



# The ‘co’ in co-production of climate action: Challenging boundaries within and between science, policy and practice

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## ABSTRACT

Effective action taken against climate change must find ways to unite scientific and practice-based knowledges associated with the various stakeholders who see themselves as invested in the global delivery of climate governance. Political decision-makers, climate scientists and practitioners approach this challenge from what are often radically different perspectives and experiences. While considerable work has been done to develop the idea of ‘co-production’ in the development of climate action outputs, questions remain over how to best unite the contrasting epistemological traditions and norms associated with different stakeholders. Drawing on the existing literatures on climate action co-production and from translational perspectives on the science-policy interface, in this paper we develop the concept of ‘boundary agency’. Defining this as the agency ‘possessed’ when willing and able to translate between different epistemological communities invested in a similar policy and governance challenge such as climate change, we offer it as a useful means to reflect on participants’ understanding of the ‘co’ in co-production. This is in contrast to the more established (often academic-led) focus on what it is that is being produced by co-production processes. We draw from two complementary empirical studies, which explicitly encouraged i) engagement and ii) reflection on cross-boundary co-production between climate action stakeholders from different backgrounds. Reflecting on the two studies, we discuss the benefits of (and barriers to) encouraging more active and sustained engagement between climate action stakeholders so as to try to actively blur the boundaries between science and policy and, in doing so, invent new epistemological communities of practice.

## 1. Introduction

In attempting to combat the increased frequency and severity of climate threats it is important to recognise that certain places, communities and social groups are likely to experience these disproportionately and unequally, and will have differing levels of capacity to take up and respond to the challenge through the mobilisation of knowledge-based resources (Twigger-Ross et al., 2015). Calls are therefore abound to improve the “usefulness and usability of the information product for the user” (Bremer et al., 2019:42). Critical of this limited framework, Bremer et al. argue for a ‘multi-faceted’ approach to incorporating a variety of perspectives in order to deliver “climate services that are better tailored for climate change responses in particular contexts”

(ibid.). Meanwhile, practitioner literatures have also started to champion the value of a more inclusive and democratic approach to climate service provision at different scales (e.g. WISER, 2019), as has recent application of co-production frameworks to scientific projects to move towards transdisciplinary knowledge production (Bojovic et al., 2021). Despite this, however, questions remain regarding the enduring nature of the institutional, epistemological, and scalar boundaries between the different actors involved with co-producing knowledge-based outputs, which separate knowledge ‘users’ from knowledge ‘providers’ (ibid.4).

In what are now recognised as seminal works on the role of knowledge in global environmental governance, Cash et al. (2003), Cash et al. (2006a) and Cash et al. (2006b) described the importance of ‘managing’ the boundaries that exist between the institutional conventions and

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practices of different actors involved in trying to address complex environmental problems. Focusing on the governance environmental problems in a general sense, Cash et al. (2003: 8086) describe how efforts to mobilise science in pursuit of environmental sustainability: "... are more likely to be effective when they manage boundaries between knowledge and action in ways that simultaneously enhance the salience, credibility, and legitimacy of the information they produce. Effective systems apply a variety of institutional mechanisms that facilitate communication, translation and mediation across boundaries." Subsequently focusing on climate science specifically, it is argued by Cash et al. (2006b; 465) that: "research suggests institutional mechanisms appear to be useful in managing such boundaries, including mechanisms for structuring convening, translation, collaboration, and mediation functions."

While this notion of 'institutional mechanisms' has laid the foundation for a great deal of subsequent research into the roles to be played by 'boundary actors' what if, rather than trying simply to manage boundaries, the focus of knowledge 'co-production' was to actively subvert them in pursuit of new foundations upon which action against climate change could be built? Indeed, given the proliferating emphasis on the development of universal models of 'climate services', to what extent is it absolutely *necessary* that the boundaries between different "epistemic communities" (Wan et al., 2020) are re-imagined? While the important role played by boundary actors in environmental science-policy interactions (Guston, 2001), and subsequently in climate services (Lee et al., 2014) has been well theorised, this has invariably focused on boundary *actors*, with less attention paid to the forms of agency that underpin the work of these actors. If the 'co' in co-production is regularly outsourced to the work of 'boundary actors' where does this leave knowledge generation as a co-production activity *itself*?

As argued by Dilling and Lemos (2011; 680), while 'useable' climate knowledge is in part a function of the specific contexts within which it is developed, it is also the product of "specific actors and organizations who 'own' the task of building the conditions and mechanisms fostering its creation". So how should we understand the agency of such actors and organizations in a conceptual sense, outside of the specific social, cultural and political contexts in which co-creation takes place? What are their views and perspectives on the challenges and opportunities that emerge from co-production processes? And where does this leave knowledge co-production as an aspirational endeavour for user-facing climate service delivery through journals such as *Climate Services*, or within the development of Intergovernmental Panel on Climate Change (IPCC) reporting processes and its 'global' perspective on climate governance? While closer attention is being paid within the climate service community to "the institutional frameworks and the underlying knowledge systems" associated with different parts of the world, questions remain over the extent to which knowledge re-alignments are being "endogenously driven" (Vogel et al., 2019; 1).

In this paper we take this need for a realignment of knowledge production as our starting point in order to think through what a form of co-production that actively tries to reinvent the relationship between different epistemological communities might look like and the challenges it might face. Accounting for dialogue over the often misaligned perceptions of certain groups' interests and motivations for taking part in environmental governance, we frame our analysis through literature highlighting the 'translational' nature of effective science-policy interaction, and we argue for an approach to climate change research which prioritises effective communication strategies for overcoming perceived boundaries between scientists, policymakers and practitioners. We explore the perspectives of key actors within co-production processes to assess the challenges and opportunities faced, and describe this idea as 'boundary agency' to capture the process through which boundaries might be actively subverted through sustained engagement between the origins of multiple, diverse perspectives; something we argue should be as important to co-production discourse as the involvement of different actors in the production of outputs.

The paper follows a clear methodological strategy in making this contribution, based on stages of conceptualisation (via literature review); exemplification (via empirical case study); and refinement (via reflective discussion). In the following section we engage with the existing literature on co-production and use the conceptual work on 'translational science' to develop the concept of boundary agency, building on previous work around boundary actors and boundary work. Following this we introduce two empirical case studies we draw on to further develop the concept of boundary agency and stakeholder perspectives on co-production. Rather than following an information deficit approach under the assumption that involving people in the process will encourage action, we use these two studies to reflect on the enduring cultural, political and institutional boundaries that persist during co-production processes with view to thinking through how these might be overcome. Increased engagement with audiences in a more participatory manner will therefore increase the perceived ability to change behaviour and help inform on the availability of alternative options (Lassen et al., 2011).

## 2. The landscape of climate-service co-production

### 2.1. The enduring presence of boundaries in climate service co-production

Decision-makers and practitioners working in climate mitigation and adaptation policy and action continue to face significant barriers, not only to *accessing* scientific evidence, but also to informing its production in the first place. The wealth of experience and understanding of climate change problems embodied by practitioners and end-users is often overlooked by the overly descriptive discourses used to portray their relationship with climate science (Harjanne, 2017). Mirroring previous (and ongoing) challenges within the field of medicine and environmental health (Corburn, 2007) it is increasingly suggested that a more attentive mode of service provision involving the building of coalitions, the linking of local insights to meta-policy frames and the use of intermediaries to facilitate the process, can offer productive ways forward for climate science and policy (Ferguson et al., 2016; Meadow et al., 2015; Parris et al., 2016).

Co-production, in this sense, enables a process of public debate, discussion and persuasion, which is context dependent (Vincent et al., 2021), where experts and the public can combine their knowledge, share tasks where scientists and policy makers analytically identify problems and the public help frame a democratic agenda to address them (Dewey, 1954). This enables problems to remain connected to their social settings and 'a plurality of participants engaged in everything from problem-setting to decision-making, can contribute to more scientifically legitimate and publicly accountable decisions' (Corburn, 2007: 150). Living labs, for example, have been used as a method of co-producing knowledge between different stakeholders, providing real world experience and based on research insights, such as work undertaken by Evans et al. (2015) to increase engagement and collaboration between students, staff and relevant stakeholders in embedding sustainability across universities.

As a theoretical idea, co-production enables a more appropriate response to societal challenges in providing an inclusive, self-reflective approach whilst embracing challenges the process faces and acknowledging the opportunities this provides (Corburn, 2007; Jasanoff, 2010). Maximising the impact of research requires an alignment with the needs and challenges faced by end-users and stakeholders involved in decision-making on climate change. Decision-making at the local level for example on climate adaptation and mitigation requires understanding of the intricate processes of decision-making that may involve local emergency services, the media, local government, business and NGOs when, for example faced with extreme weather events (Howarth and Monasterolo, 2016; WISER, 2019). Similarly at the international level when deciding complex processes of climate negotiations that may span multiple stakeholders, sectors and interests, active engagement with

international players in this space ensures an understanding of the context and motivation for negotiation positions resulting in better-managed processes for producing international agreement with over 150 signatories such as the Paris Climate Agreement (UNFCCC, 2015). Irrespective of the scales at which decision-making is being negotiated, a need exists for the development of a framework for facilitating effective, equitable and reciprocal engagement between stakeholders. Such a framework thus needs to adopt an iterative approach to adapt to the evolving needs of stakeholders embedded within it and responsible for the co-production of climate knowledge and action.

With this in mind, co-production has and is being implemented in different contexts and at different levels, notably the field of climate knowledge (co-)production and decision-making (Vincent et al., 2018). Efforts to develop knowledge co-production frameworks has a rich history of research exploration within public services (Osborne and Stro-kosch, 2013), principally in social and health care where ‘people’s needs are better met when they are involved in an equal and reciprocal relationship with professionals and others’ (Boyle et al., 2010: 6). Through this type of research, and a series of case studies, the value of co-production stems from its ability to ‘reframe the problem and re-establishing relationships to enable more holistic and people-centred approaches (...) and that it ‘can also tackle the lack of trust between some users and professionals’ (NESTA et al., 2012: 2). Placing considerable emphasis on the need for well-developed personal and professional networks, the body of work known as ‘translational science’ has emerged as a framework for emphasising the need for research in the environmental sciences to span boundaries between scientists, policy makers and practitioners (Enquist et al., 2017; Wall et al., 2017).

## 2.2. Conceptualising ‘Boundary agency’

Building on the work of Guston (2001), the paper by Wan et al. (2020) draws attention to the importance of boundary ‘actors’ who operate within climate science-policy networks, describing them as “institutions or individuals” who “span the boundary between science and policy and provide dedicated translational services that facilitate the communications between scientist’s and policy-makers”. Similarly, and drawing on Elinor Ostrom’s notion of polycentricity, Lee et al. (2014) apply this notion of boundaries to the overcoming of failures to address global environmental problems through the development of monolithic systems of governance. The authors argue that “boundary organisations” operate as vital nodes in the development of “climate change networks” consisting of collaborative partnerships, able to deliver actionable impact where mono-centric regulatory regimes have failed (ibid.24).

Cash et al. (2006a) describe “pervasive and difficult cross-scale and cross-level interactions in managing the environment” and that this “complexity” is affected by the “interplay of institutions at multiple levels and scales” (our emphasis). To what extent, then, is the “conscious boundary management” (ibid.1) required to engage with complex problems involving multiple stakeholder groups, something that is deeply context dependent, reliant on the establishment of particular communities of practice? At a time when, as discussed in the introduction, ‘co-production’ is being actively pushed in both academic and practitioner circles as a route forward in the delivery of climate action, it seems vital to try and better understand the agencies at work within the exercise of boundary-management and the extent to which this might represent a generalizable set of practices (as Cash et al., 2006a theorise it to be). Understanding this seems vital if climate service co-production is to move beyond aspirations to merely bring together different institutional, disciplinary and epistemological communities, and towards the production of new, evidence-based, practice-orientated communities of climate action, with a better consideration for the values, needs, priorities and perceptions of those communities.

With this poly-centric, multi-institutional backdrop to climate governance in mind, we can ask how we should best conceptualise the

work that boundary actors actually ‘do’ in forging “common cultural and epistemological commitments” on the part of different stakeholder groups from across the science-policy landscape (Shackley and Wynne, 1995: 228). Here we argue that central to their role is the act of translation, reflecting and incorporating their perspective and needs, and turning a particular way of representing the world into an alternative one, cognisant of all the political, cultural and institutional baggage that comes with this constant re-representation. In conceptualising ‘boundary agency’ as a means of addressing some of the issues discussed in the previous section, our aim is a simple one; to animate an engagement with the ‘co’ in co-production, rather than (as has been the predominant focus previously) being overly concerned with the issue of what is being ‘produced’. In other words we are less concerned here in understanding how co-production can happen to deliver more attuned and digestible outputs (and subsequently actionable outcomes) and more concerned with the different forms that the cooperation involved can take and what it might aspire to achieve beyond delivering specific outputs.

We present two studies from contrasting scales of the ‘climate regime’ (Lee et al., 2014) but which share a mutual focus on developing an understanding of the respective aims, perspectives and motivations of different stakeholders involved with addressing climate change related problems. By combining findings from the two studies, we aim to examine to what extent involving practitioners and end-users (and how they themselves perceive the process) in knowledge co-production processes helps to overcome some of the translational challenges associated with the various languages, perspectives and motivations of different stakeholders. The following section details our methodological approach which focused on directly facilitating cross-boundary dialogue and, subsequently, on offering space for reflection on the part of participants in co-production processes. agency, this allows us to identify how cross-boundary differences get subverted and why.

## 3. Empirical case studies

### 3.1. Context

Clear and effective communication of evidence, and impacts, to specific audiences is thought to raise understanding of climate change, increase resilience to climate impacts, and enhance efforts for reducing emissions, but is not always adequately achieved. The linear process of information dissemination rests on climate science being communicated to decision-makers with assumptions that they are able to interpret this information in a manner that can improve the efficacy of decision-making. Yet due to complexity and uncertainties, the expectations of decision-makers regarding how their actions can be better informed by science, may not be met (Howarth and Painter, 2016). In order to overcome this, the concept of co-production allows for communication and engagement between stakeholders of user needs and provider capabilities, in theory offering a more robust framework for interaction with a deeper embedding of stakeholders perspectives, needs, values and priorities. Questions remain, however, over how this ‘co’ production should be practiced and whether or not facilitating dialogue between users and providers of knowledge is enough to overcome the boundaries between embedded epistemological traditions (Baker et al., 2020). In particular, in our discussion of boundary themes explored in these two studies, we consider (i) how evidence is perceived, used and co-produced across scales to inform climate action, (ii) the range of responsibilities held by different climate action ‘stakeholders’, and (iii) the consideration of different stakeholder expertise and knowledge in formulating climate action according to certain timescales and political lifecycles.

We address this question by engaging with two separate, yet complementary empirical studies that we bring into conversation with each other to reflect on the boundaries at which different producers, providers and users of knowledge interact, and hence advance the conceptual framework presented in this paper. The first study adopts an

organic, open and exploratory approach to probe more explicit issues about incorporating co-produced knowledge into existing policy-aimed scientific evidence consolidation processes such as the IPCC Working Group report drafting; the second study adopts an intimate forum for honest reflection in which it identifies and unpacks boundary tensions of co-produced knowledge around climate shocks in the UK.

### 3.2. Study 1: co-producing climate evidence with practitioners

The Intergovernmental Panel on Climate Change (IPCC) provides the most comprehensive assessment of climate change knowledge through its three Working Groups (WG), each producing Assessment Reports (AR) on the science of climate change (WG I), impacts, adaptation and vulnerability (WG II), as well as mitigation of climate change (WG III) (IPCC, 1998). The production of these Reports is complex and lengthy with experts nominated by government focal points, observer organisations and the IPCC Bureau (IPCC, 1999) based on criteria such as “scientific, technical and socio-economic expertise, geographical representation; a mixture of experts with and without previous experience in IPCC; gender balance; experts with a background from relevant stakeholder and user groups, including governments” (IPCC, 1999: 4). Evidence synthesis for the IPCC reports is conducted primarily by the scientific and political communities, and while comprehensive and thorough, it does not fully take into account the needs of end-users working on the ground (Devès et al., 2017; Howarth et al., 2017) by considering, for example, how its reports will be accessible to or used by practitioner communities. This has been addressed to some extent in the IPCC through its process of admitting observer organisations to sessions of the IPCC and its WGs as long as they are “qualified in matters covered by the [IPCC]” (IPCC, 2012: 1).

The IPCC process is a unique mechanism through which the latest academic knowledge on climate change is consolidated and shared. This enables the policy community to design and implement policies based on the most up-to-date assessment of scientific evidence. However, the potential benefits of practitioners and end-users contributing more to the IPCC WGII process are rooted in the extensive experience and timely evidence of practical examples of climate adaptation that could be brought to the table. The types of work they undertake (e.g. impact assessments) provide real world examples demonstrating the potential for transferability to wider international contexts. Despite this, the thorough peer review process undertaken by the IPCC in drafting its reports is not suited to incorporate this type of knowledge. This is mainly the result of the IPCC’s role to consolidate climate science (without offering recommendations) through an academic-oriented and peer-review mechanism with long lag times, as well as communication challenges, including different language and cultural interpretations (IPCC, 2015).

Data from three workshops in the UK with 46 representatives from the academic, policy and practitioner communities (Table 1) explored the extent to which practitioner-based evidence incorporated in IPCC reports could enable better scientific advice on climate responses. Participants were invited to attend one of three identical workshops conducted over three consecutive days to maximise chances of participant availability. If specific invitees were unable to attend, they were asked to send a substitute from their organisation. All three workshops aimed to address the following questions: (i) How are IPCC outputs used to inform decision-making? (ii) What is the role of practitioner-based evidence in

**Table 1**  
Workshop participants.

	Academic	Practitioner	Policy
Workshop 1	3	6	5
Workshop 2	5	7	3
Workshop 3	7	6	4
Total	15	19	12

the IPCC WGII process? (iii) Can a process of co-production facilitate this process? Building on the findings of Howarth and Painter (2016) and Howarth et al. (2017) regarding the potential for more engagement with practitioners in the development of IPCC reports, the data reported in this paper focuses on the third question explored in the workshops: How can a process of co-production facilitate the incorporation of practitioner knowledge(s) into this process? The workshops, lasting half a day each, were semi-structured to enable a free flow of discussion considering the mix of stakeholders participating, and participants were randomly split into two or three groups within each workshop. The design of the study enabled an organic approach to be adopted whereby honest accounts, experiences and reflections on tensions within and across the boundaries of the scientific-practitioner-policy interface were obtained by the deliberate mixing of the diverse workshop participants. Workshops were conducted under Chatham House rule with a note-taker capturing discussions. Discussions were analysed using thematic analysis and a draft of the analysis was shared with participants who considered it to be an accurate and representative account of the discussions held.

### 3.3. Study 2: co-producing decision-making in response to climate shocks

The UK Nexus Shocks project, funded by the ESRC Nexus Network, sought to facilitate constructive conversations on climate shocks topics and explore some of the practical challenges associated with the integrated and transdisciplinary approach required to effectively manage and respond to climate shocks. With the likelihood of such shocks predicted to increase due to a changing climate, the need for effective, inclusive decision-making across sectors is increasingly important. The first phase of the project consisted of five workshops held in 2015 to analyse the range of barriers and opportunities for decision-making in the context of climate shocks in the UK (see Howarth and Monasterolo, 2016, 2017). Reframing the nature of decision-making as a transdisciplinary process involving multiple people, organisations, sectors and strategies, opens opportunities to examine issues within these decision-making processes and to identify ways to improve resilience to these shocks through the development of more appropriate knowledge bases.

This paper reports on the second phase of this study with data on stakeholder perspectives presented through 27 semi-structured interviews from three pre-defined categories: (i) Policy communities (involved in formulating policies and decisions on climate change related issues, N = 9), (ii) Practitioners (involved in implementation of climate-related solutions or decision-making processes on the ground, N = 9) and (iii) Academia/Science (N = 9). Organisations represented by interviewees ranged from academic institutions, (national and local) government departments and agencies, government funded independent bodies and organisations, utility and infrastructure companies, and local resilience forums. Individuals were approached based on their knowledge, expertise and experience of decision-making in relation to climate change related issues. This was assessed based on the literature, a review of UK organisations and institutions, attendance lists to recent climate events and project contacts. A snowball technique was adopted by asking interviewees for recommendations on additional people to interview for the research.

Interviews were treated as anonymous and confidential, within the bounds agreed. The semi-structured interviews followed a broad funnel approach and the analysis presented in this paper focuses on the following themes referring to the co-production of evidence and knowledge: (i) extent of involvement of end-users in the production of evidence, (ii) opportunities and benefits of involving end-users, (iii) barriers to involving end-users and overcoming these. The use of semi-structured interviews enabled a more intimate, trusted and honest setting in which interviews could reflect as freely as they wanted on their own experiences and knowledge of the tensions experienced at the science-practice-policy interface relating to climate action. Individual

interviews were transcribed using intelligent verbatim transcription and a quality assurance process was applied whereby each interview was checked by the interviewer and then sent to the interviewee for accuracy and verification. Transcripts were cleaned, formatted and imported into NVivo 11 for analysis and coding using a combination of inductive and deductive thematic coding.

#### 4. Findings

##### 4.1. Study 1: co-producing climate evidence (e.g. IPCC reports) with practitioners

###### 4.1.1. Understanding the value of co-production as a process

Co-production was not understood in the same way by all workshop participants, with the majority considering the term in a loose way, to simply capture whether or not end-users had been involved in evidence production. Whereas, others familiar with the term, considered a stricter definition with workshop discussions showing that, while practitioners may already have some limited involvement in the IPCC process (particularly for WGII), embedding their evidence further through a process of co-production, and consideration of their evidence as complementing that of scientists and policymakers, would be more useful in from their perspective, and would thereby strengthening the findings and usability of the IPCC reports (Workshops 1, 2, 3). This aligns with the recommendations made by Howarth et al. (2017) to allow IPCC outputs to enable more actionable decision-making: that the IPCC WGII should incorporate more practitioners as authors, and that a new IPCC-linked body and a practitioner-led IPCC Special Report are needed to synthesise and report on good-practice responses to climate change. However, this would not be without challenges: discussions raised concerns related to maintaining the academic rigour of IPCC outputs and the extent to which this approach would conflict with the IPCC’s remit to be policy relevant whilst not being policy prescriptive. For example, workshop participants generally agreed this should be the case for WGI but was not appropriate for WGII, as the very scope of WGII means it is perceived by many as inevitably being “action orientated,” therefore creating a need for “actionable evidence” (Workshop 2). Many participants identified this as an opportunity where practitioner-based evidence could add value to the IPCC, as practitioners are well placed to

provide case studies of what successful climate adaptation looks like on the ground. In addition, their vast experience in best practice and lessons learnt would provide valuable insights in what to pursue and what to avoid in the future.

###### 4.1.2. Defining the co-production of scientific outputs

Workshop participants were invited to define what co-production would look like to produce IPCC outputs, however it was felt to be a process particularly difficult to define, nonetheless a set of key characteristics were agreed (Fig. 1). Through the process of co-production, participants discussed how each stakeholder would enable space for the incorporation and discussion of opinions and expert knowledge of others – if facilitated properly – hence providing the opportunity to take into account alternative perspectives and views. The co-production of outputs would therefore engage practitioners in the process while also allowing for joint-ownership of the process and outcomes between scientists and practitioners. Participants considered this to be a significant help to end-users if they were involved from the outset and given co-ownership of the process (Workshop 1). There was consensus across the workshops that co-production would enable the IPCC and its scientists to provide a stronger case for more resilient, useful and usable solutions to climate change. In addition, sharing lessons learnt as well as informing the IPCC about on-going work on climate responses would consequently become intrinsic to the process, rather than an afterthought. It was felt that this would avoid the pitfall that the Summary for Policy Makers fall into whereby the findings are presented to policy-makers to debate and negotiate the wording themselves. It was also generally agreed that the more actors co-owned the delivery and production of the IPCC reports, the more likely they would be used.

*“You are going to struggle to understand, be motivated or feel something is relevant if that document has not had input from people like you.”*  
(Workshop 2)

The process of co-production would thereby aim to incorporate end-users in a process of co-design of objectives, processes and outputs to better and more accurately capture existing evidence and experience to inform practical climate action on the ground. Consequently, outputs and processes produced will have been co-designed by individuals and organisations already involved in shaping decision-making as well as

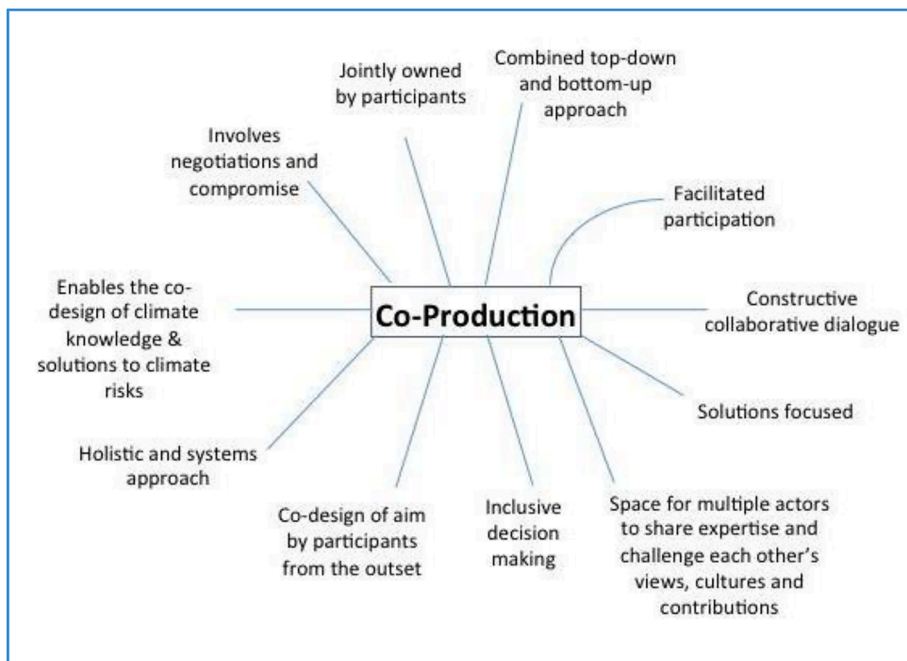


Fig. 1. Characteristics of co-production from workshop deliberations.

those who could potentially be affected by those decisions. In doing so, an understanding of people's interests, needs and experiences would be achieved, providing a platform for negotiating conflicting interests and shaping mutually beneficial outputs. Solutions to climate change require cross-sector and cross-stakeholder interaction and collaboration with combined leadership from academic, political and practitioner communities whose expertise and knowledge contributes to the development of climate action. Adopting co-production approaches would enable those participating to gain an understanding of the roles of others involved in the process, enabling them to better adopt these roles themselves, to self-reflect on overlapping motivations, which could help better shape climate policy and related processes (Workshop 3).

This could be done in one of two ways (Workshops 1, 2, 3): the first is through *co-production between policymakers, practitioners, academics* which would enable a better understanding of the needs of each of these stakeholders through a collaborative process: policy makers and practitioners mapping out specific needs and areas of policy relevance for which academic research is needed; practitioners bringing expertise and evidence of best practice and their take on what is required to implement solutions; academics bringing expertise in trans-disciplinary knowledge, methodologies, processes, rigour and systemic thinking. Adopting this approach would ensure the interests and needs of stakeholders and end-users are relevant. The second would entail *academics co-producing evidence with practitioners*: whilst providing similar benefits to the first option, this would also address concerns around the impact of incorporating practitioner-based evidence on the rigour and standard of academic research. This would enable a direct transfer of knowledge between academics and practitioners and enable each to gain a better understanding of the knowledge, needs and methods of the other.

#### 4.1.3. Challenges and opportunities for knowledge co-production

A number of challenges and opportunities for adopting a process of co-production were discussed (Table 2) in the workshops. Overall, through its collaborative approach, participants thought co-production moves beyond a traditional process of stakeholder engagement, which often resembles an end-user consultation process where they do not (co-) own the process. It was widely recognised as a process that provides a trusted space for open and transparent discussion and negotiation where stakeholders can push, support, challenge or find compromises on proposed policies or solutions. Workshop discussions concluded that IPCC WGII Coordinating Lead Authors could include and encourage practitioner evidence through co-production, and that climate scientists could adopt co-production approaches in the production of their science (Workshop 2), ultimately maximising the use of produced outputs. However, while this could make IPCC WGII more actionable, participants stressed there would be significant challenges in implementing this in practice. Trust was a key issue raised (Workshop 2) in asking stakeholders to come together through a process of co-production due to the risk of dilution of each actor's desired outcome to compromise with others' agendas. However, approaching an issue as a group ensures that outlier views are filtered, resulting in a more robust outcome. It was therefore agreed that this may only be the right course to take if all group members were working towards the same goal with mechanisms to assess transparency and accountability in place.

#### 4.2. Study 2: co-producing decision-making in response to climate shocks

##### 4.2.1. Understanding the value of co-production as a process

Interviewees provided a range of examples of projects in which end-users had been involved: impacts of climate change on UK electricity distribution (AC2); urban heatwaves (AC6); public dialogues on flood risk (P06); water utility companies (PR10). Co-production was embedded throughout many processes mentioned and the way in which co-production was implemented varied depending on the nature of the project in question and/or stakeholders involved. For some, it was the standard way to develop a product or tool with ideas at the start, then

**Table 2**  
Challenges and opportunities of co-production (from Workshops).

	Opportunities	Challenges
<b>Collaboration</b>	<ul style="list-style-type: none"> <li>● Goes beyond engagement through empowering those involved in the process</li> <li>● Includes broader range of experts</li> <li>● May overcome tensions and incompatibilities within and across different stakeholder groups</li> <li>● Access to new expertise, knowledge and funding</li> <li>● Encourages shared knowledge</li> <li>● Breaks down the silo culture into a more system-based view</li> </ul>	<ul style="list-style-type: none"> <li>● Hard to have an inclusive process if the system it exists in is heavily politicised</li> <li>● Potential incompatibility between stakeholders involved</li> <li>● Assessing level of seniority of stakeholders needed to take part</li> <li>● Different stakeholders work to different timescales and interests</li> <li>● Risk of (perceived) damage to credibility and accountability of those involved</li> <li>● Deciding who to include/exclude</li> <li>● Participants may not want to divulge information if not commercially beneficial for them</li> </ul>
<b>Focus on outcome and impact</b>	<ul style="list-style-type: none"> <li>● Can help build relevance into the outcome for all those involved</li> <li>● Enables those involved to think of the impact of their work and contribution to wider society</li> <li>● Demonstrate impact to funders</li> <li>● Considers outcomes of the process from the outset hence producing more resilient solutions</li> </ul>	<ul style="list-style-type: none"> <li>● Maintaining a sense of direction and aim when responsibility and leadership are diluted</li> <li>● Framing the question to address is key to maximise collaboration</li> </ul>
<b>Co-ownership</b>	<ul style="list-style-type: none"> <li>● Jointly owned and engaged by those involved</li> </ul>	<ul style="list-style-type: none"> <li>● Difficulty in encouraging those involved to relinquish leadership in process for better collaboration</li> <li>● Question of who owns the intellectual property</li> </ul>
<b>Structure</b>	<ul style="list-style-type: none"> <li>● Time restrictions can lead to a more efficient process</li> <li>● Can identify the range of potential uncertain societal impacts of an approach</li> <li>● Challenges scientific approach that solutions are created by consensus</li> </ul>	<ul style="list-style-type: none"> <li>● Practicalities of getting people together</li> <li>● Potential to overcomplicate process</li> <li>● Requires significant resource and time</li> <li>● Need to understand the context of the co-production process</li> <li>● Transferability to different contexts</li> </ul>

meetings set up with end-users to make sure the product or process meets needs and is as helpful as possible (AC7).

*"We are going to be, ultimately, some of the biggest end-users of a £4 million investment in natural flood management, and I think it was really helpful that NERC approached us right from the very start. Before they'd actually got the programme sorted out, they were seeking our input in terms of planning, how it should work, what it should cover, what the call should set out, what priorities we had, right from the very start then. So, we had about a year's worth of planning before the call actually went out. So, we were fully engaged in the process and I think that's been a really positive experience"* (PO9)

Co-production was characterised in a number of ways including co-creating knowledge on how to communicate risk to enable collaboration between experts and communities (AC4); creating a steering group for research council-funded research programmes (PO7); developing

responses based on local needs (PO3); combining insights from different academic disciplines to understand how future trends will evolve (e.g. climate change security scientists collaborating with World Food programme on Sudan food security, to understand how food systems and food security will be affected in the future) enabling flexibility and agility providing much clearer information to support adaptation activity (PR7).

#### 4.2.2. Opportunities and benefits of involving end-users

Interviewees were asked about how useful they thought it was to involve end-users in the production and communication of evidence to inform climate decision-making, views were mixed although overall this was seen as positive and useful whilst still raising challenges (PR6). It was seen as critical by many (PR10, PO9, AC7, AC4) and that *“there’s no point in developing a product that is not understood or not used by the end-user”* (AC7). For some, almost everything that is done is through co-production by incorporating experience of both end-users and developers of research as early as possible in the process (PO7). A key benefit of engaging end-users through a co-production process considered by interviewees included ensuring evidence, outputs, tools are fit for purpose and meeting needs, that questions asked are relevant (AC4) particularly when stakeholders need to *“be driven by what works for people and I don’t think our traditional ways of working encompass that yet.”* (AC4); this is especially relevant at the local level as this type of collaboration is essential to fund infrastructure projects (PR10).

*“I think they are crucial in all of this because otherwise we are designing things that are not fit for purpose and they won’t use it and it won’t help them.”* (AC4)

*“There’s no point us doing interventions if we’re not sure about how they’re actually going to work on the ground. And I think the problem in the past is we’ve been talking to people, we’ve not been working with people. We need more in the future to work with people.”* (PO3)

Co-production was considered as enabling more effective, better decisions to be made and essential as *“co-production is a way to get good impact”* (PO9). Involving end-users was seen by practitioners as hugely relevant to frame the challenges to overcome, to get some steer making the end product more useful (PR6) and ensuring whether specific processes or products works for them and whether accompanying information was sufficient (PR5).

*“I think being able to present the outputs from these climate models into the terms that the people are actually interested in is critical. You can’t do that without working with the decision-makers about what information you need to make a decision.”* (PR7)

*“They help us frame the problem and help us to frame it differently so we might contextualise something differently.”* (AC4)

Furthermore, co-production was seen to enable access to valuable knowledge, such as community knowledge on locations of vulnerable people (AC6), that would otherwise be untapped. Accessing personal experiences and stories experienced by end-users further enriches the process particularly when this involves direct interaction with end-users and those working on the ground. This is especially true when information dissemination and knowledge exchange can lead to distillation of important evidence which can highlight areas that need more attention and where new empirical evidence can challenge anecdotal information received from other sources (PO3). Similarly, co-production also enables collaboration to bring funding and funders together to develop innovative, agile and responsive modes of funding. For example, end-user collaboration involving a water company and local stakeholders enabled the funding of infrastructure projects and similarly making a joint case for action and the production of evidence (PR10).

#### 4.2.3. Barriers to involving end-users

A number of barriers were identified in the process of involving end-

users in co-production. Some interviewees failed to see how co-production was carried out in practice and that at times it merely felt like an *“empty slogan”* (AC3) and was seen as a way for government actors to pass on protective responsibility to the people it should be protecting (AC3). A ‘Policy’ interviewee felt co-production was not relevant to operational spaces or professional services (e.g. consultancy) and that it was seen as an academic exercise where the outputs might be used but would not necessarily be enticed to participate in the process itself (PO10). Within this context, clients are often considered to be end-users however clients themselves are increasingly interested in their own end-customer (PR3).

Co-production was considered to be time and resource intensive (PO9), particularly as it takes time and investment to engage and maintain relationships with sustained trust and willingness of end-users to engage (AC4). As a result it may not always be possible to fully involve end-users but instead they could be incorporated in an event or project during the preparation and planning stage (PR5) with forward planning helping to overcome this barrier *“to balance time investments with other work demands”* (PO9). The lack of resources often experienced by those who might wish to engage in co-production, also signalled an inability to generate data, or running the risk of duplicating what others were already producing (PO10). Similarly, Research Councils’ emphasis on novelty and scientific excellence, could lead to application or impact considerations suffering (PO7). In the context of policy, funding is limited in government departments suggesting Research Council’s may have greater control over what is funded (PO7). In addition, there is a need for commitment to fund projects which deliver long-term strategic research/advice as it is often felt there is a gap between what governments need in the immediate to demonstrate clear policy relevant results, and Research Council’s wanting long term scientific excellence (PO7). Both are needed with a focus on long-term strategic advice that doesn’t necessarily deliver high impact journals or immediate policy advice, but in the longer term, can have built capacity and developed long-term solid projects and networks (PO7).

Another challenge is the possibility of widespread apathy to engage with a co-production process (e.g. PR4) and individuals may not recall their own experiences of impacts of climate events (such as floods) that they feel can contribute to the process (PR4). While some individuals were willing to engage by providing advice, it is not always seen as a worthwhile activity and can be seen as resource intensive (AC4) with little immediate gain (PO10). Similarly, there are often cultural and epistemological barriers to overcome across the different stakeholder groups who would participate in such a process, siloed perspectives are another barrier in regards to what is considered to be science and evidence, who owns these, how they are produced and which is to be considered most effective to inform decision making: *“that’s my piece not yours”* (PO7).

A range of practical issues emerge when involving end-users which can further exacerbate the challenges discussed above, this can range from not having the adequate know-how to engage in co-production, not understanding what co-production is, interpreting this in different ways, having to explain different scenarios, having to present evidence differently to different stakeholders, striving to avoid stakeholder fatigue and overcoming difficulties around conflicts of interest. There are different ways of working where stakeholders and end-users may not speak the same languages, data or evidence can often be very numeric or computational which is often very difficult to integrate with local knowledge of individual communities (AC4, PR7). It can be practically challenging to identify and define who end-users are as an end-user could be considered to be a farmer or the person who advises him/her (PO7). These different end-users will have different needs (PR6) and there may be different interpretations of who actually is an (AC3).

## 5. Discussion: a translational mode of co-production for climate action

Having presented the findings of the two studies in the previous section, in this integrated discussion section we want to reflect back across the two together and provide a perspective on co-production, which goes beyond reflections on the process often led by academics who are attempting to engage in co-production research. We seek to draw on the insights drawn from the two studies on stakeholders' perspectives on the value and constraints to co-production in climate services and climate knowledge production. In so doing, these insights help us to further our understanding of boundary agency and the role it plays (or needs to play) in delivering more integrated knowledge bases which sit between the 'general/universal' and 'specific/contextual' poles identified by [Cash et al. \(2006a: 3\)](#). Informed by the literature review in section 2, we organise our reflections around three boundary 'themes' (spatial and jurisdictional boundaries; institutional and managerial boundaries; and political and temporal boundaries) in order to explore the nature of the boundaries identified through the empirics and how they manifest during processes of co-production.

Spatial and jurisdictional boundaries refer to the scales at which both the causes and the impacts of climate change can be identified, described by [Cash et al.](#) as comprising global, regional, 'landscape' and 'patches'. Meanwhile, jurisdictional boundaries correspond to the different levels of administrative geography from international cooperation down to local authorities. This is particularly pertinent to the findings that emerge from the two studies above in considering the role of evidence, how it is perceived, used and (co) produced at different scales to inform climate action. This emerges in the IPCC study in relation to the synthesis of evidence from different geographical scales (with the national scale dominating) alongside who the producers of this evidence are (e.g. scientists, policymakers or practitioners) and the extent to which they worked together to produce it. Considering the IPCC, and other science-driven processes, seek to be policy relevant without being policy prescriptive, serious discussion is needed as to whether this is in fact possible considering the range of actors involved in the production of evidence (and whether in fact this can lead to a co-production of evidence) and the different ways in which this knowledge is viewed, produced, valued and stored. Our analysis shows that co-production is highly valued by stakeholders involved in enabling a complementarity of knowledge, experience and evidence from different stakeholders to come about enabling a greater usability of outputs. Development and applications of knowledge to inform climate action at the international, national, regional and local levels is highly context dependent, and by its very nature is and needs to be policy prescriptive, challenging the notion that available evidence (such as that synthesised in the IPCC process) can and should be policy neutral.

Institutional and managerial boundaries refer to the various responsibilities associated with certain climate action 'stakeholders'. These boundaries include both 'formal' differences between places and groups (such as laws and regulations) as well as more 'informal' cultural elements associated with management practices and traditions. These boundaries are those which remain 'in the background' when co-production processes (such as those discussed in section 4) explicitly bring together different groups of stakeholders. While the 'physical' gaps between these stakeholders may be closed through co-production, certain assumptions and epistemological traditions associated with the different groups may remain as highlighted in the opportunities and challenges to co-production identified above. Our analysis of the two studies highlights the many opportunities recognised with engaging in co-production processes and the benefits of having a plethora of stakeholders involved. It empowers those who take part to share their broader experience and knowledge, it provides a structured and co-owned process and enables collaboration that focuses on outcome and impact, inevitably leading to outputs that are understood and used by end users. In so doing, outputs are better aligned and fit for purpose enabling more

effective decisions to be made, and generally the process is accepted and perceived as credible and useful by those stakeholders involved. Co-production of climate action and solutions requires input and expertise from different stakeholders, calling for a mirrored process in the production and synthesizing of evidence to produce climate action-relevant outputs (e.g. IPCC reports, climate risk assessments) and ultimately support decision-making ([Lemos and Morehouse, 2005](#)). The process of co-production allows for a sharing and communication of stakeholder interests, considered vital to those actors involved, and providing a platform for negotiating conflicts and shaping mutually beneficial objectives and outputs.

Political and temporal boundaries refer here to those boundaries related to the timescales across which climate change is rendered as an urgent (or not) governance 'problem' as well as the lifecycle of political systems at different scales and the impact this has upon the shifting prioritization of climate action. Our analysis of the two studies highlights the benefits of co-production processes and the value of including a range of expertise and knowledge in the planning, development and implementation of climate evidence nevertheless it can be practically challenging to identify and define who the end-users of climate information are, and often cultural barriers need to be overcome across different stakeholder groups participating in order to deliver impact on the ground. Co-production offers the opportunity for inclusion of diverse voices, however the identification of local and small-scale stakeholders and an understanding of how to navigate theirs and others cultural barriers and epistemological histories may be neglected. With this in mind, co-production is not understood or valued in the same way by those partaking, and considerations of its implementation vary substantially depending on the nature of the project in question, the intended output/outcome and the stakeholders involved. As highlighted in the previous section, co-production can be seen as an empty slogan and a way to pass on responsibility for climate action to others, calling for a deeper consideration of how the process can be effective and robust while maintaining rigour and without subverting responsibilities or passing these onto others.

Through two empirical studies on co-production, we have explored the concept of boundary agency, seen here as a set of active measures (such as communication strategies) aimed at mediating and overcoming boundaries between epistemological communities invested in a similar policy and governance challenge such as climate change. Our exploration of spatial and jurisdictional boundaries, institutional and managerial boundaries, and political and temporal boundaries within this context, as well as considering insights from stakeholders on the role and value of co-production, demonstrate that co-production should be seen as an essential and inclusive process, with the mutual construction of 'good science' not solely determined by the scientific community but also by interactions with internal and external stakeholders and with a wide end-user community. Involvement of a range of stakeholders in co-production processes forces them to go beyond their role as (passive) recipients of research knowledge and play an active role in commissioning, overseeing and assessing research. As demonstrated in this reflections above, involvement of practitioners and end-users in the inception of research projects and climate policy drafting can offer a means of communicating the values and perspectives of different stakeholders and ultimately lead to higher levels of engaged and utilised work, better aligned with end-user needs ([Martin, 2010](#)).

## 6. Conclusion

The disconnection between the producers of climate knowledge and its users remains an impediment to the delivery of effective climate services and ultimately to progress on climate action ([Bremer et al., 2019](#); [Viner and Howarth, 2014](#)). As targets implemented through international and national policies will affect and require participation, through co-production, by different stakeholders, their awareness, understanding, engagement and action is necessary to ensure uptake of



measures and sustained changes fill gaps where legislation and technology fail. Our analysis highlights the many benefits of co-production as well as the challenges including: the focus being on process rather than impact; production of evidence not always aligning with what constitutes sound evidence to inform decision-making; and an insufficient evidence base on the successful use of co-production approaches within climate services. Whilst it was not within the scope of this paper to explore these in the context of the specific stakeholders involved in the studies (e.g. policymakers, practitioners, scientists), this would be an interesting and important area for future research to gain a deeper understanding to the contextualisation of evidence, needs and expertise of these actors in the co-production of climate action.

A co-production process requires power relations between actors involved to be addressed, consideration for the inter-connections of issues and interests at stake and the implications these may have as well as identifying common goals in the process (Pohl et al., 2010). In order to enhance the co-production discourse which predominantly focuses on the involvement of different actors in the production of outputs, in this paper we have framed our discussion around the concept of boundary agency to capture the process through which boundaries between science, policy and practitioner communities come to be blurred (or not).

The capability to translate something from one language to another brings with it considerable agency (in addition to responsibility). Drawing on the literatures on co-production and translational science, we have discussed how, rather than co-production being an exercise focused on developing mutually agreeable and understandable outputs and actions, it is a process specifically focused on appreciating why different actors are participating in the process itself and in doing so, opening up the potential to invent new communities of practice, better suited to the multiscale governance challenge of climate change.

Our findings go beyond academic studies that attempt to engage with and observe co-production, by demonstrating the importance of incorporating stakeholder perspectives in the design, implementation and uptake of 'co' production. In so doing, co-production enables a better understanding of how evidence is perceived, used and co-produced across scales to inform climate action; it provides clarity on the range of responsibilities held by different climate action 'stakeholders', and it enables more efficient consideration of different stakeholder expertise and knowledge on climate action within different contexts. Rather than filling gaps between assumed scales, further discussion is needed on how scales of action might be something that can be co-produced though the development of new knowledges, and to what extent scale and polycentricity can be renegotiated and debated via co-production rather than taken for granted? The potential for this seems to be increasing, with greater attention now being paid to the adaptive capacity of an increasingly 'polycentric' mode of global environmental governance itself (Carlisle and Gruby, 2019). Devolution of responsibility to various different scales allows for a new appreciation of 'non-expert' communities in deliberative processes, ultimately enabling these communities in the delivery of impactful outcomes (Collins and Evans, 2002; Durose et al., 2011; Fischer, 2000; Ostrom, 1996). In order to embrace this polycentricity, however, we argue significant attention needs to be paid to how boundary agency can work to enable climate service participants to gain an understanding of the roles and perspectives of others, adopt these roles themselves and reflect upon divergent and convergent motivations.

#### CRediT authorship contribution statement

**C. Howarth:** Conceptualization, Methodology, Investigation, Funding acquisition, Project administration, Formal analysis, Writing – original draft. **M. Lane:** Conceptualization, Methodology, Validation, Writing – original draft. **S. Morse-Jones:** Investigation, Formal analysis, Writing - review & editing. **K. Brooks:** Conceptualization, Investigation, Writing - review & editing. **D. Viner:** Conceptualization, Resources, Writing - review & editing.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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#### References

- Baker, Z., Ekstrom, J.A., Meagher, K.D., Preston, B.L., Bedsworth, L., 2020. The social structure of climate change research and practitioner engagement: evidence from California. *Global Environ. Change* 63, 102074. <https://doi.org/10.1016/j.gloenvcha.2020.102074>.
- Bojovic, D., St. Clair, A.L., Christel, I., Terrado, M., Stanzel, P., Gonzalez, P., Palin, E.J., 2021. Engagement, involvement and empowerment: three realms of a coproduction framework for climate services. *Global Environ. Change* 68, 102271. <https://doi.org/10.1016/j.gloenvcha.2021.102271>.
- Boyle, D., Coote, A., Sherwood, C., Slay, J., 2010. Right Here, Right Now. Taking co-production into the mainstream. NESTA Discussion paper. <[https://b3cdn.net/nefoundation/8678a9d67320a294b4\\_38m6ivak1.pdf](https://b3cdn.net/nefoundation/8678a9d67320a294b4_38m6ivak1.pdf)>.
- Bremer, S., Wardekker, A., Dessai, S., Sobolowski, S., Slaattelid, R., van der Sluijs, J., 2019. Toward a multi-faceted conception of co-production of climate services. *Clim. Serv.* 13, 42–50.
- Carlisle, K., Gruby, R.L., 2019. Polycentric systems of governance: a theoretical model for the commons. *Policy Stud. J.* 47 (4), 927–952.
- Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J., Mitchell, R.B., 2003. Knowledge systems for sustainable development. *Proc. Acad. Sci.* 100 (14), 8086–8091.
- Cash, D.W., Adger, W.N., Berkes, F., Garden, P., Lebel, L., Olsson, P., Pritchard, L., Young, O., 2006a. Scale and cross-scale dynamics: governance and information in a multilevel world. *Ecol. Soc.* 11 (2).
- Cash, D.W., Borck, J.C., Patt, A.G., 2006b. Countering the loading-dock approach to linking science and decision making: comparative analysis of El Niño/Southern Oscillation (ENSO) forecasting systems. *Sci. Technol. Hum. Values* 31 (4), 465–494.
- Corburn, J., 2007. Community knowledge in environmental health science: co-producing policy expertise. *Environ. Sci. Policy* 10 (2), 150–161.
- Collins, H.M., Evans, R., 2002. The third wave of science studies: studies of expertise and experience. *Soc. Stud. Sci.* 32 (2), 235–296.
- Devès, M.H., Lang, M., Bourrelie, P.-H., Valérian, F., 2017. Why the IPCC should evolve in response to the UNFCCC bottom-up strategy adopted in Paris? An opinion from the French Association for Disaster Risk Reduction. *Environ. Sci. Policy* 78, 142–148.
- Dewey, J., 1954. In: *The Public and its Problems*. Swallow Press, p. 242.
- Dilling, L., Lemos, M.C., 2011. Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environ. Change* 21 (2), 680–689.
- Durose, C., Beebejaun, Y., Rees, J., Richardson, J., Richardson, L., 2011. Towards Co-Production in Research with Communities. AHRF, Swindon.
- Enquist, C.A.F., Jackson, S.T., Garfin, G.M., Davis, F.W., Gerber, L.R., Littell, J.A., Tank, J. L., Terando, A.J., Wall, T.U., Halpern, B., Hiers, J.K., Morelli, T.L., McNie, E., Stephenson, N.L., Williamson, M.A., Woodhouse, C.A., Yung, L., Brunson, M.W., Hall, K.R., Hallett, L.M., Lawson, D.M., Moritz, M.A., Nydick, K., Pairs, A., Ray, A.J., Regan, C., Safford, H.D., Schwartz, M.W., Shaw, M.R., 2017. Foundations of translational ecology. *Front. Ecol. Environ.* 15 (10), 541–550. <https://doi.org/10.1002/fee.1733>.
- Evans, J., Jones, R., Karvonen, A., Millard, L., Wendler, J., 2015. Living labs and co-production: university campuses as platforms for sustainability science. *Curr. Opin. Environ. Sustainability* 16, 1–6.
- Ferguson, D.B., Masayeva, A., Meadow, A.M., Crimmins, M.A., 2016. Rain gauges to range conditions: collaborative development of a drought information system to support local decision-making. *Weather, Clim., Soc.* 8 (4), 345–359.
- Fischer, F., 2000. *Citizens, Experts, and the Environment: The Politics of Local Knowledge*. Duke University.
- Guston, D.H., 2001. Boundary organizations in environmental policy and science: an introduction. *Sci. Technol. Hum. Values* 26 (4), 399–408.
- Harjanne, A., 2017. Servitizing climate science—institutional analysis of climate services discourse and its implications. *Global Environ. Change* 46, 1–16.

- Howarth, C., Painter, J., 2016. The IPCC and local decision making on climate change: a robust science-policy interface? *Palgrave Commun.* 2, 16058. <https://doi.org/10.1057/palcomms.2016.58>.
- Howarth, C., Monasterolo, I., 2016. Understanding barriers to decision making in the UK energy-food-water nexus: the added value of interdisciplinary approaches. *Sci. Policy* 61, 53–60.
- Howarth, C., Viner, D., Dessai, S., Rapley, C., Jones, A., 2017. Co-producing climate change knowledge: incorporating practitioner evidence in the IPCC WGII process. *Clim. Serv.* 5, 3–10.
- Howarth, C., Monasterolo, I., 2017. Opportunities for knowledge co-production across the energy-food-water nexus: making interdisciplinary approaches work for better climate decision making. *Environ. Sci. Policy* 75, 103–110.
- IPCC, 1998. Annex 7 Principles Governing IPCC Work. Available online at <<http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles.pdf>>. (last accessed 21 March 2020).
- IPCC, 1999. Appendix A to the Principles governing IPCC work, available on line: <<https://archive.ipcc.ch/pdf/ipcc-principles/ipcc-principles-appendix-a-final.pdf>> (accessed 21 March 2020).
- IPCC, 2012. Summary for Policymakers. In: Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.-K., Allen, S.K., Tignor, M., Midgley, P.M. (Eds.), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge and New York City.
- IPCC, 2015. IPCC Factsheet: How does the IPCC review process work? IPCC Secretariat. Last accessed 26 June 2020, available <[https://www.ipcc.ch/site/assets/uploads/2018/02/FS\\_review\\_process.pdf](https://www.ipcc.ch/site/assets/uploads/2018/02/FS_review_process.pdf)>.
- Jasanoff, S., 2010. A new climate for society. *Theory, Cult. Soc.* 27 (2-3), 233–253.
- Lassen, I., Horsbol, A., Bonnen, K., Grethe, A., Pedersen, J., 2011. Climate change discourses and citizen participation: a case study of the discursive construction of citizenship in two public events. *Environ. Commun.* 5 (4), 411–427.
- Lee, E., Su Jung, C., Lee, M.-K., 2014. The potential role of boundary organizations in the climate regime. *Environ. Sci. Policy* 36, 24–36.
- Lemos, M.C., Morehouse, B.J., 2005. The co-production of science and policy in integrated climate assessments. *Global Environ. Change* 15 (1), 57–68.
- Martin, S., 2010. Co-production of social research: strategies for engaged scholarship. *Public Money Manag.* 30 (4), 211–218.
- Meadow, A.M., Ferguson, D.B., Guido, Z., Horangic, A., Owen, G., Wall, T., 2015. Moving toward the deliberate coproduction of climate science knowledge. *Weather, Clim., Soc.* 7 (2), 179–191.
- NESTA, NEF, Innovation Unit, 2012. People powered health co-production catalogue. Available online at <<http://www.nesta.org.uk/publications/co-production-catalogue>> (accessed 7 April 2020).
- Osborne, S.P., Strokosch, K., 2013. It takes Two to Tango? Understanding the co-production of public services by integrating the services management and public administration perspectives. *Br. J. Manag.* 24 (S1).
- Ostrom, E., 1996. Crossing the great divide: co-production, synergy and development. *World Dev.* 24 (6), 1073–1087.
- Parris, A.S., Garfin, G.M., Dow, K., Meyer, R., Close, S.L. (Eds.), 2016. *Climate in Context: Science and Society Partnering for Adaptation*. John Wiley & Sons.
- Pohl, C., Rist, S., Zimmermann, A., Fry, P., Gurung, G.S., Schneider, F., Speranza, C.I., Kiteme, B., Boillat, S., Serrano, E., Hadorn, G.H., Wiesmann, U., 2010. Researchers' roles in knowledge co-production: experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Sci. Publi. Policy* 37 (4), 267–281.
- Shackley, S., Wynne, B., 1995. Global climate change: the mutual construction of an emergent science-policy domain. *Sci. Publ. Policy* 22 (4), 218–230.
- Twigger-Ross, C., Brooks, B., Papadopoulou, L., Orr, P., 2015. *Community Resilience to Climate Change: An Evidence Review*. Joseph Rowntree Foundation, York.
- UNFCCC, 2015. Intended Nationally Determined Commitment of the EU and its Member States. Submission by Latvia and the European Commission on behalf of the European Union and its Member States. Retrieved on April 4, 2020 from: <<http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx>>.
- Vincent, K., Daly, M., Scannell, C., Leathes, B., 2018. What can climate services learn from theory and practice of co-production? *Clim. Serv.* 12, 48–58.
- Vincent, K., et al., 2021. Co-production: learning from contexts. In: Conway, D., Vincent, K. (Eds.), *Climate Risk in Africa*. Palgrave Macmillan, Cham. [https://doi.org/10.1007/978-3-030-61160-6\\_3](https://doi.org/10.1007/978-3-030-61160-6_3).
- Viner, D., Howarth, C., 2014. Practitioner's work & evidence in IPCC reports. *Nat. Clim. Change* 4, 848–849.
- Vogel, C., Steynor, A., Manyuchi, A., 2019. Climate services in Africa: re-imagining an inclusive, robust and sustainable service. *Clim. Serv.* 15, 100107. <https://doi.org/10.1016/j.cliser.2019.100107>.
- Wall, T.U., McNie, E., Garfin, G.M., 2017. Use-inspired science: making science usable by and useful to decision-makers. *Front. Ecol. Environ.* 15 (10), 551–559. <https://doi.org/10.1002/fee.1735>.
- Wan, K., Shackley, S., Doherty, R., Shi, Z., Zheng, P., Golding, N., 2020. Science-policy interplay on air pollution governance in China. *Environ Sci Policy* 107, 150–157.
- WISER, 2019. Manual: Co-Production in African Weather and Climate Services. Available online at: <<https://futureclimateafrica.org/coproduction-manual/>> (last accessed 27/05/2020).