2009). Since 1996 (IPCC, 1996), stakeholders from international institutions (IPCC, 2007) and local politicians (Kok et al., 2007) have been advising global and national scenario developments, respectively. Such involvements have led to emission scenario criticism (J. S. T. Pedersen et al., 2022), e.g., questioning policymaker intentions (Beck and Mahony, 2017).

User relevance (salience), credibility, and transparency (legitimacy) are all qualities the emission scenarios aim to enhance (Hulme and Dessai, 2008; J. T. S. Pedersen et al., 2022). Therefore, they are useful in evaluating scenarios (Girod et al., 2009; Hulme and Dessai, 2008). This paper focuses on policy user relevance related to emission scenarios' usability in designing national and facilitating UNFCCC COP treaties.
Researchers have questioned the policy relevance of scenarios (Schenk and Lensink, 2007; Schneider, 2001). According to some researchers, the complexity and lack of scientific guidance have lowered the scenario usability in the actual policy context. The high complexity of scientific information may lead to confusion and arbitrary policy decisions because policymakers do not sufficiently understand the scenarios' assumptions (Hausfather and Peters, 2020). Thus, several researchers have suggested that modelers choose the most likely scenario (best-guess scenario) to support decision-making with more straightforward recommendations of which scenarios to consider (Hausfather and Peters, 2020; Schenk and Lensink, 2007; Schneider, 2001). However, this would imply a methodological change in developing emission scenarios (Grübler and Nakicenovic, 2001; J. T. S. Pedersen et al., 2022).
Modelers aim to communicate emission scenarios more straightforwardly via different forms of communication that reduce complexity, e.g., infographics (O'Neill et al., 2020) or non-technical manuals (https://futuremodelsmanual.com/). Historically, researchers mainly evaluated scenario communication, while some studies include policymaker inclusion (Kok et al., 2007). However, the scientific literature does not explicitly cover the IPCC emissions scenarios' role in present-day policymaking and what policymakers perceive as policy-relevant scenario information and adjustments. Since policymakers are among the intended scenario users, it is essential to know how policymakers perceive emission scenarios, their policy relevance, and the requested scenario improvements to assess and understand their policy relevance.

2 Methods

2.1 Survey aims and content

The study focuses on emission scenarios, a crucial scientific tool cutting across the three IPCC Working Groups (WGs) (Gidden et al., 2019; IPCC, 2018), and short-term policy scenarios assessing mitigation policy (CAT, 2021a; UNEP, 2021). Since 1990, the four generations of emission scenario generations within the IPCC (Moss et al., 2010) are grounded in the work of WG3 (climate mitigation) and used by scientists in WG1 (climate science) and WG2 (impacts and adaptation) as essential bases for analyzing future climatic changes. Emission scenarios assess ranges of future greenhouse gas emissions (GHGs) and climate mitigation assessments (IPCC, 2014, 1990; UNEP, 2021), serving as input for climate and impact scenarios (Carvalho et al., 2020; IPCC, 2021). Since 2011 a new type of emission scenario has emerged, aiming to assess the plausible effect of the national pledges expressed within the UNFCCC. First, these scenarios assessed the non-binding Copenhagen pledges (UNEP, 2010; UNFCCC/COP, 2009) and later the National Determined Contributions (NDCs) under the Paris Agreement (UNEP, 2021).

The research design drew upon both qualitative and quantitative methods. It aimed to explore and analyze policymakers' self-reported knowledge and perceptions of the usability of emission scenarios (relevance for) designing national policies and facilitating international treaties within the UNFCCC. Emission scenarios' usability is compared with climate and impact scenarios and three other scientific tools to support policymaking. Furthermore, we examined policymakers' perceptions of scientifically discussed scenario changes to improve their policy relevance.

The data was collected via a survey. All quotes in the paper are based on survey answers unless otherwise expressed. Sometimes, we modify quotations to increase readability without compromising the meaning. The Survey data and initial answers are available in the Open Science Framework repository (https://osf.io/5qctp/). The survey was designed via pre-interviews with researchers and policymakers and informal interviews at COP25 (Madrid, 2019). The interviewees comprised scenario developers (6), researchers and IPCC authors (5), and national policymakers (5). Three policymakers were also researchers. Nine interviewees had UNFCCC, and five had IPCC intergovernmental experience.

The survey used a five-point (11) and seven-point Likert scale (3), open-ended questions (9), and social variables (e.g., age, policy role, and intergovernmental experience. The questions were tested to ensure reliability (answer consistency) via non-ambiguous, simple, and neutral questions communicated in easy-to-understand language. The survey is replicable (SI, 4.2) and hosted through SurveyXact (https://www.surveyxact.dk/). The data was processed in Atlas (qualitative), Excel, and R (statistical).

2.2 Population and Sample

We examined a sample of 57 UNFCCC COP delegates, primarily national focal points, i.e., formally listed contact persons for the respective parties (UNFCCC, 2020a). For COP25, 299 party members were listed as National Focal Point for 196 parties. Twenty-one emails were not delivered. Fifty-seven answered the survey partially or entirely, resulting in a response rate of 21%. The average age was 45 years. The participants identified their primary work role as either policymaker (77%), researcher (11%), or stakeholder/other (12%). Seventy percent expressed experience as formal UNFCCC negotiators, and 83% with national policymaking.

The sample included 38 participants from non-Annex-I countries (67%) and 19 from Annex-I countries (33%). The UNFCCC parties comprise 151 non-Annex-I (78%) and 42 Annex-I (22%), making the sample slightly biased towards Annex-I participation. The Annex structure has guided UNFCCC negotiations since 1992 and expresses developing country parties (non-Annex-I) and parties historically responsible for climate change (Annex-I). The UNFCCC Annex structure may need a reassessment. It was instrumental in designing mitigation obligations under the Climate Change Convention, the Kyoto Protocol, and the Doha

Protocol. However, to a lesser degree, with the self-determined targets under the Paris Agreement. Annex-I had climate financing obligations under the Paris Agreement to support, in particular, the 46 Least Developed Countries (LDC), comprising 25% of UNFCCC parties.

Since the World has changed since the UNFCCC's establishment in 1992, it is relevant to distinguish between income levels and countries' present respective financial capabilities to implement mitigation actions and prepare for UNFCCC negotiations, e.g., human resources and institutional capacity. The World Bank classifies nations as Low-Income, Middle-Income, and high-Income (WB, 2022), representing 28 (14%), 113 (57%), and High-Income 57 (29%) of the UNFCCC parties (J. T. Pedersen, 2022).

For the analysis, we group participants into three groups: LDC (UNFCCC definition, Medium Developed Countries (MDC, WB Middle-Income excluding UN LDCs), and Highly Developed Countries (HDC; WB High-Income) (Table 1). We note that the term developed is highly inappropriate given the massive pollution caused by high-income countries, companies, and people. Income levels account for the UNFCCC principle of respective capabilities (RE) rather than past cumulative emission responsibility of climate change (common but differentiated responsibilities (CBDR)). It is essential to distinguish between income levels since low-income countries are most vulnerable to climate change and have lower capacities to implement mitigation actions than MDCs and HDCs. We combine income levels and annex structure, keeping the UN definition of the LDC group since it is a well-established group in COP negotiations and has not been responsible for the bulk of the greenhouse gas emissions so far.

Table 1. Analytical classifications of participants grouped by income level of the countries they represent

The paper's Classification	No. of participants	Share of sample	UNFCCC population	Definition	Annex group belonging
LDC (Least)	16	28%	25%	UN LDC definition	non-Annex-I
MDC (Medium)	19	33%	46%	WB Middle-Income (excl. UN LDCs)	non-Annex-I & Annex-I*
HDC (highly)	22	39%	29%	WB High-Income Countries	non-Annex-I & Annex-I*
Total	57	100%			

* Three informants representing non-Annex-I are represented in the HDC category, and two representatives of one Annex-I party are represented in the MDC category

Further, it may be relevant to distinguish between informants who inform, advise, or follow policies (policy advisors) and those with practical experience in coordinating, shaping, and leading policies (policy enablers). We expect the latter to have more knowledge about the interests of politicians and policymakers and the kind of scientific knowledge they need and request to design climate policies. In the Supplementary material, we provide analyses of all the paper's figures where informants are grouped by their role in policymaking. The policy advisor-enabler classifications are based on the informants' definition as either having an advisory, informing, or following role (policy advisor (28)) or a coordinating or leading role (policy enabler (29)). Furthermore, when we cite participants, we label them regarding their role in policymaking and UNFCCC COPs (Table 2).

Table 2. Participant classifications for analysis: Role in Policymaking (& UNFCCC role)

	Role in policymaking		**UNFCCC COP role**	
	Policy Advisors Advisory, informing, or following roles	Policy enablers Coordinating or leading roles	Formal negotiator Participated in formal COP negotiations	UNFCCC delegate Non-formal negotiator
All (count)	28	29	40	15
Share (%)	49%	51%	70%	26%
LDC *	12	5	14	3
	21%	9%	25%	5%

MDC	9 18%	9 16%	13 25%	3 5%
HDC	6 11%	15 26%	12 21%	9 16%

* Countries classified as developed countries by the UNFCCC

Regional sample descriptions are included in Supplementary Material (SM) section 1.

3 Results

3.1 Familiarity with and usability of emission scenarios

When policymakers use scientific tools and knowledge, it is essential that they understand those tools. More than 27% of the survey participants expressed low familiarity with emission scenarios. This shows that a relatively high share of the examined delegates, who may have expertise in a wide range of other issues, do not know much about the scientific tool of emission scenarios, which is crucial for mitigation analyses and future climate conditions. Of the about 70% of delegates that have heard about emission scenarios, 40% have little familiarity (know about them but are not sure what they express), 20% were well informed about emission scenarios, and 10% participated in scenario development.

Figure 1 shows the examined UNFCCC delegates' familiarity with emission scenarios. Familiarity is measured by the participants' expressed level of knowledge about them. Low familiarity included answers between “I don't know them at all (1)” and “In-between - I have heard about/seen them but not sure what they express (3)". High familiarity included answers between “I know them (4) - I have seen them and know a *little* about the variables” to “I participated in the developments of some scenario series (6)”. The lowest familiarity was shown in the representatives of Least Developed (LDCs) and Medium Developed Countries (MDC) representatives, having, on average, insufficient or almost insufficient knowledge about the concept of emission scenarios. Most LDC and MDC representatives stated that they did either not know about emission scenarios, had only heard about them, or were unsure what the emission scenarios express. On average, HDC delegates know the concept of emission scenarios between little and very well (4.5 out 6), while MDC (3.6) and LDC (3.8) know them between not sure what they express and a little.

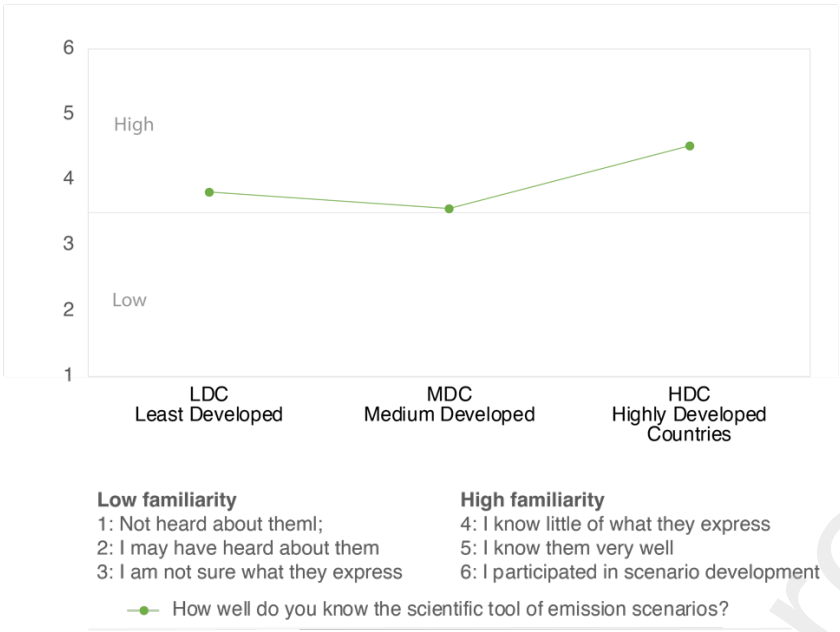

Figure 1. UNFCCC delegates' familiarity with the emission scenario concept. Party delegates' self-reported knowledge about emissions scenarios grouped by grouped least (LDC), medium (MDC), and highly developed countries (HDC).

In the open questions, several LDC and MDC representatives request scientific knowledge, technical support, and scenario training, which no HDC representatives do. This can be because HDC countries often send a large team of representatives and scientific advisors to the COP meetings, have more technical support in ministries, and have higher emissions in their home country, being more aware of related issues. Seeing themselves as the most knowledgeable may give HDC countries an advantage in COP negotiations and designing efficient national policies.

The open questions reflect two different knowledge bases. Typically, HDC participants use advanced terms related to scenario models (e.g., IAMs, variables, downscaling) and variables (e.g., CDR, AFOLU, BECCS). They have more advanced requests for scenario improvements, like "The issues of climate change and biodiversity need to be equally covered in scenarios" (US policy advisor). MDC and LDC survey participants describe scenarios in more general terms, like "reduce their complexity" and make them "transmittable to a national policy context." It is plausible that the latter does not use scenarios as frequently as HDC policymakers because they lack sufficient knowledge and the resources to process them. Another reason could be that they have lower emission levels or do not monitor them. However, LDC participants express a lack of computer power and human resources to process the highly demanding scenario data. They request expert knowledge to understand how the models work, which variables they communicate, and analyze the data for policy.

3.2 The usefulness of scientific tools in designing policies

Figure 2a and b compare the examined policymakers' perception of six types of "Scientific knowledge" related to their usefulness in designing national mitigation policies" and facilitating international climate treaties. These questions aim to assess and compare the policy relevance of the various tools, seen from the perspective of policymakers (i.e., UNFCCC focal points). The top panels contain policymakers' perception of the policy relevance of the three scenario types: emission, climate, and impact scenarios informing the three IPCC working groups since 1990. The bottom panels expresse the perceived policy relevance of policy roadmaps, mitigation costs, and impact costs assessments. The values represents "Not at all (useful)"(1), "Not really (To a low degree)"(2), "in-between"(3), "to some degree useful"(4), and "to a high degree useful"(5) for policy designs.

HDC and LDC informants generally find emissions scenarios more useful for national policymaking (averages of 4.3 and 4.2) than MDCs (3.4). MDC representatives mainly find emission scenarios between low and in-between usefulness in national policymaking. Interestingly, cost assessment is most relevant for LDC and MDC representatives for designing national policies and facilitating UNFCCC treaties. Here impact costs, loss, and damages have been a cardinal point for the non-Annex-I and least-developed countries since and before the Paris Agreement (Dimitrov, 2016; Evans et al., 2021).

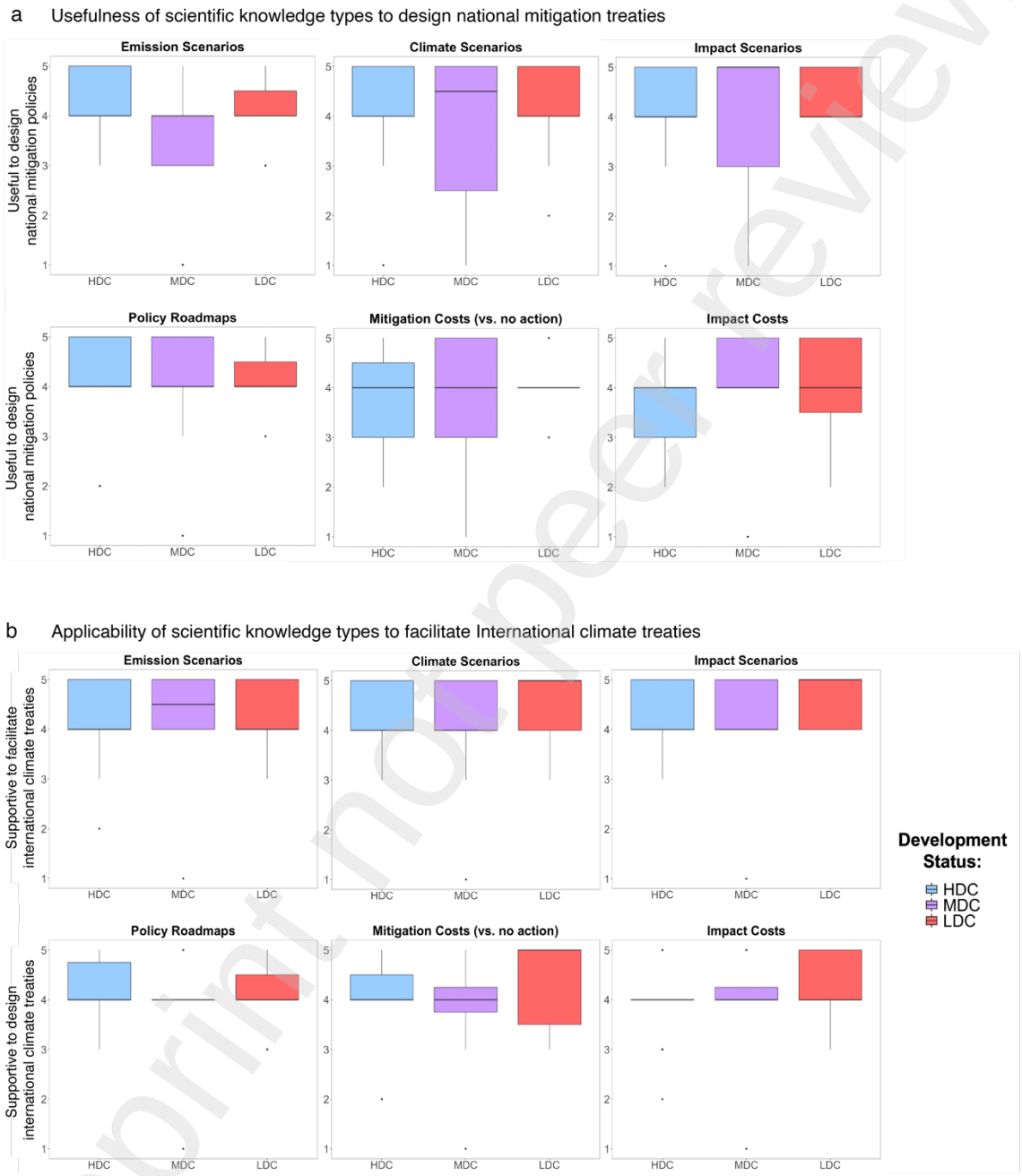

Figure 2. Usefulness of "Scientific knowledge" to design national mitigation policies (a) and facilitate international treaties within the UNFCCC (b). Emissions, climate, impact scenarios (top), policy roadmaps, and economic assessments (bottom).

The participants' perceptions are ordered and ranked according to the 5-Likert scale (1=not at all; 5= Yes, to a high degree). Informants were asked which of the following "Scientific knowledge" types are applicable/supportive to designing national/international climate policies/treaties. The graph shows the 'middle 50%' of the answers. The median (horizontal black line) represents the middle answer, while the box-ends

express the 25% quartile and 75% quartile (comprising 50% of the data responses). Each of the whiskers (vertical black lines) extends up to about 1.5 times the box size (the whiskers extend to the most extreme responses, which are within the range of the upper and lower ends of the box plus or minus 1.5 times the interquartile range (IQR - the box length). Outliers (dots) express low or high responses outside the whisker ranges.

In the context of the UNFCCC, the types of "Scientific knowledge" that are most applicable (supportive) to design and facilitate international climate treaties are the three scenario types (all above 4.2) without many differences across country representatives. In general, the delegates find policy roadmaps less relevant within the UNFCCC processes than in national policy contexts, which makes sense since policy roadmaps often are constructed for national contexts.

Fifty percent of the HDC policymakers' responses are between 4 and 5, and the middle response is 4. The minimum most extreme answer is 3, and the maximum is 5, meaning that none of the HDC policy enablers found emission scenarios unsuitable for designing national policy. The majority found them to be between to some degree supportive (4) and highly supportive (5), while a smaller group found them to be neutral or in-between applicable (3). A high HDC score might be logical as most of the scenarios are developed in HDC countries where the scholars are also familiar with the context (Riahi et al., 2017). In comparison, MDC delegates' responses are between 3 and 4 (50%) and 3-5 (100%). Thus, MDC answers have a similar spread but provide a less supportive answer toward the usability of emission scenarios as HDC delegates. The LDC policymakers perceive emission scenarios as more valuable than MDC policymakers, with 50% of answers located between 4-4.5 and 75% between 4-5, with a few outliers answering 3.

To sum up, the LDC representatives find cost assessments important. Although they represent a larger group of delegates and countries, this may reflect UNFCCC negotiations related to environmental justice and climate financing under the Paris Agreement (UNFCCC, 1992; UNFCCC/COP, 2015). Within UNFCCC, environmental justice, equity, and just mitigation concepts raise issues concerning a just transition toward a low-emission World (Okereke and Coventry, 2016). The need for HDCs to mitigate their emissions and make space for 'developing' countries' emissions has long been on the agenda. Economic support from historical HDC-polluting countries to LDC plays a key role in the Paris Agreement (UNFCCC/COP, 2015) and is continuously being discussed in successive COPs (Pedersen, 2021; UNFCCC/COP, 2022). Thus, it is no surprise that scientific assessments of economic costs are perceived as applicable in facilitating international climate treaties. Cost assessments also guide national policy decisions: "National policymaking is based mostly on economic analysis of current and future costs of actions, the burden on society, and the anticipated level of public and private investments required. Science would be helpful if focused on those economic aspects" (HDC European policy advisor). Notably, the costs of inaction and/or compensating other countries for impacts have seldom been included in such economic analysis.

3.3 Improving the Policy Relevance of Emission Scenarios

Figure 3 reflects UNFCCC delegates' perceptions of five suggested scenario adjustments to improve the emission scenarios' policy relevance. The top panels present issues related to the scenario development process and scenario methods. The bottom panels represent improvements related to scenario communication (e.g., reduced complexity). Figure 3 top shows that the LDC representatives are more favorable toward policymaker inclusion in the scenario development processes. On the contrary, MDC and HDC policy enablers do not find that policymaker inclusions in scenario development processes would increase the scenarios' policy relevance. Additionally, LDCs with the highest scenario familiarity favor policymaker inclusion less than LDC policymakers with low scenario familiarity. The survey did not reveal the causes of this. However, the interviews revealed a degree of distrust towards policy enablers from researchers and policy advisors. They feared that specific political interests rather than scientific arguments would form the scenario outcome. "It is very important to include policymakers. There is a concern, though, since not all policymakers want to know that mitigation is possible" (HDC European policy

advisor). Since 1996, modelers have aimed to include stakeholder and global institutions' perspectives in scenario developments (IPCC, 2005b, 1996), while policymakers have sometimes been included in developing national scenario extensions (Kok et al., 2019, 2007; Patel et al., 2007).

Some policymakers find a best guess (most likely) scenario to improve policy relevance. Mainly MDC and LDC policymakers welcome such methodological scenario changes, although it is very controversial among modelers (Grübler and Nakicenovic, 2001). Policymakers also request comparisons between current policies and target pathways. Several policymakers request more detail on mitigation actions, showing how to meet the Paris goals. Interestingly, the scientific community has already provided current policy pathways and policy target scenarios to calculate emission gaps (CAT, 2021b; UNEP, 2021). However, these scenarios do not explicitly assess national details on how the ideal policy mix can reach national and global policy targets.

There is an explicit request to "promote scientific assessments tailored to the specificities of the countries" (HDC European policy enabler and UNFCCC negotiator). LDC, MDC, and HDC representatives request scenarios with more national detail and real-life knowledge to improve national policy relevance. "Recreate scenarios with local data" (Asian policy enabler and official UNFCCC negotiator), "Tailoring the scenarios to specific countries" (European Policy advisor and UNFCCC negotiator), "Downscale to the national level" (MDC Small Island policy enabler & UNFCCC negotiator), and "Improve regional-scale models" (HDC North American policy advisor). Policymakers request enhanced adjustments to national policies and regional trends (e.g., increased downscaling and nationwide data availability). Here, modelers can improve the scenarios' relevance if scenarios are "analyzed in a correlated way with economic and political data" (HDC South American policy advisor). Some policymakers stated that global scenarios "are not directly driving [national] policymaking". However, scenario modeling has the potential "to check what policy mix would deliver specific emission reduction at what cost within various sectors of a country" (HDC European policy advisor and UNFCCC negotiator). "Scientific knowledge should be translated into national and local levels, like impacts, to inform policies and plans, and to create awareness and engagement of local communities" (MDC Asian policy enabler & UNFCCC negotiator). "Science would be helpful if focused on those economic aspects. National policymaking is based mostly on economic analysis of current and future costs of actions, the burden on society, and the anticipated level of public and private investments required" (HDC European policy advisor and UNFCCC negotiator). The survey did not ask about downscaling. Despite this, several policymakers requested downscaling and more national detail to inform policy designs. "Recreate the scenarios with national detail" (LDC African policy advisor). "Developing countries need localized scientific knowledge so national policies can be appropriately developed using information relevant to the national scenarios" (MDC Small Island State policy advisor). "We also need more regional convergence of social and economic scenarios. Currently, across Europe, for example, different countries are basing their expected scenarios on very different behavioral and technological change assumptions." (HDC European policy enabler and UNFCCC negotiator).

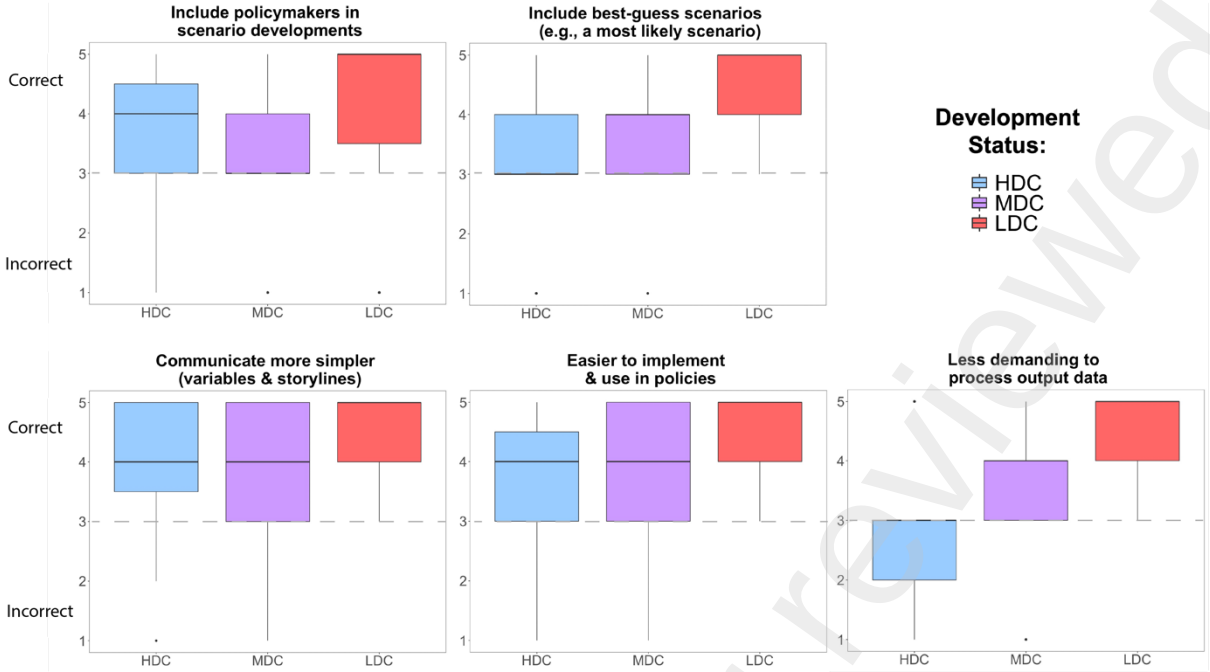

Figure 3. Possible emission scenario changes to improve policy relevance.

Policymakers' perspective on scientifically suggested scenario changes that could support national policymaking. Responses are grouped by Country development level (Least, medium, and highly developed) and policy role (Policy advisor and Policy enabler).

The bottom row of Figure 3 shows that policy enablers find it essential to improve the communication of the emission scenarios (and their variables) in simpler language. Most participants, particularly LDC and MDC representatives, request a better understanding of scenarios. "The challenge is communicating complex science to make it understandable for everyone" (HDC European policy advisor and UNFCCC negotiator). From a policymaker perspective, scenarios will "be used more and become more relevant if they are better understood and simpler information is used to explain them" (MDC South American policy advisor and UNFCCC negotiator) and "be disseminated in a simpler and more understandable format for politicians" (MDC African Policy Enabler). For LDC informants, it also includes giving "more training to technicians linked to emission scenarios" (LDC Small Island State policy advisor and UNFCCC negotiator). "Scenarios should be disclosed more simply and understandably for politicians" (African policy enabler and UNFCCC negotiator). "Emission scenarios can become more relevant and used more if simpler information is used to explain them" (MDC Small Island policy advisor & UNFCCC negotiator). "Scenarios need to be reader-friendly, using simple language" (MDC Middle East policy enabler & UNFCCC negotiator), and "communication of emission scenarios to policymakers should be simpler" (HDC European policy enabler and UNFCCC negotiator). This concerns the communication of scenarios to users with expertise in other domains.

In essence, there is a need to identify simpler forms of communication of scenarios more and focus on selecting the variables relevant for policy designs. This does not mean that scenarios should be simpler. Policymakers request additional scenario detail: to contain more national data. An HDC European-based policymaker said they used the former SRES scenarios from 2000 to develop national scenarios because the SSPs had too complex output data. This exemplifies a need for scenario developers to provide data and descriptions that are easier to analyze and use to shape policies. It covers a need to translate scientific findings into policy-relevant knowledge in less technical language. "The same technical-scientific report can have two versions, one technically rigorous and the other to inform governments, businesses, and the public to support what needs to be done" (MDC South American policy advisor). The SSP-RCP scenario developers aim to meet such improvements in scenario communication. These include infographics,

cartoons, or illustrations of simplified system dynamics and IAMs (O'Neill et al., 2020). However, based on this research, it is crucial to introduce a light scenario version for policymakers that presents easy-to-understand scenario descriptions and data easily implemented in policy analyses. These would co-exist with the current and more complex scenario databases for scientific users.

4 Discussion

The science-policy communication of emission scenarios is not sufficiently tailored to policymakers' needs, potentially constraining their use in low-, middle, and high-income countries policy designs. We show that the examined policymakers focus on understanding and using scientific tools for negotiations and national policy. This contrasts with the scenario literature, where scientists focus on issues related to the quality of content and methods.

4.1 Tailormade science communication

Scientific advisories aim to support evidence-based decision-making, injecting competent and critical intelligence into the regulatory system (Janasoff 1990). Scenarios form a critical element of the science-policy dialogue. Such a dialogue is complex: it requires the right balance between complexity, uncertainty, and clear messages. In the climate field, the information about limits, urgency, and recommended anticipative actions is deeply connected to the use of short-term (UNEP, 2022) and long-term scenarios (Rogelj et al., 2019; van den Berg et al., 2020) and carbon budget assessments (Friedlingstein et al., 2022). Formulating clear climate targets allows for understandable concepts and suitable simplification for non-specialists. This was already emphasized in the past (Rijsberman and Swart, 1990; van der Sluijs et al., 2016), with efficient scientific communication of the 2°C target, which facilitated UNFCCC negotiations toward two agreed policy targets (Dimitrov, 2016; Morseletto et al., 2017). Science communicated an (uncertain) estimate to support decision-makers on what is dangerous climate change. It was an easily understandable concept, suitably simplified for non-specialists. The scientific recommendation was accompanied by continuously highlighting its uncertainty range (Rijsberman and Swart, 1990; van der Sluijs et al., 2016), e.g., related to the complexity of variables (Morseletto et al., 2017; Shaw, 2009).

The clear targets allow for simple communication and easy-understandable messages. Science communicated a threshold customized for decision-makers. Without the customization, policymakers may have trashed it as not understandable or for not directed at a specific policy use. Part of the competent intelligence implied simplified information (with underlying uncertainty). Another part was that it comprised a clear scientific recommendation that could be translated into a policy objective.
Like the temperature threshold, scenarios contain complexity. For three decades, emission scenarios have been communicated with an uncertainty range, exemplified by high to low-emission pathways. This has led to critiques for too high complexity, compromising policy relevance (J. T. S. Pedersen et al., 2022). It led to scientific recommendations for producing frequency distributions (method change) and scientifically selecting a most likely best-guess scenario to support policymakers in choosing a scenario to follow within the range of multiple scenarios (Hausfather and Peters, 2020; Schneider, 2001). Our results show that the examined policymakers do not request a best-guess scenario. Instead, they request a current scenario and assessments of emission gaps to reach the Paris goals. Short-term scenarios provide these. In addition, they request assessments of the actions needed to fill the gap, which is neither provided by the short-term scenarios (national mitigation details) nor the long-term scenarios (global mitigation roadmaps).
The success of the 2°C intelligence may inspire scenario communication. Based on policymaker feedback, scenarios could be communicated more simpler, and the information presented tailored toward policy objectives. Providing explicit policy roadmaps with different combinations of century-long policy mix to current (baseline) pathways and Paris-compliant scenarios would meet policymaker requests for straightforward communication and details relevant to policy designs. Such assessments are demanding and uncertain and may risk being criticized for being policy prescriptive. However, it would arguably increase the applied policy relevance of scenarios.

4.2 Science-policy co-creation with focus on communication

The results reveal that MDC and HDC policy enablers do not find that the policy relevance of emission scenario would improve via policymaker inclusions in scenario development. However, there is a need for increased communication between the science and policy fields. Projecting future conditions, emission scenarios have potential to inform both national and global mitigation actions valuable to fulfill the Paris Agreement.

There is a difference between communicating a 2-degree limit for policymakers (to negotiate a temperature policy target) and a range of emission scenarios based on complex combinations of interrelated variables. Although potential to inform mitigation strategies, scenarios are not easily communicated to non-scientific users. We reveal some gaps between the aim and usability of emission scenarios, e.g., policymakers need a better understanding of them, the communication of scenario details needs to be more selective, and the content can be customized to specific policy requests and objectives.

Policymakers present a contradictory request for both more straightforward and detailed scenarios. It reveals a need for more complex scenarios that are communicated more simpler, e.g., highlighting specific details. Simpler communication is related to two policymaker issues: 1) several policymakers need to become familiar with and better understand scenarios, and 2) a general request to only communicate relevant knowledge for policymaking without unnecessary noise.

Going beyond the relatively unsurprising call for making scenarios "simpler", it is valuable to science and policymaking that scenario developers further explore effective scenario communication. This justifies science-policy co-creation on what is important information for policy is essential. Historically, researchers are divided on science-policy cooperation on whether to favor a science-policy co-productive *"one world"* over being skeptical towards potential policy-science scenario cooperation (Beck and Mahony, 2017; Lövbrand, 2011). Some researchers favor a separated *"two worlds"* approach with no collaboration between *the* science and policy fields (Sundqvist et al., 2018). This research shows that also policymakers are concerned about potential policymaker inclusion in creating scenarios. Exemplified by the European policy advisor fearing that some policymakers would argue against mitigation (section 3.3.), emphasizing the risk of too detailed policymaker interference. The risk implies that political reasoning rather than scientific reasoning might guide scenario developments, potentially interfering with credibility. Despite such risks, co-creation appears essential. Several policymakers highlight a "better coordination between public entities and academia and greater promotion of the need for informed decision-making" (HDC South American Policy Advisor). To overcome some of the concerns, the science-policy co-creation may focus on communicating scenarios rather than developing scenario content.

4.2.1 Policy relevant scenarios without unnecessary noise

Science-policy cocreation on scenario communication may include that modelling teams facilitate feedback from policymakers (and scientific users) on what specific scenarios are needed and for which types of actions, and which types of "more detailed" information are relevant for policy designs. Regarding, the request for cost assessment of mitigation actions, examples of themes could be setting emission reduction targets in NDCs, calibrate adaptation policies, figure out the correct level of CO_2 prices, or guide R&D decisions. The answer to such questions is crucial for understanding what type of knowledge is essential to communicate in scenarios and how to communicate them efficiently.

Regarding more straightforward communication, the policy relevance of the scenario series could be improved by introducing a non-technical description for policymakers, communicating only the key variables that are related to policymaking. It could express easy-to-understand scenario data connected to a new type of policymaker scenario database including easy-to-implement-data for policies and processes (side-by-side with the existing scenario databases for scientific users). The light version includes "developing appropriate storylines that lead people [non-scientists] to identify with the scenarios" (Portuguese policy enabler and UNFCCC negotiator). What these scenarios express, the type of information communicated, and how they are displayed could be developed in co-creation with policymakers, particularly policymakers representing a wide variety of LDC countries.

4.2.2 Science-policy comprise two different worlds

For efficient scenario communication and science-policy interactions, it is relevant to acknowledge that the science and policy fields are two very different contexts. They are interested in similar knowledge areas but have different understandings of that knowledge and use it for various purposes.
One relevant consideration in the communication is that policy processes do not frequently reach a consensus over science use (Janasoff 1990). However, it is up to policymakers to make the final conclusion and decision based on the scientific recommendations (Gupta and van Asselt, 2006; Morseletto et al., 2017; Rijsberman and Swart, 1990). Therefore, policymakers need to communicate their specific needs and the relevance of their request to modelers. In turn, researchers need to ensure that scenarios are communicated efficiently to policymakers profoundly. This may not imply the co-creation of scenarios but an exchange of needs, e.g., what type of knowledge is relevant for which policy objectives, and afterward usability-testing if policymakers sufficiently understand the communicated scenario knowledge.
Another consideration is that, in science-policy communication, the time horizons also differ. "Politicians are concerned with short-term plans based on their time of 4-5 years, so they tend to gravitate towards shorter-term goals" (MDC South American policy advisor and UNFCCC delegate), while climate scientists work with planetary timelines and long-term goals. New fora for science-policy communications may facilitate solutions to overcome or efficiently deal with such fundamental challenges related to long-term climate assessments and scenarios and a specific policymaker need for current and near-term action recommendations.

In essence, policymakers need to communicate their specific needs regarding scenarios. In turn, researchers need to ensure that scenarios are communicated efficiently to policymakers profoundly. This may not imply the co-creation of scenarios but an exchange of needs, e.g., what knowledge is relevant for which policy objectives, and afterward, usability-testing if policymakers sufficiently understand the communicated scenario knowledge. More effective communication between the science and policy fields may support developing policy-relevant knowledge. It is essential to develop processes where the scientific content reflects the needs of policymakers and sufficiently informs and addresses the challenges of policy designs without compromising the scenario's credibility.

5 Conclusions

The paper aimed to assess the policy relevance of emission scenarios seen from a policymaker's perspective. This is less explicitly communicated in the literature. We show that several policymakers have insufficient scenario knowledge and need guidance to use scenarios correctly and efficiently. Least- (LDC) and medium-developed country (MDC) representatives have less insight about emission scenarios than highly developed country (HDC) representatives. Because low scenario knowledge and few human capacities, several LDC and MDC representatives request scenario training to be able to use scenarios in policymaking.

Policymakers find emission scenarios to be, to some degree, relevant for designing national policies and facilitating international climate treaties. According to the least and medium-developed country representatives they are less relevant for national policymaking. Paris-compliant scenarios are perceived as relevant, communicating processes toward policy goals. Policymakers also like that scenarios communicate economic growth. However, they face problems in communicating policymaker-requested actions to reach below 1.5 °C, facilitating the understanding of the problem, identifying the conditions that make action effective, and developing appropriate storylines that lead policymakers to identify with the scenarios.

Scientific communication of scenarios is not sufficiently tailored to policymakers needs. Two issues transcend the policymaker's requests. On the one hand they request simpler communication and reduced complexity. It implies presenting scenarios in a more basic language and also provides capacity building and training on how to use them, e.g., to policymakers and technicians. The policymakers want to know what the scenarios express (narratives and variables) and what they can be used for. We show that also in high-income countries, the emission scenario complexity risk constraining their use in current policy designs. Thus, scenario policy relevance depends on simpler communication of the scenario narratives and

the databases and numbers underlying the storylines. One suggestion is to communicate two versions: a technical-scientific and non-technical, to inform governments, businesses, and the public.
Second, several policymakers request additional scenario information (not yet explicitly included in emission scenario communication), e.g., more national detail, cost and efficiency of mitigation (and adaptation) actions. Several policymakers express that the global scenarios are not directly driving national policymaking but have the potential to communicate what policy mix would deliver specific emission reduction and at what sectoral costs. Since national policymaking is concerned with economic analysis of current and future costs of actions, scenarios must assess the needed mitigation investments. On a global level, policymakers request the long-term scenarios to become more action-oriented, e.g., information about the needed increase in renewable energy capacity, and targets for particular sectors instead of theoretical indicators like emissions reductions or intensity changes. Policymakers request knowledge about where the World is now, which is provided by the short-term baseline scenarios assessing current national targets. They also request scenarios explaining how to reach the Paris policy targets. Today's mitigation scenarios do not reveal recommendations for policy-mix actions needed to reach one key policy objective of staying below 1.5 °C increase by 2100.

The two types of requests contradict each other. On the one hand, emission scenarios need to be communicated simpler to be understandable for policymakers. This is crucial for them to be useful in policy designs and facilitating international treaties. On the other hand, they need to contain more variables, increasing their complexity. The request for more national detail, however, despite becoming more complex, scenarios can still be communicated simpler, including what is most relevant for policymakers (and other users). Today no policy roadmaps are connected to scenarios. Scenarios may increase their policy relevance if they clearly focus on policymaker needs and explain how they can be used to support policy objectives, e.g., communicating various policy-mix for national and global mitigation.

The paper's key recommendations imply strengthening scientific communication of scenarios to a broader audience that, to a higher degree, includes practical policy communication with clear links for policy implementation to policymakers (and the public) and that the UNFCCC and HDC parties strengthen the knowledge base and use of scientific tools in MDC and LDC countries. We show that the examined policymakers focus on understanding and using scientific tools for negotiations and national policy. This contrasts with the scenario literature, where scientists focus on issues related to the quality of content and methods. Scenarios' policy relevance may improve when policymakers are provided ways to communicate their needs, requests, and (scenario) challenges to scientific developers. Such processes have already been facilitated by scientific institutions and the IPCC but could also include the UNFCCC.

Data availability

The datasets generated during and/or analyzed during the current study are available in the Open Science Framework repository https://osf.io/5qctp/ and SI Excel. Additional data analyses, figures, and datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request. Identities and nationalities are anonymized. Besides that, no data availability restrictions exist. The survey is accessible in SI Word and on the SurveyXact platform (https://www.surveyxact.dk/).

Code availability

The t-Test codes used in this study are available in SI Excel and the Open Science Framework repository, https://osf.io/5qctp/. Additional R codes or algorithms used during the current study (but not used in results and conclusions) are available from the corresponding author upon reasonable request.

Ethical statement

Because of the nature of intergovernmental negotiations, the information provided is potentially sensitive. Thus, the survey participants' identities and nationalities are excluded from the manuscript and

Supplementary information. The xx provided guidelines for study procedures. The xx and yy approved the study protocol. More detail about the different stages of the research is available from the corresponding author on reasonable request.

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