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# Stakeholder engagement and decarbonization pathways: Meeting the challenges of the COVID-19 pandemic

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Climate change is an extremely complex challenge characterized by its systemic nature and deep uncertainties. Thus, finding solutions requires a continuing and constructive dialogue between the research community and a wide range of stakeholders from governments, non-governmental organizations, civil society, international organizations, industry, businesses and financial institutions. The ENGAGE project (<https://www.engage-climate.org/>) is advancing knowledge co-production through an iterative process of stakeholder engagement with two main streams: (i) stakeholder co-design and assessment of global decarbonization pathways and (ii) stakeholder dialogues on national policies and pathways. Both the global and national stakeholder processes are designed to inform multiple project activities, including: conceptualization of feasibility and assessing the feasibility of decarbonization policies and strategies; decarbonization pathway development using integrated assessment models and considering both feasibility and equity; and assessment of the relative importance of climate change impacts vis-à-vis potential co-benefits. With the start of the COVID-19 pandemic 6 months after the beginning of the project, all of the stakeholder engagement activities had to be organized as online events. Between March 2020 and April 2022, 5 online workshops were organized, two at the global level and 3 at the regional/national level. This paper documents how the challenges of effectively engaging stakeholders in a co-design and dialogue process in an online setting have been met through a process of evaluation and learning that led to the introduction of new approaches and tools to support an inclusive exploration and development of low-carbon transition pathways. We show that a combination of interactive visualizations, open channel surveys and moderated breakout groups are particularly useful tools for online stakeholder engagement. The learning that has taken place through the use of these tools is demonstrated with reference to both the research team (e.g., learning about stakeholders' views on the feasibility of decarbonization pathways) and the stakeholders (e.g., learning about experiences in other countries in dealing

with the challenges of decarbonization). The results of using these tools have been used within the project in the design of new decarbonization pathways using integrated assessment models, in the development of a framework for feasibility assessment and in increased attention to socio-economic drivers of change. We conclude that despite several advantages of online engagement, such as the expanded geographical coverage and reduced CO<sub>2</sub> emissions, the need to keep online meetings short means that important elements of face-to-face meetings cannot be included. Online activities cannot completely replace physical meetings when dealing with complex issues such as climate change.

#### KEYWORDS

stakeholder engagement, COVID-19, decarbonization, feasibility, online tools, learning

## 1. Introduction

Climate change is widely recognized as one of the most important challenges of our time (EEA, 2018). As a complex and persistent problem characterized by deep uncertainties, it poses challenges to a very broad range of societal actors, including the research community (Tàbara et al., 2017, 2019). As pointed out by Tàbara et al. (2019), conventional solutions to deal with the causes and consequences of climate change will not be enough to prevent so-called “high end” global warming scenarios. They call for new modes of agent interaction, engagement and knowledge co-production to support transformative change and point to the need for open processes of dialogue that focus less on the problem (e.g., impacts, risks, and vulnerabilities) and more on the solutions. Moving the focus toward solutions is challenging, because, as Chomsky (2022) has pointed out, the solutions are not only technical and will require consideration of issues such as justice and just distribution. To find solutions requires an understanding of the political, social and economic systems that lead to climate change and shape responses to it (Chomsky, 2022).

Moving toward agent interaction, engagement and knowledge co-production within research requires careful attention to the process of stakeholder engagement. There are different levels of engagement starting from simply informing or consulting with stakeholders to strong involvement at all stages (Arnstein, 1969). The level of engagement and thus the approaches used depend on the context (Jetoo, 2019). For example, the Climate Investment Fund<sup>1</sup> considers five levels of engagement: information access and dissemination; policy dialogue; policy and programmatic consultation; collaboration and partnership. While all of these levels except the first (dissemination) involve a two-way interaction between the

project team and the stakeholders, the expected outcomes of each level of engagement differ. For example, while a partnership approach can lead to common goals and action, the expected outcome of consultation is simply that the views of stakeholders are taken into account. In this paper, we focus mainly on information access, policy dialogue and consultation.

Several reasons for engaging stakeholders in scientific research have been discussed in the scientific literature (see, for example, Bohunovsky et al., 2011). Stakeholder engagement “can help ensure the inclusion of the broad range of knowledge necessary to work with complex systems, as well as increase legitimacy, ownership, and accountability for both the problems and potential solutions” (Schoonover et al., 2019, p. 1).

Engagement enhances the use of local and specialized knowledge, such as lay, experiential, and intuitive knowledge that can lead to the emergence of new ideas to deal with complex, wicked societal problems and supports “buy in,” since people are more willing to accept results and insights, if they are part of the process in which they were produced (Hirsch Hadorn et al., 2008; Jäger et al., 2008; Drews and van den Bergh, 2016). Through the engagement process, mutual (social) learning between science and society can take place (Pahl-Wostl, 2002; Jahn et al., 2012), which is an important factor for overcoming rigid positions to be able to collaborate. For modeling, engagement can help to provide a better representation of social agents’ behavior and a social-ecological robust depiction of the system of reference under consideration (Tabara et al., 2007). In addition, the participants also contribute to the communication of the results of the study and support the implementation, in particular if the research tackled a topic which is important to them and which addresses their needs. While many projects have engaged stakeholders from decision-making, business and industry, and civil society and environmental non-governmental organizations, more attention has been paid recently to the engagement of youth as an important category of stakeholders.

As noted by UNDP (2022) has pointed out, there is an urgent need for more youth-inclusive and youth-responsive

<sup>1</sup> [https://www.climateinvestmentfunds.org/sites/cif\\_enc/files/knowledge-documents/country\\_level\\_stakeholder\\_engagement\\_study.pdf](https://www.climateinvestmentfunds.org/sites/cif_enc/files/knowledge-documents/country_level_stakeholder_engagement_study.pdf)

environmental action given both the disproportionate impacts that the climate crisis has on youth and future generations, and the need to address youth rights, needs and aspirations.

This paper reports on and analyses results from the Exploring National and Global Actions to reduce Greenhouse gas Emissions (ENGAGE) project (<https://www.engage-climate.org/>). This project, which started in September 2019, is developing, using integrated assessment models, a new generation of global and national decarbonization pathways that meet the goals of the Paris Agreement. A particular focus of the project is on the feasibility of decarbonization pathways (Jewell and Cherp, 2020; Brutschin et al., 2021). Furthermore, the project is quantifying national avoided impacts of climate change and identifying decarbonization pathways that maximize co-benefits and minimize trade-offs. All of these activities are supported by a process of stakeholder engagement to allow a co-production of project results.

The stakeholder engagement in the ENGAGE project has two main streams: (i) stakeholder co-design and assessment of **global** decarbonization pathways and (ii) stakeholder dialogues on **national** policies and pathways. Both the global and national stakeholder processes are designed to inform multiple project activities. The initial project design proposed to hold three global stakeholder dialogues and four national level dialogues in countries/regions in which project partners are active: China, India, Brazil, and Europe. However, with the start of the COVID-19 pandemic 6 months after the beginning of the project, all of the stakeholder engagement activities had to be organized as online events. Between March 2020 and April 2022, five online events were organized, two at the global level and three at the regional/national level.

The impact of the COVID-19 pandemic on stakeholder engagement in research projects in Europe has recently been documented in other papers. Süsser et al. (2021) show how the pandemic affected engagement in energy-related projects. In the projects surveyed by Süsser et al. (2021), they found that during the first wave of the pandemic in 2020 only one of six engagement activities could be implemented as planned, and almost half were canceled or delayed. Engagement activities that went ahead were mainly carried out through webinars or online workshops. Köpsel et al. (2021) examined the impact of the first wave of the pandemic on ongoing EU-funded marine science projects, in which stakeholder engagement was carried out online. These papers both report on the early stages of the pandemic and focus on the immediate impacts on research and engagement without going into detail on the process of online engagement.

This paper documents how the challenges of effectively engaging stakeholders in a co-design and dialogue process in an online setting have been met in the ENGAGE project through a process of evaluation and learning that led to the introduction of new approaches and tools to support an inclusive exploration and development of low carbon transition pathways. Within

the ENGAGE project, we were faced with three challenges: (1) obtaining feedback on results from integrated assessment models, which involved communicating systems thinking that is unfamiliar to some of our stakeholders; (2) engaging in dialogues on feasibility and effort sharing, which are multidimensional concepts for which participants can have slightly different definitions and perceptions; and (3) carrying this out in an online setting due to the pandemic. In this paper we demonstrate how these challenges can be managed by combining different communication tools in an online setting.

Section 2 of the paper provides more information on the five online workshops and a detailed discussion of the tools and approaches used for stakeholder engagement. Section 3 assesses the results of using these tools and approaches with a focus on the insights gained by the stakeholders and the research team, as well as a comparison of the potential advantages and disadvantages of tools and approaches in online vs. physical meetings. Overall we find that an online setting offers new avenues to systematically collect data through interactive tools but generally does not allow for more personal and in-depth discussions. The final section draws some conclusions on the challenges and opportunities for stakeholder engagement in online settings and concludes that despite the learning that has taken place in the ENGAGE project, there will always be a need for face-to-face dialogues as well.

## 2. Methods

### 2.1. Online workshops with stakeholders

As noted in the Introduction, the ENGAGE project aims to engage with stakeholders in order to co-produce decarbonization pathways, to discuss multidimensional topics such as “feasibility” and “effort-sharing” and to share information to support the achievement of the Paris Agreement goals. We argue in this paper that the challenge of collecting stakeholder feedback in an online setting on highly complex issues can be met through a systematic combination of different tools and approaches (see Figure 1), containing three key parts: (1) introduce, (2) involve, and (3) reflect. We have used a variety of tools to **introduce** topics to stakeholders, especially presentations and, in one workshop, posters. We often invited prominent speakers for introductory presentations to elicit more interest on the stakeholder side. This was an essential part of any stakeholder engagement, to explain the “big picture,” the purpose of decarbonization pathways developed in the ENGAGE project, and the overall goals of a meeting. To **involve** stakeholders in our work during a meeting, we have used short surveys and interactive visualizations pertaining to key concepts or results from integrated assessment models. This way we could collect structured feedback from all stakeholders. We have also included moderated discussions in small groups in

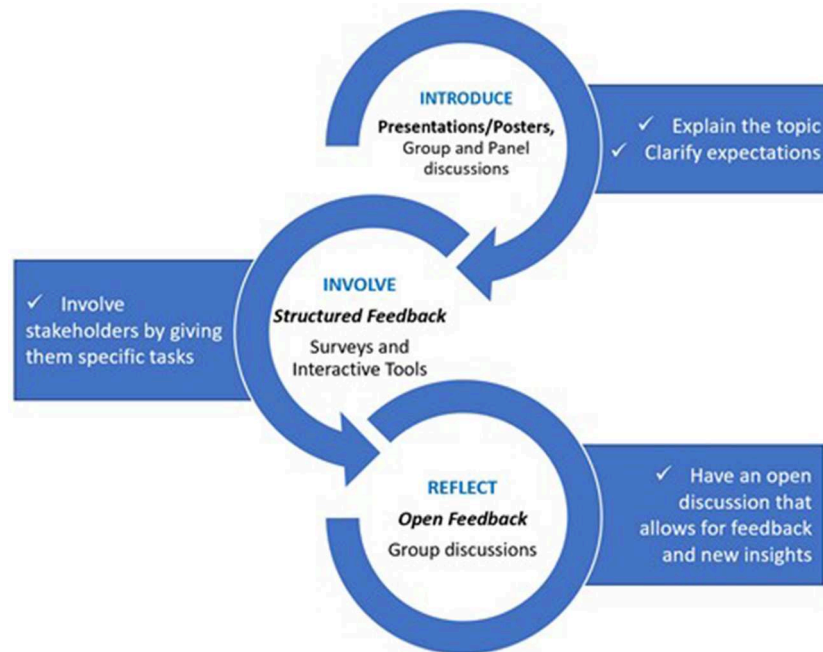


FIGURE 1 Tools and approaches to achieve the diverse goals of stakeholder engagement in the ENGAGE project.

order to provide an open space for *reflection*—this allowed us to collect more general feedback and gain new insights. Finally, after each workshop, the project team has collected internal feedback in order to improve the design of following workshops if necessary. In addition to the direct interactions during online meetings, we also conducted more systematic surveys that were sent out to and thus *involved* a larger pool of stakeholders.

As noted above, stakeholder engagement has been carried out between March 2020 and April 2022 in online Workshops. In addition, as discussed further below, broader engagement has used an online survey. Table 1 provides information on the five online workshops.

## 2.2. Stakeholder selection

The first step in the stakeholder engagement process was to identify the key stakeholders with whom we would like to engage in workshops. Our approach was based on the process set out by Gramberger et al. (2015). This process sets quotas for the different types of stakeholder (e.g., policy, business and industry, academia, and environmental non-governmental organizations), as well as for gender distribution and age distribution. An initial invitation list is set up to provide a distribution of participants relevant to the planned workshop (see next paragraph). After a first round of invitations, further invitations were sent out in order to get as close as possible to the desired distribution of participants. For example, if the

initial decision is to aim for 50% female participation, the initial invitation list will contain 50% females. If the response to the invitations is such that the participant list has only, say, 30% females, then the second round of invitations will include more females in order to get closer to the desired level of participation.

While policy-makers at the national level and those participating in international negotiations are obviously key stakeholders, we also felt that it was important to engage with other societal actors, who are either strongly affected by decarbonization pathways or whose decisions can affect those pathways. This meant that the goal was to identify stakeholders from the realms of policy-making, business and industry, finance, and non-governmental organizations and academia. The latter category was not prioritized in the stakeholder selection. All project partners were asked at the ENGAGE kick-off meeting and in e-mails thereafter to contribute to this task. The suggestions for stakeholders are kept in a non-public database. A list of more than 300 potential stakeholders was collected. The compilation covered all of the categories of stakeholders and the geographical areas covered by the project, as well as the national and global levels (Table 2). This list has been updated throughout 2020–2022, to increase coverage and to generate specific lists for regional workshops.

Stakeholder selection always depended on whether the workshop was for a particular region (Europe, Asia, and global) and what the topic of the workshop was. For example, for the Asian workshop, with advice from regional project partners, we selected participants who would be interested in

TABLE 1 Online workshops with stakeholders.

	Workshop 1	Workshop 2	Workshop 3	Workshop 4	Workshop 5
Date	March 2020	June 2021	September 2021	January 2022	April 2022
Global/regional	Europe	Global	Asia	Global	Brazil and Latin America
Thematic focus	Decarbonisation pathways	Net-zero	Net-zero	The implications of COP26 for research	Net-zero
	Barriers and enablers	Pathways to net-zero	Modeling results on net-zero		Modeling results on net-zero
	Gamechangers	Feasibility	Feasibility		Feasibility
			Equity		Equity
Number of participants (including the project team)	45	31	83	80	53
Stakeholder types**	Policy, research, e-NGOs, s-NGOs, business and industry	Policy, research, e-NGOs, s-NGOs, business and industry, youth	Policy, research, e-NGOs, s-NGOs, business and industry, youth	Policy, research, e-NGOs, s-NGOs, business and industry, youth	Policy, research, e-NGOs, s-NGOs, business and industry, youth
Stakeholder country*	EU, RO, DK, BE, NL, IT, SI, AT, DE, HU	EU, RO, DK, BE, NL, IT, SI, AT, DE, HU, US, PA, FR, ID, ZA	TH, EU, IN, KR, VN, JP, IT, AT, CN, UZ, LK, PH, ID, DE, LB, MY, PK, KH	EU, RO, DK, BE, NL, IT, SI, AT, DE, HU, US, PA, FR, ID	BR, MX, AT, EC, AG, UK, NL, BE, EU, PY, HU, PA
Engagement tools used	Presentation	Presentations	Presentations	Presentation	Presentation
	Posters	Group discussions	Group discussions	Panel discussion	Group discussions
	Group discussions	Panel discussion	Feasibility tool	Group discussions	Feasibility tool
	Survey	Feasibility tool with survey	Survey	Survey	Survey

\*Where the stakeholder is currently living/working.

\*\*Environmental NGOs (e-NGOs); civil society NGOs (s-NGOs).

TABLE 2 Composition of the initial stakeholder list.

Sector	Number of stakeholders	Diff. types of organizations	Countries represented	Gender balance male: female: undefined
Policy/administration	107	64	29	57: 37: 6%
Finance	17	14	9	65: 35: 0%
Business and industry	42	39	14	58: 33: 9%
NGOs	48	33	19	46: 54: 0%
Academic and research	61	45	22	56: 31: 13%
Other	30	26	20	50: 40: 10%
In total (approx.)	305	221	35	55: 38: 7%

the results of modeling of decarbonization pathways using models developed in the region. In addition, we also selected participants, who would provide regional information on the feasibility of decarbonization pathways.

In addition, a broader list of stakeholders to be contacted only for the administration of online surveys was compiled. This list includes 878 contacts and was put together with a snowball sampling methodology from different seeds, with the objective of covering the most comprehensive set of countries, focusing on the highest emitters. The list was

compiled combining (1) publicly available contact details of members of UNFCCC focal points, Green Climate Fund focal points, and UNFCCC COP delegates, (2) contacts of stakeholders and policymakers made available through direct connections of ENGAGE consortium members, and (3) contacts of other policymakers and stakeholders made available by direct contacts of ENGAGE members. Importantly, the list is treated in accordance with the ECPR regulation, and all survey responses were treated as completely confidential.



## 2.3. Engagement in the workshops

This section briefly describes the tools and approaches used in the workshops. [Figure 2](#) shows the timing and focus of the workshops. Each workshop was designed to provide input for the project. For example, in the first workshop, a set of existing decarbonization pathways was used to inform the stakeholders but also to collect ideas on possible other pathways that could be modeled in the ENGAGE project, an interactive session was used to involve stakeholders in the exploration of enablers for and barriers to decarbonization that were subsequently used to develop a multidimensional feasibility framework and a further session explored stakeholder perspectives on possible gamechangers (see below) and provided time for reflection on the results.

### 2.3.1. Presentations

Each of the online workshops has included one or more presentations by members of the ENGAGE project team. These have covered modeling results for global and national decarbonization pathways, the meaning of “net-zero carbon” and “net-zero greenhouse gas emissions,” empirical results on feasibility of decarbonization, the feasibility tool (see 2.3.6), and principles of effort-sharing. The aim of all presentations was not only to provide information (“Introduce,” [Figure 1](#)) on the results of research in the project but also to stimulate thinking and obtain input (“Involve,” [Figure 1](#)) from stakeholders to guide future research. Since the workshops were being held online, all presentations had to be kept short and while some were limited to 5 min, others were allocated a maximum of 15 min.

### 2.3.2. Posters

Since the first workshop was designed to be a face-to-face event, a poster session was planned as an introduction to the various aspects of decarbonization pathways. With the onset of the COVID-19 pandemic, the entire workshop had to be designed as an online event at very short notice. The posters were seen as a key approach to stimulating discussion on decarbonization (“Introduce,” [Figure 1](#)), so it was decided that in an online “marketplace” session, each of the 6 posters would be presented in a pre-recorded, 2-min presentation to inform participants about the key elements of the poster. Subsequently, the participants were asked to identify which poster they were most interested in discussing in more depth (“Reflect,” [Figure 1](#)). Groups were formed for these discussions and the group then had a longer, more detailed, pre-recorded 7-min presentation of the content of the poster. In a physical meeting, a marketplace session would provide each person that wishes to present and discuss his/her work with 1 min to tell the whole group what he/she is presenting and then participants can decide where they wish to spend time. Since the online marketplace session had

to be organized at very short notice, we opted for short pre-recorded introductions that were then discussed in more depth. In the meantime, as experience with holding meetings online has grown, other software solutions have been developed for holding poster sessions in an online setting.

### 2.3.3. Group discussions with key questions

One key element of good practice in stakeholder engagement is skilled facilitation that opens a safe space for participants discussing or talking about complex or emotional issues in an open way, allows for deep connection between the people and for creativity and the emergence of new, innovative ideas. The approach of “Art of Hosting and Harvesting” serves these objectives ([Handler et al., 2019](#)) and was thus used for framing the stakeholder engagement in the ENGAGE Project. Cultural differences in how to act in and contribute to the workshops discussed in this paper became visible quite soon. We had participants from Latin America, Europe, India, South-East Asia. Whereas, people from Latin America, for example, were quite proactive and spoke frankly and without having to be motivated, our stakeholders from South-East Asia were often more shy and had to be invited to talk, especially if other participants from a higher hierarchical level within their institutions were present. Barriers to the ability to speak are poor English skills and little experience in attending workshops. Those could be overcome by setting up break-out groups with people sharing the same mother tongue and one person being able to report back in English and by directly asking younger participants to give their opinion.

Each of the online workshops has included group discussions. Care was taken to have groups that had not more than eight participants, in order to give all of the stakeholders the opportunity to contribute to the discussion. Group facilitators were from the project team and they were briefed ahead of the workshop on the timing and the key questions to be covered. Most group discussions started with a short round of reflection (“Reflect,” [Figure 1](#)) on the preceding presentation(s). Then the discussion moved to responding to key questions ([Table 3](#)), to provide guidance for further work in the project (“Involve,” [Figure 1](#)). Two of the workshops involved four separate sessions spread over 2 days, so there were multiple opportunities for group discussions.

### 2.3.4. Panel discussions

Two of the online workshops have included a panel discussion. In the first global workshop (June 2021), a panel of youth representatives was invited to respond to the two preceding presentations on the meaning of “net-zero” and modeling results on global decarbonization pathways (“Reflect,” [Figure 1](#)). The panel members were asked to voice their concerns regarding the feasibility of achieving “net-zero” greenhouse



**TABLE 3** Key questions to guide group discussions.

Workshop	Key questions
1	What are the hard/soft constraints to the implementation of the decarbonization pathway? What are the enabling conditions that would remove/reduce these constraints?
2	Survey on feasibility (see Section 2.3.5)
3	What are the challenges posed by the modeling results for Asia? What are your suggestions for further modeling (national/global) that needs to be carried out? Which of the elements of decarbonization strategies in your countries (e.g., expansion of solar power, CCS, decarbonization of industry) has most feasibility concerns and why?
4	What do you see as important research needs post-COP26?
5	What are the main challenges in Brazil/Latin America in achieving 2050 decarbonization targets? What are the implications of the timing of net-zero CO <sub>2</sub> emissions in Latin America? What are the key implications of the results of the empirical study on feasibility of decarbonization technologies for decarbonization pathways in Latin America?

gas emissions and/or what needs to happen now, if we are to achieve that goal. In the second global workshop (January 2022), a distinguished panel composed of representatives from the UNFCCC secretariat, the European Commission, Brazil, India and the USA reflected on what had been achieved at the UNFCCC Conference of Parties (COP26) in Glasgow and the resulting need for research.

### 2.3.5. Surveys administered to workshop participants

Surveys have been used in four of the online workshops to involve stakeholders and to collect feedback on key inputs for

future work in the project. Short online surveys were developed and administered during or immediately before the workshop to participants in order to collect their views on the topics upon which the workshops focused (gamechangers, feasibility—in two workshops, effort-sharing). Survey results were presented during the workshops in order to provide a basis for subsequent discussions that focused on more specific and technical issues. The surveys mostly included closed questions so that survey results could be easily shared immediately after responses were recorded. We provide more details on the specific purpose, structure, and questions of the surveys in the subsections below, and we provide the full survey questionnaires in the [Supplementary material](#).

### 2.3.5.1. Gamechangers workshop survey

One of the topics covered in the first workshop was “gamechangers.” This topic is one area of focus in the ENGAGE project, which aims to assess the potential of four different game-changing societal trends and innovations for enabling higher climate mitigation ambition, but also looks at potential hurdles. The four areas are demand and behavioral change, digitalization, deep electrification of end-uses, and sustainable innovations in agriculture and land-use. In the workshop, after a short presentation explaining the concept of gamechangers, participants were asked to use an online form to list what they felt would be key gamechangers. This provided a short list of the most frequently mentioned gamechangers, which was used as the basis for a further online questionnaire, in which the participants were asked to respond to two questions: Which gamechangers would have the highest impact with respect to decarbonization? Which gamechangers have the highest likelihood to materialize?

### 2.3.5.2. Feasibility workshop survey

A core goal of the ENGAGE project is to assess the feasibility of different mitigation pathways. Feasibility of climate mitigation pathways is a complex concept and has many possible definitions and operationalizations (Jewell and Cherp, 2020; Brutschin et al., 2021). We used surveys as a tool to get stakeholders more familiarized with climate mitigation scenarios and indicators that could be used to evaluate those scenarios from a feasibility perspective; and to collect more systematic and quantitative feedback on specific indicators regarding which levels of transformation are perceived to be feasible and which are not, and which trade-offs stakeholders are willing to make. Based on work by Brutschin et al. (2021), we focused on four key indicators at specific points in time to keep the survey short and comprehensible, rather than including all indicators that are depicted in Figure 3. The survey was also a useful tool to explain the categorization of observed values into low, medium and high areas of concerns (see Figure 3).

In a first section of the survey, respondents were asked to provide their estimates of the feasible levels of transformation of four key indicators: (1) the share of non-biomass renewables in 2030; (2) the share of Carbon Capture and Storage (CCS) technologies in total electricity generation in 2030; (3) the level of carbon price in 2030; and (4) final energy demand in 2050. For each indicator, they were required to provide an estimate of what is plausible given current structural trends and an estimate of what is possible in the “best-case scenario”—assuming a major structural shift, such as an unprecedented global climate mobilization or a major break-through in negotiations, that enables a faster transition. In a second section of the survey, personal preferences on key typologies of mitigation pathways were assessed. These typologies included (1) early mitigation action with no CCS; (2) delayed mitigation action and CCS; and (3) early mitigation action and demand reduction. In a

conjoint-like design, respondents were exposed to three couples of scenarios reaching the same ambitious mitigation goal, with each couple including a combination of two of the three typologies above.

### 2.3.5.3. Effort sharing workshop survey

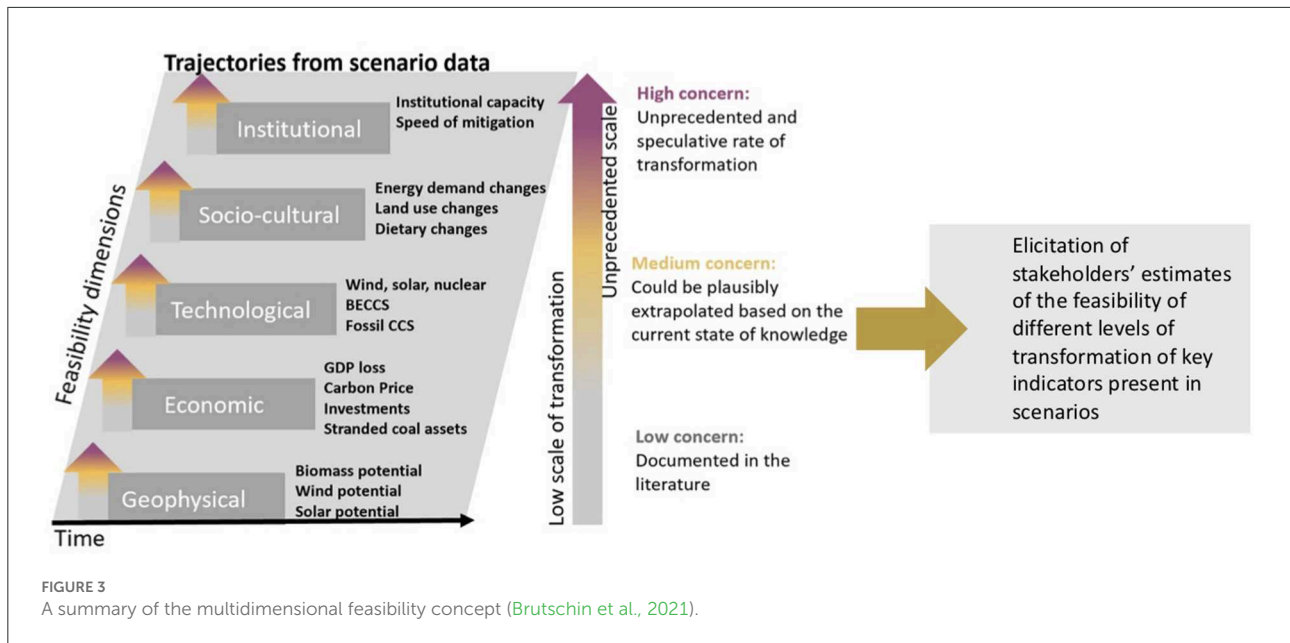
Another important question addressed in the ENGAGE project concerns how mitigation effort can be distributed across different countries and regions. This is a key topic in current international climate negotiations that touches on fundamental ethical questions. A survey was developed to assess preferences for climate mitigation effort-sharing mechanisms based on different ethical principles, and to compare preferences of respondents in countries with different current and historical emission levels and different levels of economic development. Respondents were first provided with the description of five effort sharing mechanisms, with an indication of the ethical principles upon which each of these mechanisms was based (Figure 4). They were then asked to indicate the mechanism that most reflected their sense of fair climate mitigation effort sharing. In a second section of the survey, respondents were shown the mitigation effort that was allocated to their region and the two major emitters, the United States and China, under the five effort-sharing mechanisms, and were then asked whether their opinion on the fairest mechanism changed after being provided with this information. The survey questionnaire is provided in the Supplementary material.

### 2.3.6. Interactive feasibility tool

We used an interactive visual tool as an additional element during workshop sessions focusing on feasibility to make sure that all stakeholders are actively involved; and that they gain a better understanding of climate mitigation pathways, what type of variables are reported and how they can be evaluated. By including an interactive tool as a core element during our workshops, we are following literature that suggests that interactive tools are particularly useful when explaining complex phenomena with which stakeholders might not be familiar (Pidgeon et al., 2014). However, “stand alone” interactive tools are not always superior to simple presentations in conveying key messages and ensuring a better understanding of the topic (Xexakis and Trutnevyte, 2019). We thus always used the interactive tool in combination with short surveys, and open discussions, in order to explore and discuss feedback from surveys, and to allow each individual to explore more if she/he was interested.

We ensured that the visual tool was reflecting the structure of our short survey (See Section 2.3.5.2). Using the visual tool, stakeholders could first explore the global and regional CO<sub>2</sub> emissions trajectories of 2°C pathways that were developed in the ENGAGE project. This was done to highlight the overall speed and scale of decarbonization assumed in the models.





Mechanisms	Criteria to allocate future emission allowances	Ethical principles
<b>Grandfathering</b> (GF)	In <b>proportion to current emissions shares</b>	<b>Sovereignty principle</b> – 'acquired rights' of nations justified by established custom and usage
<b>Per capita convergence</b> (PCC)	To <b>converge over time</b> to being proportional to population shares ( <b>equal per capita emissions</b> )	<b>Sovereignty and equality</b> principles
<b>Immediate per capita convergence</b> (IEPC)	<b>Immediately</b> allocated in proportion to population shares ( <b>equal per capita emissions</b> )	<b>Equality principle</b> – equal value of all humans, having equal claim to global collective goods
<b>Greenhouse development rights</b> (GDR)	Based on a Responsibility-Capacity Index combining <b>past emissions, GDP per capita and income distribution</b> measures	<b>Responsibility and capability</b> principles – idea of safeguarding people's right to reach a dignified level of sustainable human development
<b>Ability to pay</b> (AP)	Inversely proportional to annual GDP per capita, with <b>richer countries undertaking higher emission reductions</b>	<b>Capability principle</b> – ability to bear the burden

**FIGURE 4**  
Description of the selected climate mitigation effort sharing mechanism and the underlying ethical principles.

In the next step, stakeholders were shown three panels for four indicators that we asked about in our brief surveys (see also Section 2.3.5.2): (1) the share of non-biomass renewables in 2030; (2) the share of Carbon Capture and Storage (CCS) technologies in total electricity generation in 2030; (3) the level

of carbon price in 2030; and (4) final energy demand in 2050. In Figure 5, we show an example of how stakeholders could interact with scenarios and specific feasibility indicators. In panel (C) stakeholders were shown the trajectories over time for a given indicator across all models for the 2°C scenarios. In panel (A),

the indicator was briefly explained and a slider was included that was defining the upper threshold below which the values would be considered as low feasibility concern (in this example below 60%), and the lower threshold above which the values would be considered as high feasibility concern (in this context above 80%). Panel (B) was linked to the inputs from panel (A) and allowed stakeholders to evaluate how many scenarios would follow into low (gray color), medium (yellow color) and high (purple color) feasibility categories.

## 2.4. Broader engagement through surveys beyond the workshops

The ENGAGE project also included a strategy to elicit the perspectives of a broader range of stakeholders, besides those who participated in the project workshops. Two online surveys were developed and circulated to a more extensive list of policymakers and stakeholders that was collected through a snowball sampling strategy (see details in Section 2.2).

### 2.4.1. Survey on expected impacts of COVID on climate policy ambition

Shortly after the beginning of the pandemic, a key question that emerged was the possible impacts of the pandemic on climate policy ambition in different countries. A survey to elicit expectations of policymakers and stakeholders on policies in the energy and transport sector, which were expected to be most affected by the pandemic, was developed. The survey was distributed online to the extended list of stakeholders (see Section 2.2) and completed by 223 stakeholders from 55 different countries, almost half of whom (104) declared that they were at least in part involved in the formulation of future climate, energy, or environmental policies (Pianta et al., 2021). The results of the survey were used to inform modeling efforts within the ENGAGE project on the impacts of the pandemic. The survey questionnaire is provided in the [Supplementary material](#).

### 2.4.2. Survey on climate mitigation effort sharing

The topic of climate mitigation effort sharing emerged as a second key and timely topic in the research of the ENGAGE project, as climate change negotiations progressed. The survey on effort-sharing mechanisms was sent to our extended list of stakeholders, besides being administered in two of the project's stakeholder workshops. The survey was completed by 117 stakeholders from 43 different countries. A shorter version of the effort-sharing survey was developed and distributed *via* social media, in order to collect responses from a broader population. 54 additional responses were collected and compared with the ones collected through our selected stakeholders list. The results

of the effort sharing survey were used to validate the effort-sharing mechanisms to be included in the modeling protocol of the ENGAGE project.

## 2.5. Evaluation and learning

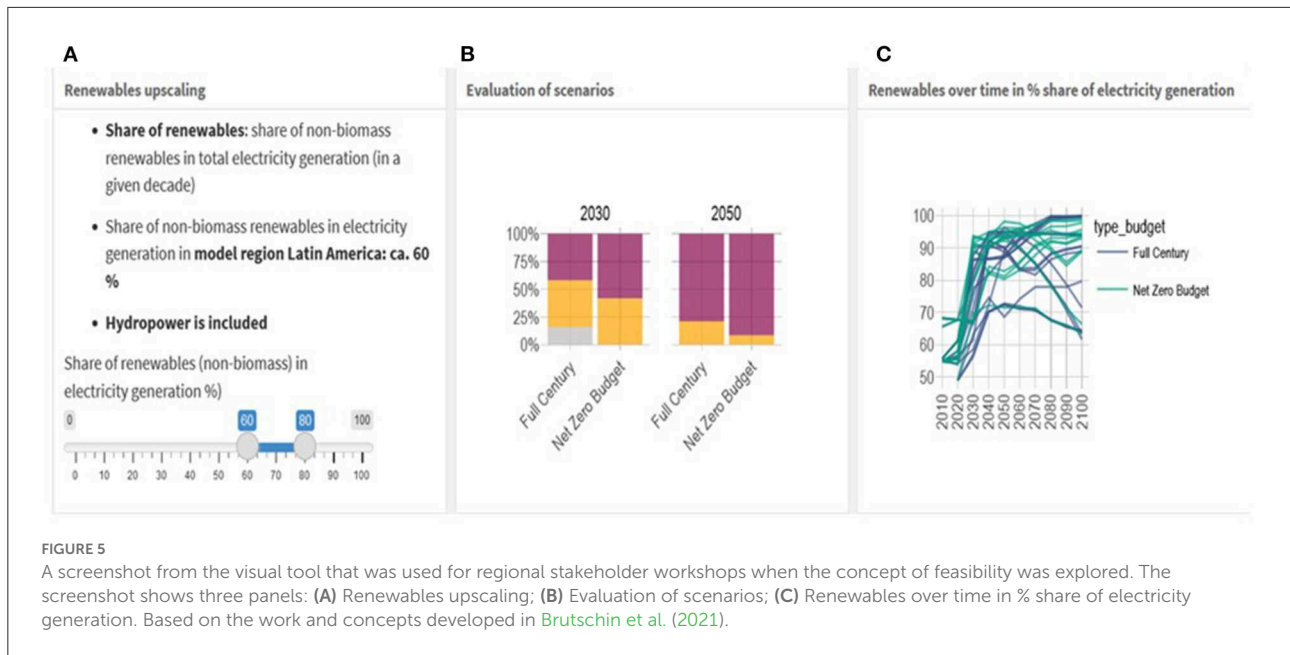
Van Eijndhoven et al. (2001) demonstrated clearly that in the area of managing environmental risks there is a glaring absence of evaluations addressing the overall process. They pointed to the need to move away from *ad-hoc* and accidental pursuit of social learning toward organized and self-conscious use of evaluation to stimulate learning. Siebenhüner (2005) examined learning in environmental assessment processes, underlining that learning can improve the process and make it more effective in issue development. Evaluation and learning are seen by Weaver and Rotmans (2006) and Tuinstra et al. (2008) as an essential step in participatory processes dealing with complex issues within social-ecological systems.

After each of the ENGAGE online workshops the project team has evaluated the workshop process and used this evaluation, together with overall evaluations carried out at annual project meetings, to make changes in the organization and running of the online workshops. These evaluations were based on discussions held after the online workshop. In most cases, it was possible to organize an online discussion among the project partners involved in the organization and running of the workshop. In two cases, reflections were sent by e-mail and collated to provide clear feedback and suggestions for following workshops. The evaluations considered what worked and what was less successful. The learning process continued over the entire time period considered in this paper, leading to adaptations in the timing of meetings, topics covered, tools used and the invitation process. Unfortunately, due to the need to keep online workshops short, no stakeholder evaluations have been carried out.

## 3. Results

### 3.1. The design and running of online workshops

Between March 2020 and April 2022, the ENGAGE project used the insights of the internal evaluation and learning process to improve the design and running of online workshops and wider engagement with stakeholders. The first workshop (March 2020) was originally designed as a face-to-face workshop but had to be redesigned as an online workshop at very short notice when the COVID-19 pandemic led to the first lockdowns. The redesign meant that the workshop was reduced from a 2-day event to a 5-h event with short breaks. Subsequently, efforts were made to organize further online events in the summer



**FIGURE 5**  
A screenshot from the visual tool that was used for regional stakeholder workshops when the concept of feasibility was explored. The screenshot shows three panels: (A) Renewables upscaling; (B) Evaluation of scenarios; (C) Renewables over time in % share of electricity generation. Based on the work and concepts developed in Brutschin et al. (2021).

and autumn of 2020, but low registration led to the cancellation of one event and low overall participation in a second event led to a decision to report that event as an outreach activity, since it did not lead to significant engagement. In retrospect, these “failures” were due to factors also noted by Süsser et al. (2021) and Köpsel et al. (2021) in the early phases of the pandemic: people were overburdened, for example with extra family responsibilities such as home schooling and childcare; the number of online events quickly increased leading to “zoom fatigue” (e.g., Fosslien and Duffy, 2020); and some stakeholders did not have the technology/internet bandwidth to participate effectively in online events.

At a full project meeting in March 2021, a new strategy for stakeholder engagement was developed on the basis of the experience of the past year. Several innovations for online events were introduced:

- Stronger involvement of project partners in identifying stakeholders and in sending personal invitations;
- Organization of events that have four separate sessions of 1–1.5 h with the possibility to register for the sessions rather than for the event as a whole;
- Making it possible to have breakout group discussions in languages other than English, hosted by project partners from the country concerned;
- Ensuring that the timing of events is aligned with the timing of climate negotiations;
- Providing more preparation for hosts of breakout groups before events to ensure that the aims of the breakout session and the key questions to be covered are clear.

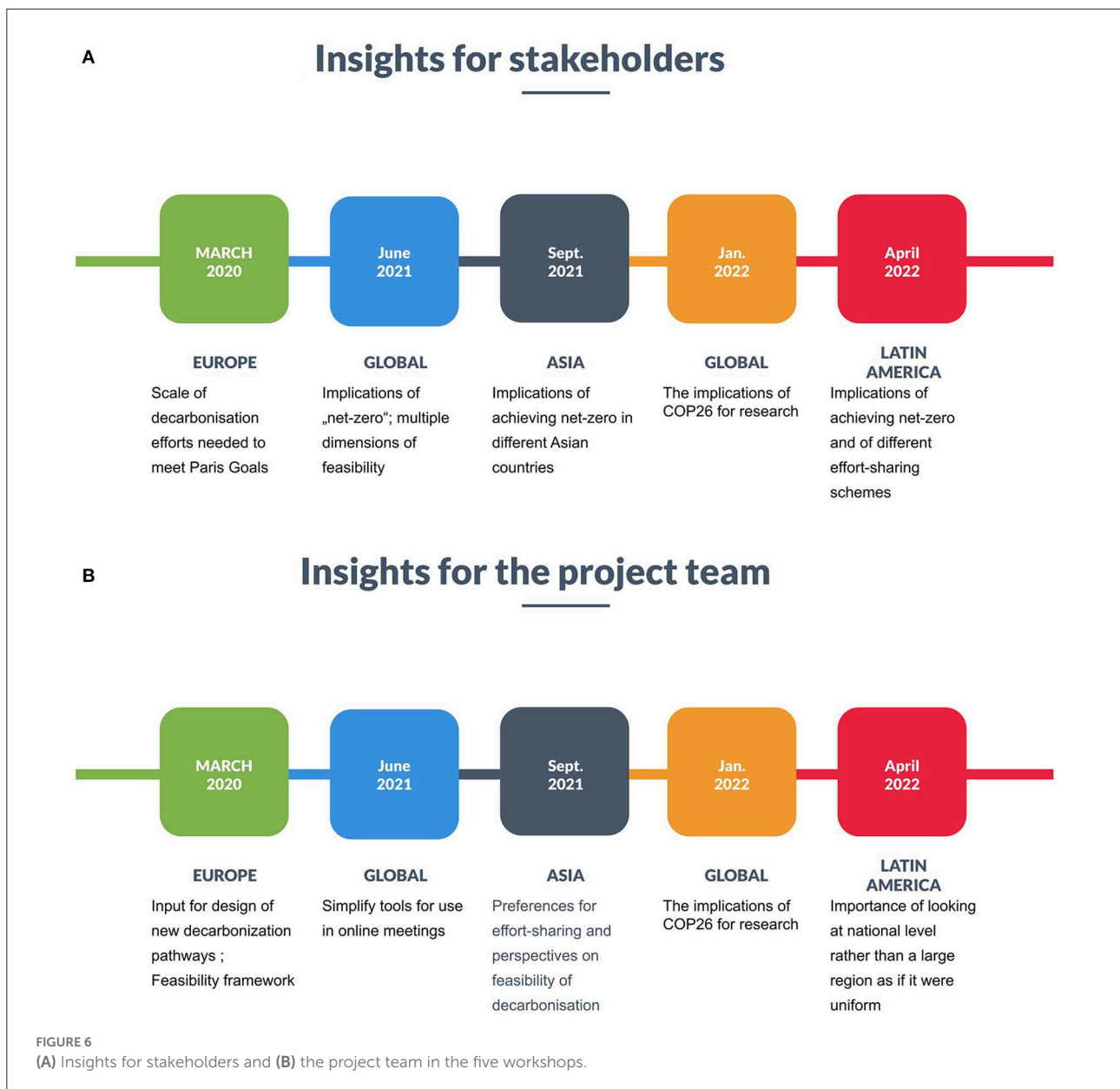
These innovations were certainly successful in increasing the number of participants and meant that the overall aims of the stakeholder engagement process—to inform, involve and reflect—could be met in the workshops held in 2021 and 2022.

### 3.2. Insights from a stakeholder and researcher perspective

As noted in the Introduction, our aim for the stakeholder engagement activities in the ENGAGE project included both informing stakeholders about the results of recent research on decarbonization pathways and their feasibility, as well as getting stakeholder feedback and inputs for research taking place in the project. Figure 6 summarizes the insights gained by the stakeholders and the project team in the five online workshops. These are discussed in more detail in the following subsections.

#### 3.2.1. Insights for the stakeholders

Given the need to keep online workshops as short as possible, there was no feedback round during the online workshops. However, particularly during the discussion groups, participants often gave feedback on the presentations, with indications of things that they had learned. For example, the short presentation on “What do we mean by net-zero?” (Rogelj et al., 2021) at the beginning of three of the workshops, elicited positive responses from stakeholders, who became aware of the importance of distinguishing



between net-zero CO<sub>2</sub> emissions and net-zero greenhouse gas emissions. Additionally, the presentation at the Asian and Latin American workshops on historical evidence of growth rates in energy supply technologies examined whether the growth rates required to meet climate goals can be found in the past. The empirical evidence shows, for example, that the rate of decline of fossil fuel use required for the years between 2025 and 2035 in some decarbonization pathways is unprecedented (Cherp et al., 2021; Vinichenko et al., 2021). This provided insights for many participants, as evidenced by the subsequent discussions. Furthermore, discussions during both the Asian and Latin American workshops demonstrated that stakeholders were learning from

each other about experiences in other countries, and which topics dominated the feasibility evaluations and discussions in different countries. Finally, the sessions on effort-sharing have always stimulated stakeholders to think about the principles they are using when asked which effort-sharing scheme they would prefer. At the end of the session on effort-sharing in the Latin American workshop, in which the effort-sharing scheme of “Green Development Rights” (Van den Berg et al., 2020) was the overall favorite option of the participants, one stakeholder contributed the following insight: “When thinking about Greenhouse Development Rights, care must be taken not to assume that development should take place as it has in the past. The paradigm of “development” has

to change, to align with the global climate and sustainable development goals”.

### 3.2.2. Insights for the project

The stakeholder meetings led to several important inputs to the research in the ENGAGE project. As described in Section 2.3.5.1, during the first workshop participants were asked to identify potential game-changers that could accelerate decarbonization and also to indicate which game-changers they expected to have the most impact in terms of decarbonization and which game-changers they found most likely to materialize. The results showed that while participants believed that social movements, finance and political leadership would have a strong impact on decarbonization, their likelihood of materializing was judged to be low. In contrast, while the impact of digitalization on decarbonization was held to be low, the likelihood of materializing was the highest of all of the game-changers. All of these results influenced further work on game-changers and decarbonization pathways in the ENGAGE project, in particular through paying more attention to social dimensions of decarbonization.

During the sessions on feasibility, stakeholders generated inputs for the project regarding the need to consider the role of institutions in decarbonization pathways, the role of public opinion, and low demand pathways. Furthermore, in Workshop 1 the surveys and discussions on feasibility helped define the framework used in the feasibility assessment methodology that was subsequently developed.

The sessions on effort sharing and equity provided useful input for the development of the scenario framework by prioritizing the schemes that were selected the most by stakeholders. Modeling teams that were not able to or did not have the resources to perform the scenario analysis for all equity principles and effort sharing schemes had the opportunity to focus only on the schemes that were cited the most by stakeholders. The online participation and the use of online surveys also enabled us to get responses from different parts of the world, hence to provide insights to global models with respect to the region-specific preference of stakeholders, that otherwise would be limited to a few countries/regions. In addition, the research team was able to obtain insights on the policy relevance and acceptance of the different effort sharing schemes and on the appropriate framing of this research.

In Workshop 4, project partners and a broad group of stakeholders from across the world explored what had taken place at the UNFCCC Conference of Parties (COP26) in Glasgow and discussed consequent demands for research. These research needs were taken up by the ENGAGE project consortium and helped shape the modeling protocols for the final sets of global and national scenarios that are being produced in the final 18 months of the project. They also provide important inputs for proposals for future work (until August

2023). Two further important points made at the workshop will shape the final reporting of the project and the design of further workshops: Clear and transparent reporting of the results of scientific research is needed and policy making must be informed in a holistic manner; It is important to translate model results into more tangible near-term strategies that can better inform policy makers. These feedbacks from the stakeholders will shape the narratives of the final outreach from the ENGAGE project.

## 3.3. The usefulness of tools and approaches for stakeholder engagement

Based on the experience in 5 online workshops, [Table 4](#) evaluates the tools and approaches and compares their use in online and face-to-face settings. Overall, we could utilize online tools to our advantage and collect a wide range of systematic data that informed other project activities such as the conceptual thinking about the feasibility concept and how feasibility concerns could be incorporated in the next generation of decarbonization pathways.

In recruiting stakeholders for our workshops, we saw some advantages of online settings that allowed us to reach out to a much wider and diverse pool of potentially relevant groups. It was also easier to recruit prominent speakers as an online contribution meant a much lower time investment on their side. At the same time we faced some challenges with estimating the final number of participants as it was easy for people not to show up or not to actively participate in an online setting as compared to a face-to-face meeting.

All online workshops included presentations from the ENGAGE project team as part of the “Introduce” element within our overall framework (see [Figure 1](#)). They were useful in showing new results from modeling and empirical research as well as explaining concepts. As in face-to-face workshops, the presentations need to be as short as possible and understandable for a broad range of participants. In the first workshop, poster presentations were also made, using a pre-recorded format. These pre-recorded presentations had the advantage that the sessions could be run to time and that the recordings could be posted on a website for later viewing.

The main bulk of the “Engage” element within our framework (see [Figure 1](#)) consisted of feedback collection through short surveys, interactions with the visual tools and open discussions. Group discussions allow more people to voice their opinions, concerns and perspectives than in a large plenary group. The success of group discussions depends significantly on preparations before the workshop. Preparatory meetings are essential to brief the moderators on the expected number of participants and their characteristics (gender, sector, nationality etc.), to define the key questions to be tackled



TABLE 4 Comparing tools and approaches for online and face-to-face stakeholder engagement.

Tool/approach	Online	Face-to-face	Challenges and opportunities
Stakeholder pool	Easier to have a larger and more international pool of participants (in case funding is not available for everyone). At the same time it is difficult to know the final number of participants as it is easy to register but not show up	More motivation for some stakeholders in case some prominent speakers are involved. A clear commitment about participation and more security about the final number of participants	Generally opportunities for a bigger pool of participants at lower costs. Difficulties to estimate the final number of participants as it is easier not to show up and not to participate in an online setting
Presentation	Keep short and clear for a broad audience	Keep short and clear for a broad audience; can be longer for an audience that particularly requests detailed information	Inviting a prominent speaker is easier to achieve in an online setting
Poster	Works well with a pre-recorded presentation of the poster. A short recording for plenary discussion can be paired with a longer, more detailed recording for breakout group discussion or for watching after the workshop	Provides participants with the opportunity to get up and walk around and interact with other participants	Pre-recorded presentations have the advantage that the sessions could be run to time and that the recordings could be posted on a website for later (or prior) viewing
Group discussion	Requires good preparation of group moderators with key questions for the discussion and information about the expected participants. Keep groups small Could be enhanced by the use of online whiteboards Moving in and out of groups online can be interrupted by technical glitches, but this is happening less, as everyone has become more accustomed to running online workshops	Requires preparation of moderators with key questions for the discussion and information about expected participants. Keep groups small. Can use various methods such as world café, open space and others and various ways to record results of the discussion, such as flipcharts, whiteboards, writing on a table-cloth	Moderating an online discussion requires different skills to moderating in a face-to-face workshop. It is particularly challenging to get everyone to participate, so more preparation and short (interactive) energy booster exercises are required. Group discussions can often be longer in face-to-face workshops, while online workshops have more time constraints
Survey	Works well in an online setting and gives all participants a convenient way of indicating their preferences and perspectives Provides an opportunity for structured feedback, also from participants who are normally not too active	Less convenient in a face-to-face setting, since it requires that all participants have a computer and access to the internet during the workshop. Can be used online before the workshop, with a summary of the results during the meeting	The questions in the survey must be easy to understand for effective use in an online setting. They should not require deep prior knowledge
Visualization tools	Works well, if the tool is easy to understand and use	Can be demonstrated during the workshop. Less convenient for use by all participants during a face-to-face workshop, because of the need for a computer and internet	Sometimes technical issues with the tool, it is good to have a few versions of a tool that can be shared
Check in/check out	Usually not enough time for this, if the online workshop is to be kept short. However, there are methods to make this neat and quick, allowing the participants to “arrive” or reflect	Valuable addition to the workshop. Check-in brings participants into the meeting and allows time for short introductions in a relaxed atmosphere Check-out allows a round of reflection on what was learned, what was appreciated and how the process could be improved in the future	Needed for both versions, but needs some experience and a box full of methods at hand, as they need to be used in a flexible manner, given the time left and the energy of the group for instance

(Continued)

TABLE 4 (Continued)

Tool/approach	Online	Face-to-face	Challenges and opportunities
Panel discussion	Requires preparation of panelists with key questions and timing of the session and an experienced moderator being able to include the audience in a motivating way. Provides inspiration for subsequent discussion	Requires preparation of panelists with key questions and timing of the session and an experienced moderator being able to include the audience in a motivating way. Provides inspiration for subsequent discussion	In a face-to-face meeting a panel discussion can often use more time, allowing more interaction between panelists and between panelists and the audience A panel of well-known speakers can attract a larger audience to online and face-to-face events
Workshop evaluation	Usually not enough time for detailed evaluation. Can ask the participants to fill out a form and submit it after the workshop, but the rate of response can be low and perhaps not representative of all participants	Valuable addition for designing subsequent workshops (what worked well and what worked less well). Can be used to document clearly what insights were gained during the workshop. Can be done in the closing session of the workshop with a printed form to be filled out	

during the group discussion and to be clear on the timing of the session. In the Asian workshop, we also recognized the need to allow some breakout groups to be conducted in the national language.

The panel discussions in Workshops 2 and 4 provided valuable inputs to the workshops and stimulated subsequent discussions. The youth panel responded to the need mentioned in the introduction of the paper for engagement of the next generation in climate change research. The panelists not only reflected on the decarbonization pathways that had been presented but also pointed to further opportunities for meeting the challenges of climate change. In Workshop 4, the panel was composed of representatives from the UNFCCC secretariat, the European Commission, Brazil, India and the USA. The timing of the workshop, 2 months after the UNFCCC Conference of Parties in Glasgow, and the composition of the panel, were strong incentives to participate in the workshop.

Overall, the tools and approaches used in the online workshops were effective in stimulating a two-way dialogue with stakeholders. Evaluation by the project team after each workshop played a role in improving both the tools and the approaches over time. This was particularly the case for the online feasibility tool, which has been simplified for use in online workshops. Despite the overall usefulness of the group discussions, some areas remain challenging in an online setting.

One of the main challenges posed by holding workshops online is the need to keep them short. This means that there is no time for participant introductions and an opportunity to get to know other participants in a group activity. In addition, breakout groups do not have the time to cover more than one or two key questions or engage in an in-depth discussion. Limiting an online session to 1 h duration also means that there is no time for a feedback round and workshop evaluation at the end of the session. A further challenge is the need for detailed preparation and briefings for the project team before the online stakeholder event, especially when new tools and approaches are introduced.

Conducting a successful discussion online is difficult, when people do not know each other or when they are hesitant to speak due to cultural norms. In a face-to-face workshop, which is usually considerably longer than the 1–2 h sessions for an online event, there is time to include a session at the beginning, in which participants briefly introduce themselves and get to know each other, referred to in Table 4 as a “check-in” session. Face-to-face workshops often also have refreshment breaks in which participants can discuss with each other informally. All invited participants have significant inputs to make, so it is important to find ways for them to engage in the discussion. In addition to asking participants to fill out online surveys, the moderators of group discussions tried to ensure that everyone had an opportunity to speak. However, post-workshop evaluations suggest that other approaches are also needed. One possibility is the use of online whiteboards that can be used to collect responses to key questions before opening up a discussion.

Another challenging area was the reporting back from group discussions as part of our “Reflect” element (see [Figure 1](#)). There is often great value in hearing what other groups have concluded, since this can lead to new insights or highlight that a particular topic stimulated discussion in multiple groups. However, if an online workshop is restricted in length, there is no time for a lengthy reporting back from each group. Moreover, we found (a) that those reporting back sometimes did not just summarize two or three key points in the discussion but the rapporteurs wanted to do justice to the participants and cover all the points, and (b) that it is more difficult for a moderator to stop a long report in an online workshop than it is when he/she can walk over to the speaker and respectfully ask them to come to a close. This could be solved by providing rapporteurs with a template for reporting back, clearly indicating the time limit for speaking and that the report should cover only two or three main points from the discussion. Collecting notes from each group would still make it possible to produce a more detailed written report after the workshop. At the same time, we noticed that open feedback is much easier in a face-to-face setting. Lack of time and overall more barriers to open discussions are thus the main drawbacks of stakeholder workshops in an online setting.

Finally, it is important to note here that while the tools and approaches listed in [Table 4](#) were all useful in an online setting, we learned through the workshop series that the combination of approaches and tools brings additional value. Thus, we found that linking surveys, visual tools, presentation and open discussion not only worked well, but provided valuable insights for stakeholders and the project team.

## 4. Conclusions

The aim of the ENGAGE project to use stakeholder engagement to provide inputs to the project and to discuss interim results was originally based on a plan to have face-to-face workshops. With the onset of the COVID-19 pandemic, we had to hold all of the workshops online. The 5 stakeholder workshops hosted online by the ENGAGE project between March 2020 and April 2022 constituted a learning process, in which the tools and approaches were modified and all participants became familiar with meeting online.

Online workshops and surveys provide the opportunity for participants from a large geographical area to join the workshops without travel time and costs. This is clearly demonstrated across the five ENGAGE online workshops (see [Table 1](#)). The online activities lead to a lower carbon footprint than an equivalent physical workshop. [Klöwer et al. \(2020\)](#) reported that the annual meeting of the European Geosciences Union in 2020, which was held online, had increased participation compared to pre-pandemic meetings and a 90% reduction of CO<sub>2</sub> emissions caused by the event. It is also easier to attract prominent speakers

for an online meeting, since providing a short input only requires ca. 20–30 min of their time and no associated travel.

The effectiveness of the ENGAGE online stakeholder events was certainly enhanced by the benefit of having project team members from a wide range of countries (including India, China, South Korea, Japan, Thailand, Vietnam, Brazil, and Mexico), who could support the design of workshops that were conscious of regional cultural differences and also invite local stakeholders. In addition, the team members could offer to host breakout groups in languages other than English. In an online manual on stakeholder engagement, [Bammer \(2021\)](#) points out that stakeholders feel that their participation is valued if they perceive it to be credible, relevant and legitimate ([Cash et al., 2003](#)). This includes the need to create the conditions in which stakeholders can freely voice their concerns and perspectives in the language in which they are most fluent.

Our experience has shown advantages and disadvantages of online stakeholder engagement, but with the use of new tools and approaches and also with combinations of tools and approaches (e.g., an online tool in combination with a survey and moderated discussion groups), we obtained valuable inputs for further work in the project and the stakeholders gained relevant insights on the challenges and opportunities for decarbonization. However, in line with the conclusion of [Süsser et al. \(2021\)](#), our experience shows that online activities cannot completely replace physical meetings. The issues that we are dealing with are complex and there is no single solution. There is a need for dialogue in a carefully designed and facilitated transdisciplinary process that provides time and space for people to get to know and understand diverse perspectives and to dive deep where necessary. An open knowledge system to find solutions for problems of unsustainability can be supported by online meetings but also needs longer physical meetings that are part of a longer-term social learning process.

## Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

## Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was collected to participate in the stakeholder dialogues in accordance with the national legislation and the institutional requirements

## Author contributions

JJ took the lead in producing the first draft of the paper. All authors participated in two rounds of reviewing and editing the paper and contributing further text and figures and agree to be accountable for the content of the work.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/frsus.2022.1063719/full#supplementary-material>

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