Use of research in climate change adaptation: participatory research

Chief Scientist's Group report

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Dr Robert Bradburne
Chief Scientist

Contents

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Executive Summary

The UK's national climate change risk assessment is clear that more needs to be done to prepare for climate change. Knowledge about climate change to inform adaptive action has historically been generated by scientists and typically shared with users in a linear, unidirectional manner. However, there is evidence that the use of different approaches to knowledge exchange and development could lead to more useful and useable climate-related data, information and knowledge and support decision making at pace. This report describes different approaches to knowledge exchange and development and experiments with these through an Environment Agency case study.

Co-production, defined as the exchange and integration of existing knowledges or the generation of novel knowledge that results from the interaction of multiple knowledge holders (e.g., scientists, policymakers, practitioners, citizens, etc.), has been identified as a powerful tool for developing salient knowledge. The case study reported here brought together a group of external facilitators (the 'researchers'), a Working Group of scientists and practitioners from the Environment Agency (the 'participants'), and an embedded researcher placed at the Environment Agency who mediated the relationships within and between these two groups, to share and co-produce knowledge for advancing and enabling the adaptation of the Incident Management Service to climate change. The participatory research process was conducted over an eight-month period and comprised diverse online activities including individual reflexive exercises, informal café-style conversations in pairs, facilitated workshops with all participants, and self-led brainstorming activities by the Working Group.

Participants were positive about their experience of taking part in the research and valued the opportunity to work with colleagues across the organisation with different expertise. Discussions between Working Group members coalesced around several themes:

- **The nature and impact of future incidents**, including flooding, drought, and environmental incidents, due to climate change, the spatial variability of incident risk across the country, high impact – low likelihood scenarios, and compound and cascading incidents.

- **Resilience**, specifically what this looks like in practise, and how resilience to incidents can be increased. Participants were keen also to understand what the Incident Management Service is currently resilient to and what an increased demand on the service might mean for the wider organisation.

- **Service provision**, inequity in service provision, and the influence that external factors such as public behaviours and investment will have on the risk 'owned' by the incident management service, as well as the opportunity this presents.

- **Barriers to adaptation**, including external and internal blockers of change, and the limitations of climate models and current understanding.

Knowledge gaps and ideas for future research identified by participants fell under two broad research questions ‘What does the future look like?’ and ‘What are we resilient to?’. The former encompasses research questions around the spatial variability of incident risks, what future summers may look like, and the nature of specific incident types and how these may change due to climate change. With regards to the latter, participants proposed undertaking stress-testing exercises to establish what the Incident Management Service is already resilient to and identify ‘pinch-points’ within the wider organisation.

Actions which may help enable adaptation were also identified by participants, including embedding knowledge developed from the participatory research programme in ongoing projects addressing the future of the Incident Management Service, and including members of the Working Group in adaptation advisory groups.

This project highlighted the importance of reflexivity and evaluation throughout the research process and embedding this type of research in existing projects. Lessons were learned about how to best select and recruit participants and cope with staff turnover during the process, and how to keep participants engaged throughout. Insight was also gained about when participatory research approaches, and specifically outcome-oriented versus process-oriented participatory research is most appropriate, and what conditions need to be in place for co-production to be sustained. These lessons were translated into recommendations and practical considerations for future projects and initiatives intended to experiment with similar participatory approaches for knowledge co-production.

Introduction

Knowledge exchange and development for climate change adaptation

Knowledge about climate change to inform adaptive action has historically been generated by scientists and typically shared with users in a linear, unidirectional manner. Yet, it is hard to assess the extent to which scientific knowledge is actually taken up to inform and support policy and practice on adaptation. Scientists, policymakers, practitioners, and advisors, including the UK Climate Change Committee (2021), have recognised for some time that the pace of adaptation needs to accelerate to ensure adequate preparation for the current and future risks that climate change poses, and that solutions need to be implemented by multiple and diverse decision makers. There is evidence that the use of a greater variety of approaches to knowledge exchange and development could lead to more useful and useable climate-related data, information and knowledge and support decision making at pace.

About this report

This report is one of the outputs derived from a project aimed at

> (1) exploring different approaches to knowledge exchange and development to enable adaptation at pace and
>
> (2) making recommendations to inform the way that Environment Agency scientists work in the future.

The project had two phases: Phase one involved an evidence review (see Annex 1: Evidence Review) which informed the second phase, a case study within the Environment Agency that followed a participatory research approach (the focus of this report). This case study brought together individuals from across the Environment Agency, including scientists, experts in adaptation, and staff working on Incident Management Service (IMS) strategy, to collectively explore and co-define what might be needed to ensure the service functions in the context of a changing climate. It was decided to focus on the IMS because staff working on the development of a new IMS strategy were actively seeking to explore how climate change may affect future incidents and the Environment Agency's capacity to respond to them. There is wide recognition that climate change will have significant, complex and uncertain impacts on the IMS, and it was unclear whether developing new scientific knowledge could help inform its adaptation to climate change, as this has not been the subject of extensive research by the Environment Agency previously.

This report presents the findings from the participatory research phase of the project. The report focuses on the case study and describes who was involved, what was carried out, and what was found (Section 2) and the lessons that have been learned from the entire participatory process (Section 3). Drawing on these lessons, the report suggests a list of recommendations to orient the design and facilitation of participatory processes aimed at experimenting with knowledge exchange and development (Section 4). The full methodology of the participatory research can be found in Annex 2: Participatory research methodological note. Details of participants, including the directorate and team to which they belong in the Environment Agency, and the activities in which they took part, along with workshop agendas can be found in Annex 3.

Key concepts: approaches to knowledge exchange and development

Evidence from the literature (see Annex 1: Evidence Review) suggests that **knowledge co-production**, which brings together knowledge holders from a diversity of disciplines, social groups and stakeholders to jointly develop new knowledge and/or exchange and integrate their knowledges, can be particularly advantageous to climate change adaptation. Bringing together different knowledge holders and knowledge types can lead to the production of relevant knowledge that is more accepted, trusted, and used by decision makers, generates a greater sense of ownership by all parties and tends to be more easily communicated.

In addition to co-production, **boundary spanning** is identified in the literature as a relevant approach to knowledge exchange and development for enabling adaptation. It means that an individual (i.e., **boundary spanner**) or organisation (i.e., **boundary organisation**) crosses between different groups to enable knowledge exchange or development. Individuals and organisations responsible for spanning boundaries are usually external to, and separate from, the groups involved in knowledge exchange and development.

Finally, there are other approaches where the role of linking knowledge holders and knowledge types is played by someone placed within the boundaries of one of the organisations involved. This is the case, for example, of **knowledge brokers** and **embedded researchers**.

For all definitions of key concepts, please refer to the Glossary.

Why take a participatory research approach?

Participatory research can be defined as an umbrella term for methodological approaches that vary along three axes:

1. level of engagement of participants in the research (i.e., the extent to which participants are co-researchers),

2. role of researchers (i.e., the extent to which the researcher is a facilitator from within), and
3. intentionality of the research process (i.e., the extent to which the focus is on applied research that is aiming to change the social world (Blaikie, 2010; Wittmayer and Schäpke, 2014; Sellberg *et al.*, 2021).

Drawing on the axes of participatory research, a series of principles were defined to orient the design of the methodological framework. Table 1 synthesises the principles that underpinned the methodology for this research project.

Table 1: Axes and principles of participatory research

Axes	Principles
1. Level of engagement of participants in the research	i. Careful selection and commitment of participants who can then lever and sustain the processes of change that have been started.
	ii. Attitude to listening to others, respecting diversity of opinions and openness to questioning own assumptions and ways of doing. Willingness to engage in constructive and challenging dialogue. Feeling comfortable with the uncomfortable. 'Rules of engagement' are mutually agreed and adopted by participants from the outset of the process.
2. Role of researchers	iii. Joint delineation of priorities, objectives, and steps, by researchers and participants.
	iv. Clarity of research journey and management of expectations (what is possible and what is not).
	v. Reflexivity (individual and collective) throughout the process, with moments to share learning and adjust while doing.
3. Intentionality of the research process	vi. Build on existing processes or initiatives.
	vii. Using existing relationships, networks, and formal/informal spaces.
	viii. Encourage lasting commitment to operationalising or implementing research outputs or outcomes, according to agreed research goals and objectives.

Participatory research was selected as the most appropriate approach for this project to experiment with interfacing and co-producing knowledge between knowledge holders placed in different directorates and teams in the Environment Agency. The participatory research aimed to achieve the following objectives:

1. **Interfacing**: To strengthen the linkages and collaborative capacity between and among science-policy, science-practice, and science-policy-practice interfaces across teams within the Environment Agency for improving climate change adaptation.
2. **Co-producing knowledge**: To co-design and work together in an ongoing process/initiative relevant for climate change adaptation.
3. **Sustaining the process to enable implementation and continued learning**: To commit participants to build on this pilot and sustain the co-production approach and interfaces, drawing on identified good practices or ways of working.

Importantly, while the participatory research represented an end in itself (with clear objectives, outputs and associated timeframes), it was considered by the project team and some participants to be part of a longer-term process to be sustained by those individuals who engaged in this experimental phase.

The case study: knowledge exchange and development for mainstreaming climate change adaptation into incident management

This section synthesises the methodological framework proposed for interfacing and co-producing knowledge for climate change adaptation across the Environment Agency and expands on the details of the case study on which it was piloted.

Selection of the case study

A case study approach was used to experiment with different approaches to knowledge exchange and development for climate change adaptation across the science, policy, strategy, and practitioner interfaces within the Environment Agency. The case study aimed to bring together staff from across the Environment Agency to explore climate change and its impact on the Agency's IMS and the knowledge needed to inform climate change adaptation decisions and activities in the future.

Who was involved?

Participatory research processes rely heavily on who is involved, including the relationship between participants and researchers and the roles that each of them undertakes during the process. This project involved 13 participants from the Environment Agency brought together in a Working Group, a project team of external consultants leading the design and facilitation of the research process, and an embedded researcher from the Environment Agency mediating the relationships between participants and the project team.

The selection of participants is crucial for the impact and sustainability of a participatory research process. The Working Group was created to bring the same participants together on an iterative basis and build a sense of group belonging and identity. Thus, the same participants engaged on a series of multiple activities and committed their time and experience over a relatively long period of time. In this regard, the Working Group was a part of the experiment in interfacing and co-producing knowledge. Specifically, it brought together staff from across the Environment Agency (see Table 2), including from the Chief Scientist's Group (CSG), Water Resources (WR), and Sustainable Business and Development (SBD) in the Environment and Business (E&B) directorate, Strategy and National Adaptation (SNA) in the Flooding and Coastal Risk Management directorate, and Incident Management and Resilience (IM&R) in the Local Operations (LO) directorate. Exploratory conversations were organised with staff working in these areas, with the aim of building on existing processes and relationships.

Table 2: Directorate and team of participants in the Working Group

Participant	Directorate	Team (Director level)
1	Environment & Business	Chief Scientist's Group
2	Local Operations	Incident Management & Resilience
3	Local Operations	Incident Management & Resilience
4	Environment & Business	Chief Scientist's Group
5	Environment & Business	Water Resources
6	Environment & Business	Sustainable Business & Development
7	Local Operations	Incident Management & Resilience
8	Local Operations	Incident Management & Resilience
9	Local Operations	Incident Management & Resilience
10	Flooding & Coast Risk Management	Strategy & National Adaptation
11	Environment & Business	Sustainable Business & Development
12	Flooding & Coast Risk Management	Strategy & National Adaptation
13	Flooding & Coast Risk Management	Strategy & National Adaptation

The initial selection of members of the Working Group was guided by the experience of the Environment Agency embedded researcher, who was also the project manager for the Environment Agency, together with the advice of other members of the project team. Participant selection aimed to secure an appropriate balance across knowledge types related to different incidents and aspects of the incident management service, educational

background / professional expertise, job position and gender representation (see Annex 3 for a full list of participants' characteristics).

The project team was comprised of five researchers and facilitators from the consultant's project team. The project team brought significant expertise in applying social research methods and undertaking interdisciplinary research projects as well as in facilitating expert and stakeholder engagement processes to inform research and policy. The project team had a key role in defining the rationale of the participatory process and designing the sequence of activities. As part of this curation role, they were also in charge of carefully selecting the groups of participants for each of the activities depending on the objectives.

The embedded researcher from the Environment Agency had a key role throughout the entire process. The project was originally conceived by this person drawing on their long-standing experience working within the Environment Agency (approximately 20 years) and their strong relationships with colleagues from multiple departments and areas in the organisation. The embedded researcher influenced the selection of the case study and contributed significantly to the initial recruitment of participants, convincing them of the relevance and value of their engagement in the project. While co-designing the activities of the participatory research with the project team, there was a change in staffing and a different member of staff from the Environment Agency undertook the project management and embedded researcher roles for the rest of the project.

What was done? Steps in the process

In the light of the nature of participatory research, the project team suggested a methodological approach that outlined the principles of engagement with participants and proposed an overarching roadmap with core milestones to be shaped by the preferences and expectations of participants (see Figure 1). The roadmap was introduced and discussed with participants at the beginning of the process and was translated into a series of activities over a period of eight months (33 weeks). Each of the activities was carefully curated, including objectives, format, content and who should be involved. The sequence of activities and how they built on each other was of particular relevance, including feedback mechanisms and learnings. It is important to emphasise that the entire process was conducted online, mainly due to the dispersed location of participants across different offices and places. The original design suggested a hybrid approach that included face-to-face interactions, but this was discarded when the final process was agreed by the project team due to the challenges in facilitating workshops across two mediums and keeping participants, particularly those joining online, engaged. Throughout the activities, the same online Mural board was used to synthesise the discussions and findings, with support from members of the project team. It worked both as a space and support for doing the workshop activities but also as a repository to which participants could come back at any time to add further thoughts or reflect on the discussions. This Mural board is referred to in the various activities below.

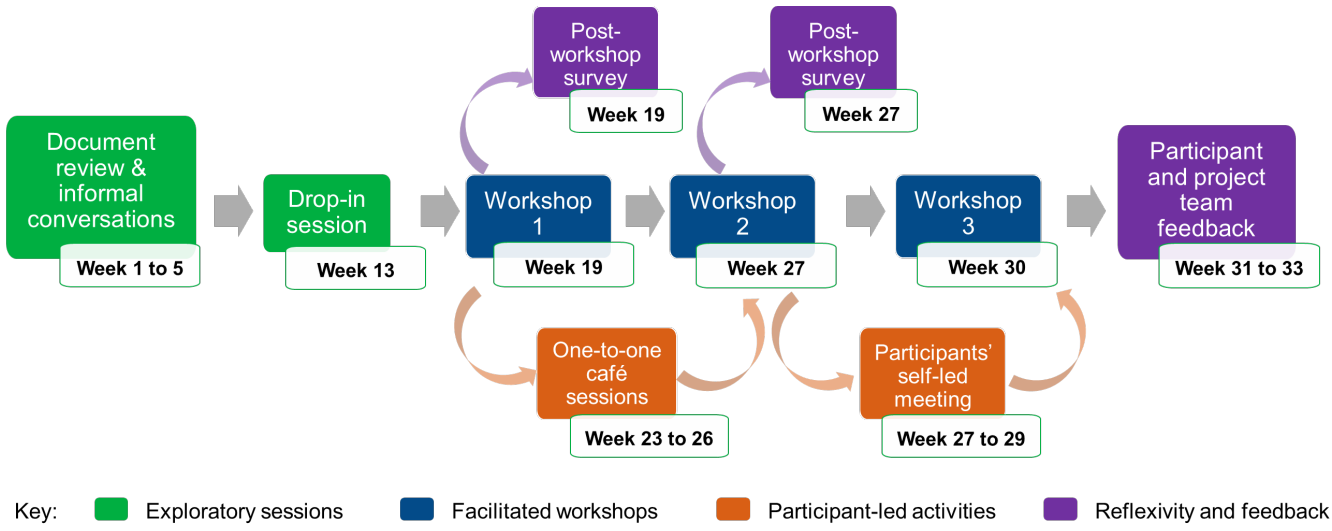

Figure 1: Milestones and timeline of the participatory research journey

Week 1 to 5: Review of key documents and one-to-one informal conversations with Working Group participants

The process began with the familiarisation of the project team with the organisational context. This included various meetings with the embedded researcher as well as the review of key documents from the Environment Agency related to the organisational structure, responsibilities of different directorates and teams, and strategic documents and policies on adaptation and incident management. These documents were flagged and provided by the embedded researcher, reviewed by the project team and, in some cases, used to inform the design of some of the activities (e.g., Environment Agency organisational chart).

Alongside the review of key documents, a set of six preliminary interviews were scheduled to help the project team's understanding of the roles and everyday work of different participants across the organisation, the questions they had in relation to climate change impacts and adaptation, and how they currently work and interact within the Environment Agency and externally. Out of the six participants, three were scientists working in CSG (E&B) and SNA (FCRM) and three worked in IM&R (LO). Separate sets of guiding questions were developed for the scientists and the IM&R (LO) practitioners with around ten questions each. All the interviews were designed as open conversations to discuss:

- Work routines (including in relation to adaptation).
- Data and information used on a regular basis (specifically in relation to adaptation).
- Awareness of other areas/departments/teams within the Environment Agency when generating or using data/information/knowledge for climate change and adaptation.
- Data/information/knowledge flows about climate change and adaptation across the Environment Agency.
- Interest in being part of the participatory process.

The analysis of these preliminary interviews helped shape the next steps in the process, including the interest of participants in joining a drop-in session and better understanding the purpose of the project, their preferences and availability for joining the Working Group, and the key initiatives and projects in which they were working.

Week 13: Drop-in session

A drop-in session was run pre-workshops for members of the Working Group. The aim of the session was for the participants to meet the external consultants who facilitated and oversaw the participatory process and ask questions about the process and their involvement.

Week 18 to 19: Workshop 1

Pre-workshop

One week before the workshop, an email was sent to all participants providing the objectives and structure of the workshop as well as a pre-workshop activity. The pre-workshop activity involved encouraging participants to reflect on the following questions:

- Who produces/uses knowledge about climate change and adaptation within the Environment Agency? What is this knowledge about (i.e., details of the content)?
- Can you trace the main flows between these producers and users of knowledge?
- Can you specify how this knowledge is transferred or circulated? Are there any specific instruments (e.g., reports, online repositories) or people mediating these transferring processes?
- What are the main research gaps for advancing adaptation in practice? Are there any other challenges interfering with adaptation objectives?

The participants were encouraged to use the Environment Agency organisational chart as a baseline map when reflecting on these questions, and to make notes of their personal reflections and bring them to the workshop.

Workshop

Workshop 1 was titled “Where are we standing?” It was a three-hour online workshop and used breakout groups and activities with the online whiteboard, Mural, to aid with discussions. The objectives of the workshop were:

1. To start building a sense of group identity across members of the Working Group.
2. To map what knowledge is currently produced and used for climate change and reducing its potential negative impacts (adaptation).
3. To explore what knowledge is needed for adaptation and where the main research gaps and challenges lie.
4. To prioritise a list of research gaps and main challenges, delineate ‘solutions’ to address them and co-produce a roadmap of actions on which participants can work together in Workshop 2.

Eight participants from national strategic teams in the Environment Agency, including CSG, WR, SBD (E&B directorate), SNA (FCRM directorate), and IM&R (LO directorate) attended the workshop. One of the activities in Workshop 1 entailed participants placing where they saw themselves on a Venn diagram of scientist, decision-maker, and practitioner (see Figure 2).

Post-workshop

One day after the workshop, an email was sent to participants with an online feedback survey to gather their opinions about the format of the activities, suggestions for improvement and learnings. They were also provided with the link to the Mural canvas that was worked on during the workshop, so they could add to it if they wished.

Week 23 to 26: One-to-one café sessions

In between workshops, participants were invited to engage in two 30-minute online cafe-style sessions in pairs. The main objective of these open, informal conversations was to foster relationship-building and recognition of diverse perspectives around a particular topic. Each conversation was with a new partner, so they had an opportunity to interact directly with two other participants. The project team intentionally paired participants who do not interact with one another on a regular basis, to encourage discussions from different viewpoints. In the first session, the topic selected to focus on was a prioritised research gap from Workshop 1: “Where is investment in preparedness most important compared to reactive/incident response?”. In the second session, the topic focused on one of the prioritised challenges from the first workshop: “Within the Environment Agency, there is lots of information available but not always provided to those who need it. Challenge of locating information/knowledge within the Environment Agency”. For both sessions, appropriate prompts were provided to stimulate discussion. Furthermore, participants used an online template to synthesise some of their reflections in a “brain-dump” style, without much structure or guidance, allowing them to freely express their ideas in their own words.

Week 26 to 27: Workshop 2

Pre-workshop

A week before the second workshop, an email was sent to all participants providing the objectives and structure of the workshop as well as a pre-workshop activity. This involved encouraging participants to reflect on the insights gathered from the café session conversations, which were collated and summarised on the Mural board.

Workshop

Eight participants joined Workshop 2 which was titled “Co-designing a proposal for addressing climate-related hazards and their potential impacts: content and process.” It was a three-hour online workshop and utilised breakout groups and activities with the online whiteboard, Mural, to aid with discussions. The objectives of the workshop were:

1. To create an opportunity for participants to collectively think about and share their feelings about different ways of engaging with members of the group.
2. To further elaborate on emerging challenges and suggested actions coming out of the participatory process so far.
3. To relate emerging challenges and suggested actions to climate change adaptation by focusing on specific climate-related hazards and their potential impacts.
4. To start to develop a sense of group ownership of the process going forward and collectively prioritise the main objectives of the final workshop.

Post-workshop

As with Workshop 1, one day after the workshop, an email was sent to participants with an online feedback survey to gather their opinions on the format of activities, suggestions for improvement and learnings. They were also provided with the link to the Mural canvas that was worked on during the workshop, so they could add to it if they wished.

Week 27 to 29: Participants' self-led meeting

Building on the ideas discussed in Workshop 2, participants were required to co-design a workshop agenda for the final workshop (Workshop 3). The workshop plan was to consist of a maximum of 3 sessions and for each session, participants suggested an objective and up to three key questions to be explored during the session. The project team then built on this initial workshop plan to develop the full workshop programme and activities to explore the objectives and questions identified by participants.

Week 30: Workshop 3

Workshop

Twelve participants joined Workshop 3 which was titled "Collectively deciding on next steps for improving resilience." It was run online over three hours and utilised breakout groups and activities with the online whiteboard, Mural, to aid with discussions. The objectives of the workshop were co-designed by participants in the self-led meeting after Workshop 2 and were:

1. To unpack what is meant by 'resilience' and 'to be resilient' within the Environment Agency, in general, and IMS, specifically.
2. To explore the internal challenges the Environment Agency generally and IMS specifically, currently experience in responding to shocks and stresses and identify actions to improve resilience.
3. To explore the external factors that affect IMS residual risk and discuss the opportunities that the Environment Agency has to reduce it.
4. To collectively prioritise actions and agree a plan for sustaining the Working Group moving forward.

Week 31 to 32: Participant feedback conversations

Once the participatory research had been completed, all participants were interviewed for their feedback about the process. These conversations were led by the Environment Agency embedded researcher to provide a space where the participants could freely share their honest thoughts and reflections. In particular, they were asked questions on the themes of:

- The participatory process (for example, enjoyment of the process and usefulness)
- Outcomes and achievements of the process
- Lessons learned
- Areas of improvement

Week 32 to 33: Project team feedback survey

Similar to the participant feedback interviews, members of the project team also gave feedback on the participatory process via an online survey. The questions focused on:

- Usefulness of the various approaches to knowledge exchange and development
- Outcomes and achievements of the participatory research process
- Lessons learned and challenges
- Areas of improvement

What was found? Knowledge gaps, research needs, and challenges around incident management and climate change adaptation

This section focuses on the subjects that were discussed during the multiple activities, that is: incident management and adaptation. Specifically, it is structured around two subsections: the first one, which highlights the key themes that emerged from discussions; the second one, which synthesises areas for future research.

Key themes

Nature and impact of incidents

A recurring theme throughout the workshops was a desire of participants to better understand the nature and impacts of incidents (specifically, flood, drought, and environmental incidents), in particular future incidents, to inform IMS planning and investment. Participants, especially those who work on IMS strategy, wanted to know about the nature of future incidents, in terms of their type, frequency, and the spatial variability of risk across the country as well as what impacts will look like for specific locations. Participants agreed that high impact/low-likelihood scenarios likely pose a threat to the country and therefore it could be beneficial to understand what impacts may look like and how the IMS will need to prepare for and respond to these, possibly through scenario-based exercises.

Participants generally thought that the understanding of drought and other environmental incidents and their environmental and economic impacts was poorer than for flooding. Participants suggested this is because of the historic focus of the IMS on flood incidents, the greater frequency of (historic) floods compared to drought events, and the significant work that has gone into the Long-Term Investment Scenarios which has provided substantial economic data for fluvial and coastal flooding. Furthermore, the responsibility for drought sits across multiple organisations. The risk and possible impacts of compound, cascading, and interacting incidents and how the Environment Agency may need to adapt to managing these was also identified as an area of concern.

Resilience

Participants agreed that it would be beneficial to understand what the IMS is currently resilient to, as well as what the implications of an increased demand on the IMS and its ability to deliver key operations might be. More generally, participants were interested in understanding what resilience looks like, in terms of societies, communities, and landscapes, and what can be done to increase resilience to incidents. Participants were also interested in understanding how catchment resilience measures and nature-based solutions may help reduce incident risk/and or severity.

IMS provision

It became clear through the workshops that there are many factors other than climate change that affect the risk ‘owned’ by the IMS, including public behaviours and attitudes and response to past incidents, the investment made in resilience measures, and the influence of national strategies and risk assessments. Participants highlighted that this presents an opportunity to reduce the risk ‘owned’ by the IMS through interventions in these areas. There was a lot of discussion around the balance of internal investment across the prevent, prepare, respond cycle and how this differs or could differ for different types of incidents. Participants also reflected on how the responsibilities and role of the IMS may change in the future or need to change.

Participants working on IMS strategy were also keen to understand how social inequality and vulnerability and exposure to incidents intersects with the provision of the Environment Agency services and the IMS.

Barriers to adaptation

Participants identified several barriers to the IMS adapting to climate change. Some of these related to limitations of climate models and the state of current understanding; however, many were organisational barriers including the siloed nature of working in the Environment Agency, the volunteer-based model of the IMS, and challenges around sharing data and information across the organisation and with external partners. Furthermore, the responsibility for many factors that affect the risk the IMS deals with lies outside of the Environment Agency, making adaptation even more challenging.

Future Research

What does the future look like?

Many of the ideas for future research that emerged from the workshops were around understanding what the future looks like due to climate change and what this means for the IMS. Specifically, research questions developed through discussion between participants included:

- How do the risks of specific incident types vary spatially? How will climate change influence incident risk across the country?
- How will the nature of specific incident types alter due to climate change?
- What compound incident scenarios are plausible?
- What does a future summer look like?
- What is the nature of drought as an incident? What do future droughts look like?

What are we resilient to?

Participants established that it would be beneficial to understand what scale, duration and combination of incidents the Environment Agency is currently resilient to, and what scenarios the Environment Agency would not be able to cope with, in particular for high impact/low likelihood scenarios. It was suggested that a scenario-based stress testing approach could help establishing this and identifying the pinch points in the IMS and wider organisation. Similarly, participants suggested that it could be valuable to explore what a resilient IMS looks like.

Participants also spoke about the difficulties in quantifying the amount of risk that is currently prevented by existing assets and interventions; as such, it was suggested that it could be beneficial to assess the state of current assets and the amount of protection they offer.

Other research topics

Other ideas for research topics identified in the workshops include:

- Quantifying the economic cost and environmental impacts of incidents, particularly for drought and environmental incidents;
- Behavioural and social science research to improve understanding of water demand and how to reduce it, the public's attitude to water consumption and understanding of drought and behaviour during incidents;
- Exploring what resilient landscapes, such as landscapes resilient to fire, look like.

Other actions

To build on this work going forward, it was suggested that some members of the Working Group could sit on a climate change adaptation steering group for the IMS, which is currently being established by the Environment and Business Climate Adaptation team.

Participants working on IMS strategy planned to feed ideas from these workshops into a project (i.e., the IMX project) exploring and determining the future of the IMS, including the development of the new target operating model for the service.

Participants also identified several actions that may help to overcome some of the barriers to climate change adaptation and help build resilience. These include feeding back on organisational challenges to senior leaders and raising the importance of preparing for high impact/low likelihood scenarios up through the organisation and up the national agenda. Participants also suggested that the development of a more integrated communication strategy around water and learning from other countries and their incident services could be beneficial.

Lessons learned: undertaking participatory research in the Environment Agency

The lessons learned focus on the process of designing and implementing a participatory process for experimenting with knowledge exchange and development for adaptation. They specifically elaborate on what worked well and some of the main challenges during the process, drawing on the views and perspectives of participants, members of the project team and the embedded researcher.

The lessons learned were derived from the analysis of post-workshop feedback surveys (for Workshop 1 and Workshop 2), feedback interviews with participants conducted by the embedded researcher, and feedback surveys completed by all members of the project team. These data were transcribed and qualitatively analysed using software Dedoose following the agreement by the project team of a list of preliminary themes. The identification of key themes as well as the analysis and discussion of findings have been further informed by the ongoing discussions and reflections of members of the project team during the entire participatory process. Whenever possible, key lessons have been related to, and contrasted with, the evidence identified in the literature.

The lessons learned are presented below, structured around seven themes that emerged from the analysis.

Coping with staff turnover in participatory research processes

Participatory research processes are affected by the context in which they develop. Therefore, prior to designing a participatory process, taking time to develop a detailed understanding of the organisation or situation in which the process will occur is important for the process to be successful. Some organisations have a high turnover of staff, with staff either rotating between job roles and departments or leaving and being replaced completely. Furthermore, potential participants are often busy, and if their time is not protected or ring-fenced for participating in research activities, gaps in their attendance

can be disruptive for the project, especially if this occurs at the beginning of the process. Designing a participatory process in these environments requires more flexibility than in organisations or situations where the participants are more stable in their roles as it can be difficult to get a group of participants to commit to a long-term research process.

Feedback from the project team and the participants reflected the difficulties of getting consistent participant involvement throughout the process. Several members of the project team talked about the difficulty of keeping the same people for each session and the change in the Environment Agency project manager and embedded researcher early in the participatory process. Similarly, some of the feedback provided mentioned the challenges of maintaining the continuity of participants over a long timeframe (such as several months) because of the number of participants that moved jobs or were temporarily seconded during the research period. It was important to keep participants interested and engaged, to retain the same group over the entire process, even if some of them could not attend every session or their role changed. A major success of the research was that nearly all participants remained engaged throughout the whole process, with nearly all participants attending at least two of the workshops and contributing to high completion rates for reflexive activities such as the café sessions. Furthermore, only one of the thirteen participants dropped out of the process entirely, which was due to a secondment to a different role. This demonstrates that participants were engaged, and found the process valuable, interesting, and/or enjoyable, which are important conditions for activating change within an organisation. Participants confirmed their appreciation of the process in the post-workshop surveys and feedback conversations. The embedded researcher was key to keeping people updated if they missed sessions and to recruiting suitable participants for the process itself. The embedded researcher also contributed to actively monitoring participation and interest and worked closely with the project team to suggest adjustments to the process that were suitable for the organisation.

The challenge of participant and staff continuity in participatory research is not unique to the Environment Agency. It has been acknowledged in the literature that continuity of staff is a determinant of success in knowledge co-production processes (Goggin *et al.*, 2019), while it is also recognised that government departments often suffer from high turnover of staff and limited inter-departmental communication (Lee *et al.*, 2021; Costa *et al.*, 2022). One solution to this issue that is suggested in the literature is to integrate a boundary organisation to enable continuity in co-production processes even when staff rotate roles (Robards *et al.*, 2018). In this project, although there was no boundary organisation, the embedded researcher acted as a stabilising figure between the project team and the Environment Agency in the short-term. However, this role was also subject to continuity issues as the first embedded researcher was replaced early in the process.

Key lessons:

- Keeping participants interested and engaged is important throughout the process, even when they may not be able to attend all events (especially over the long-term). This can be achieved through checking in on participants and ensuring they continue to think about what they hope to get out of the process.

- Having flexibility in the approach to recruiting participants. For example, if someone changes job role but is still the right person to contribute a certain perspective, keeping them involved in the process.
- Project managers and staff commissioning and delivering participatory research need to be mindful that participants need the support of line managers or team leaders to take part in these processes, to ensure that their time is set aside, and they can fully commit.
- The embedded researcher can be key to recruiting and communicating with participants due to their knowledge of the organisational context.
- There may still be disruption in the project due to not having continuity of participants throughout the process.

Participants – Facilitators' relationships and ownership of the process

Relationships between members of the participatory process can affect both the process itself and any outcomes that result from the process. Being aware of the different dynamics between participants and their interaction with the facilitators is important before the process starts. Understanding who works with whom and the level of seniority of participants is important so that the design of the activities ensures any hierarchies are not reinforced, and participants can be involved on an equal basis. The facilitators and the embedded researcher recruited participants with the aim of bringing together scientists, advisors, and practitioners from CSG, WR, and SBD (E&B directorate), SNA (FCRM directorate), and IM&R (LO directorate). In Workshop 1, participants placed themselves on a Venn diagram of scientist, decision-maker, and practitioner, and explained the reasoning (see Figure 2). This was valuable in helping facilitators understand participants' perspectives of their positionality in relation to these roles and identities. Perspectives of their positionality in relation to these roles and identities.

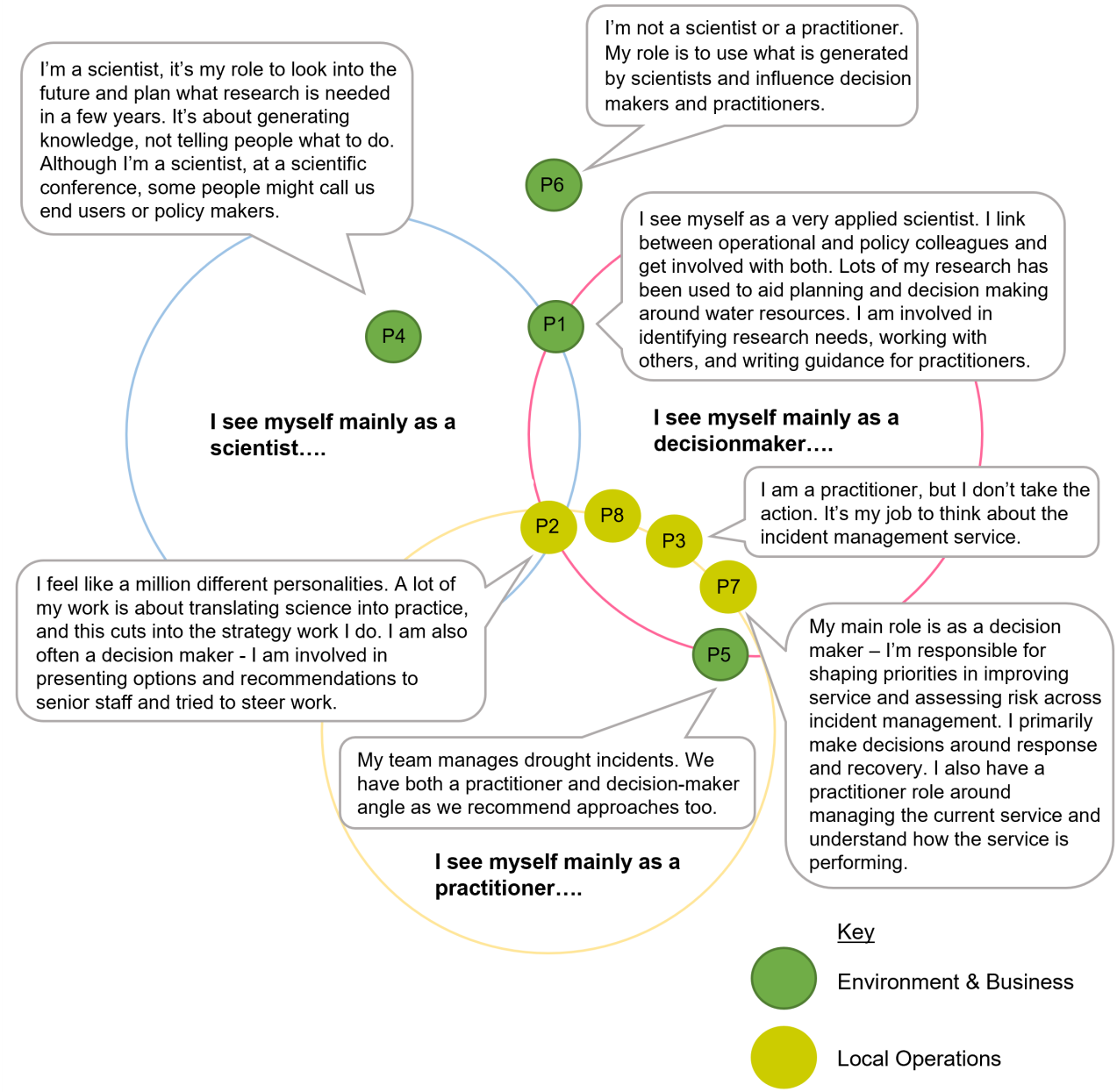

Figure 2: 'Positioning yourself' activity – Workshop 1 (20/07/2023)

In this project, it was important to have the embedded researcher from the Environment Agency being integrated into the facilitators' group. Acting as the nexus between participants and facilitators, they were able to explain the roles and responsibilities of the different participants and to ensure there was a mix of perspectives in the project. Feedback from the project team reflected on the benefit of having the embedded researcher from both a practical point of view, in terms of organising and collating feedback, but also in building the appropriate relationships between participants and the project team. The benefits of having an embedded researcher to help foster relationships and overcome institutional barriers (e.g., organisational culture) have also been identified in past research (Fazey *et al.*, 2013; Kench *et al.*, 2018).

While the facilitators tried to enable the participants to have collective ownership of the process, this was difficult to achieve. It was noted that, at times, the facilitators and some

participants (particularly those from CSG) had more steer and decision-making power than others. This was likely a result of the project being commissioned and steered by CSG scientists from the beginning. The context in which individuals operate as well as the institutional norms by which they are constrained are recognised in the literature as key factors influencing the success of co-production processes (Cvitanovic *et al.*, 2015). In this project, institutional norms and existing power dynamics around the research commissioning process may have inhibited true co-production. Furthermore, participants who do not have time for knowledge exchange and development activities as part of their formal workload may be more apprehensive about taking ownership of a project such as this due to time constraints and competing priorities. Interventions, such as tasking participants to design the agenda for the final workshop, were aimed at encouraging participants to take ownership of the process. Feedback provided suggested that taking more time at the beginning of the process to speak with all participants and understand what they want to achieve could help participants to feel greater ownership of the process.

Key lessons:

- Letting participants self-identify themselves rather than ascribing them categories as knowledge holders (for example, scientists, practitioners, and decision makers) contributes to a sense of ownership and belonging from the beginning of the process. Furthermore, having participants self-identify in relation to other participants starts to build an understanding of each other's positionality and how they perceive themselves.
- The designation of an embedded researcher as a boundary spanner between the project facilitation team and the participants was beneficial in terms of the practicalities of organising participants as well as helping to overcome institutional barriers and build relationships between the participants and facilitation team.
- Participant ownership of the process will build over time and does not happen automatically. It also requires trust between participants and facilitators and self-confidence. Alongside building and developing a sense of ownership among participants, facilitators balanced this with the transition from steering the process at the very beginning to stepping out and handing over the control to the participants to organise themselves at the end.
- It is important to have representation from all groups of knowledge holders from the beginning of the project (e.g., at the design stage) to generate ownership. However, in practice, this can be challenging due to institutional norms, commissioning processes for research projects, and workload models which do not allow for time to be allocated for knowledge exchange and development activities.

Diversity and multiplicity of activities

Participatory processes take time and usually extend over a relatively long period of time. A long-term process allows for experimenting with multiple and diverse activities. This is important for many reasons. In the first place, different activities might be suitable for defining and working towards different objectives. This is relevant given that, while

activities are stand-alone and have a specific purpose, they need to build into each other and provide continuity of learning (of ways of communicating, ways of interacting and ways of knowing). Secondly, diversity of activities allows recognition and incorporation of the needs and preferences of diverse participants. Some individuals might prefer to engage in smaller groups and with people they already know, while others might feel more comfortable and enjoy interacting with, and getting to know, new colleagues in larger groups. Thirdly, diversity is also important to keep participants engaged and not getting bored throughout the journey. Finally, multiplicity contributes to enabling everyone to participate (e.g., if someone could not attend one activity, they could join the next one).

In this project, we used different activity formats to allow participants to experiment with different forms of communicating, interacting, and exchanging and developing knowledge. The diversity of activities pertained not only to the format itself (e.g., online workshop, café-style conversation, informal meeting, etc.) but also to who was involved (e.g., number of participants, disciplinary/professional background of participants, etc.). Different activities were designed with different objectives in mind, both in terms of the content and subtle social dynamics. Many participants really liked and enjoyed the 1-to-1 conversations in the café sessions. This is interesting, as it does not seem to be something very difficult to incorporate into the organisation. The key seems to be with whom you engage in the conversation (i.e., identifying the right person with whom you need to talk).

In addition to the variety of activities, high quality facilitation also helped to keep participants engaged during workshops and with the overall participatory process. Participants gave substantial positive feedback on the role of facilitators and highlighted the value of good facilitation in keeping discussions flowing and focused. The project team carefully designed and structured the process in a way that it could support participants to have the space and time to focus on talking and discussing what was relevant to them, without having to worry about taking notes, summarising ideas, and having to report back on discussions. A key tool for these workshops was the Mural board which the facilitators used to provide a pre-prepared visual structure for the discussions and was added to throughout the workshops by a member of the facilitation team. In their feedback, participants emphasised that the facilitation of the Mural board made a significant difference in the process and was helpful in keeping the discussion flowing and allowing participants to fully engage with the content and process. This is a reminder that care is needed when using virtual tools such as whiteboards or polls to ensure that they enhance rather than impede discussions.

In this project, all activities were held online, which comes with its own pros and cons. Some participants gave feedback on the length of the workshops, saying that three hours felt like a long time to concentrate and that given it involved looking at a screen, it was not good for physical health issues. However, other participants stated that the length of time was good, with the workshops having a good mix of plenary and breakout group sessions. If the activities were held in-person, rather than online, the dynamics between participants might be altered and the range of possible activities would change. However, the online format was advantageous in making the workshops accessible to everyone regardless of

geographical location, keeping the costs down, and reducing the time commitment required of each participant due to not needing to travel.

In the literature, many sources mention time as an important factor in co-production processes with the observation that some researchers may not commit to these processes due to lack of time (Cvitanovic *et al.*, 2015; Meadow *et al.*, 2015; Goggin *et al.*, 2019; Oliver *et al.*, 2021; Cross *et al.*, 2022). However, there is a knowledge gap on how to keep participants motivated and engaged over long periods of time, with one source stating a need for further research into the design and implementation of effective and accountable monitoring and evaluation to enable learning about long-term outcomes and intangible benefits of co-production processes (Daniels *et al.*, 2020).

Key lessons:

- The sequence of the activities is key, and careful design and curation of the entire process is required prior to commencing engagement with participants.
- The variety of activity formats used throughout the participatory research process helps to keep participants engaged and to accommodate the needs and preferences of individuals.
- A well-structured and facilitated process contributes to give participants space and time to effectively engage in the participatory process. Using interactive tools such as online whiteboards and having a dedicated group of experienced facilitators for guiding and noting discussions are crucial components in this kind of processes.
- While contracting external experts to design and facilitate a participatory research process can result in a high-quality research programme and experience, the sustainability of the process needs considering. For example, who will cover the role of facilitators going forward and are there are people within the organisation with the right training and capacities to play this role? One alternative might be for external facilitators to be involved at the beginning in training others, so that the process can be self-sustained by those who have been trained.

Outcome-oriented versus process-oriented approaches

By its very nature, a participatory co-production process focusses on “how” knowledge is produced (i.e., the process) while typical processes for knowledge generation such as evidence reviews are focussed much more on “what” is produced (i.e., the output or outcome). In this project, the substantive goal was loosely defined around incident management and climate change adaptation, and it remained quite open. This had the effect of emphasising process aspects in the learning. It was not planned with a clear set of substantive outcomes to be achieved, but rather the goal was to facilitate a participatory co-production process that was adaptive in nature allowing participants to take more ownership in deciding the direction of the process and content as it was happening. Both participants and members of the project team noted that this approach was different to previous ways of working. Participants expressed varying levels of comfort with the openness of this approach. Organisational culture and norms may also play a role here, given the focus on delivering outcomes at an organisational level, as articulated in the

Environment Agency's 'How we do things' statements ('focus on outcomes; deliver our commitments'). Moreover, where there is a culture of risk aversity across decision makers, this can prevent the use of innovative knowledge development approaches (Dilling and Lemos, 2011; Oliver *et al.*, 2021), which may result in participants feeling under pressure to develop tangible outcomes and demonstrate the value of the process.

A fundamental benefit of the whole process was that it enabled participants to have both the opportunity (i.e., facilitation and logistics) and time to engage effectively with other staff and discuss their views around current and future challenges and related new research ideas. Several participants explained that the openness of scope enabled the project to be more adaptive and avoid individuals doing the same thing repeatedly, thereby helping to break down organisational working silos in the Environment Agency. Members of the project team highlighted that giving up a certain degree of control over the process and engendering a sense of ownership in the participants was new and challenging, although it was viewed as a positive process.

Whilst members of the Working Group were positive about the project in terms of developing connections, hearing about different perspectives, and exploring new approaches to communicating and interacting, a tangible outcome was not developed during the process. As such, it was often hard to keep the topic of discussion focused on climate change adaptation among participants. Therefore, the objective of co-producing knowledge to improving overall adaptation within the Environment Agency was not necessarily perceived to have been achieved.

The evidence review also highlighted the split between co-production approaches that are focused on outcomes and the production of actionable knowledge, and those that focus on the process and inclusion of multiple voices (Vincent, 2022). Some authors propose deliberately moving towards the process-centric approach to expand networks and build relationships, using science-informed decision-making and creating climate services with actors working together (Findlater *et al.*, 2021). While there appears to be little commentary comparing the positives and negatives of these different approaches, several sources detailed the conditions required to deliver successful co-production processes.

It was emphasised that clear and continuous communication and collaboration is required throughout each phase of the knowledge co-production process (Cvitanovic *et al.*, 2015; Meadow *et al.*, 2015; Goggin *et al.*, 2019; Cross *et al.*, 2022), and it is important to create a trusting and safe space that enables participants to be fully active in contributing (Cvitanovic and Hobday, 2018; Robards *et al.*, 2018; Costa *et al.*, 2022; Vincent, 2022; Wickenberg *et al.*, 2022). From the feedback received, it appears that this process-orientated project has been successful in generating some of the conditions needed for co-production and has created a space through which participants are engaged in, and value, the process.

Key lessons:

- A process-orientated approach is most beneficial for building relationships within an organisation and exchanging existing knowledge rather than co-producing 'new' knowledge and generating a clear set of actionable next steps.

- Participatory research needs to find the right balance between openness and flexibility and a strategic steer to ensure participants understand the purpose of the process.
- Developing the mechanisms for affecting change at the beginning of the process can help ensure that tangible outcomes are produced that can be progressed (rather than just discussion).
- External facilitators and participants, project managers, research managers, line managers, and project sponsors in the Environment Agency need to acknowledge the potential uncomfortable and uncertain nature of participatory research processes and manage expectations about what can be achieved through the process, especially when exploring new topics.

The importance of reflexivity (individual and collective)

Reflexivity can be defined as a continuous self-interrogation of positionality in research practice (Markham, 2017; Sellberg *et al.*, 2021). It applies to both researchers and participants, especially in the context of participatory research where participants are deeply immersed in the research process to the extent of becoming co-researchers. The participatory research undertaken as part of this project incorporated reflexivity as an individual and collective exercise. Participants were encouraged to critically think about their role and the role of their knowledge in the organisation and the extent to which this relates to the work of others during specific activities. These activities included the exploratory conversations at the beginning of the process, the pre-workshop activities ahead of facilitated workshops, the post-workshop online feedback surveys, and the feedback conversations held with participants individually at the end of the process. All these activities were designed to encourage reflexivity at the individual level.

Similarly, moments for collective reflexivity were integrated into the process, including the one-to-one café sessions after Workshop 1 and the strawman-style brainstorming exercise of the whole group after Workshop 2. The objective of these self-led activities was to allow participants to pause, reflect back on what was discussed in the previous activities, and share reflections with peers through dialogue and the exchange of views. The progression of reflexive activities entailed a gradual transition from individual moments for self-interrogation, through reflexivity in pairs to collective reflexivity with the entire group. Facilitators distanced themselves from these activities, to allow participants to have a private and safe space to reflect, but had a critical role in curating the activities to steer participants to engage with the act of reflexivity (e.g., through prompt questions, format of the activity, etc.)

The one-to-one café sessions were particularly well received by the participants. Many highlighted that these discussions were beneficial in promoting more detailed and valuable conversations with other participants than they would otherwise have had the space or time to complete. One of the participants emphasised the importance of this dialogue for breaking down silos and constructively challenging one's own views. Facilitators noted during the workshops, particularly at the beginning of the process, that participants did not

always answer the questions they were being asked and instead used their time to speak about what they wanted from the process. Therefore, it may have been beneficial to embed more time for reflexivity at the beginning to better understand what the Environment Agency participants wanted to get out of the process. Allowing time for participant feedback was also seen as beneficial and contributing to a more engaging process.

Reflexivity was also important for the entire project team, although it unfolded in a more subtle manner during weekly catch-up calls between the external facilitators and the embedded researcher. Reflexivity for facilitators and the embedded researcher was prompted by the feedback provided by participants through the various mechanisms and helped them to review and refine the next steps in the process. One facilitator commented that receiving regular feedback and comments from the embedded researcher and participants enabled the project team to adjust the activities so that the process met participants' needs and aspirations. In addition, there were more formal reflexive moments for the project team. These included the creation of a lessons learned register where members of the project team could drop their reflections in a shared repository on an ongoing basis, and the feedback survey that was completed by all members of the project team at the end of the process. The latter had similar guiding questions to those asked to participants.

Key lessons:

- Facilitators should consider reflexivity and set aside dedicated time for individuals and the wider group to critically think about the participatory process and how this can feed into the work being undertaken. This can help them to deliver more joined-up and coherent activities to support a more effective participatory process.
- Enabling participants to reflect on their own roles and the extent to which these relate to the work of others can promote relationship building and help to break down organisational silos.
- Facilitators need to be aware of changing emotions and feelings – both their own and those of participants- during participatory processes. This can be achieved through regular feedback sessions that help facilitators to understand needs and expectations of participants and to tailor the participatory process accordingly.
- It is important to formally embed reflexive moments for the project team (i.e., external facilitators, embedded researcher, and anyone else involved in the design and curation of the participatory process for co-production). This is as important as providing for reflexivity for the participants, and they should inform each other to contribute to a meaningful and valuable process for all the parties involved.

Embedding participatory research in ongoing processes and initiatives within an organisation

Participatory processes can be most effective when they become embedded in existing practices, processes, and structures within an organisation, rather than being isolated and

one-off exercises. This is especially relevant for generating interest and ownership from participants, as they can appreciate the value of spending time and committing to a long-term process, but also for securing the sustainability of the process once the research project has concluded. Sustainability is most valuable when trying to co-produce new knowledge with others.

This research project was conceived, designed, and delivered in the context of the Environment Agency action plans and the research themes of the CSG, and it was aimed at informing the development of the IMS national strategy through an adaption lens. The project was commissioned by the CSG and benefitted from the time, knowledge and expertise of a dedicated embedded researcher placed within this team.

Emerging findings from the project indicate a general acknowledgement from participants that committing to participatory processes for co-production, such as those explored in this project, though important, is difficult to sustain in the long run. This seems to be specially the case given the time investment requirements. There do not appear to be any concrete plans to continue this participatory process amongst the group of participants in its current form. Some participants acknowledged that this project would be beneficial in informing future work (e.g., in developing research questions based on ideas raised in workshops or designing a new target operating model for IM). It was highlighted that more emphasis on generating concrete outcomes from the participatory research, rather than just discussion, would help to develop potential next steps and hence sustain the process. Moreover, a formal delivery mechanism (i.e., a working or steering group), plus additional resources/sponsorship and support from senior management within the organisation are important factors to enable the participatory process to be sustained. One of the facilitators suggested that it might have been beneficial to keep a “collective open diary”’ among participants of the Working Group as a repository for their main discussions, areas of agreement/disagreement and/or decisions that were made during the workshops. This output could have helped create a shared ‘manifesto’ (vision) and ‘action tracker’ (plan) that would have ensured that a tangible outcome was produced and, in turn, helped to sustain the participatory process within the Environment Agency.

Despite this, there are some indications that this research project has helped to generate new connections across teams which have begun to promote different ways of working. Participants explained that they now know who to approach for information or insight on a specific area within the Environment Agency (e.g., IM&R or CSG), while the embedded researcher highlighted that they are aware of conversations and meetings that have taken place outside the scheduled participatory research process because of the connections made through the project. Moreover, the process has been useful in exposing participants to new ways of engaging and communicating with others within and outside their own team. This was seen as particularly useful in supporting the use of more social science, participatory methods to help shape future research agendas within the Environment Agency. The project team were unsure about the extent to which this participatory approach would be sustained within the Environment Agency but felt that the contacts made between participants from different teams were significant and hoped that this ‘small community of practice’ would continue after the project ended. As participants gave very

positive feedback about the 1 on 1 ‘café session’ meetings, it was also considered that these could be an attractive exercise to integrate into future ways of working.

The evidence review revealed that a key factor influencing the effectiveness of joint knowledge development and exchange is the extent to which participants, as well as potential future stakeholders, are involved in the process through frequent interaction rather than only at a single point (Kirchhoff, Carmen Lemos and Dessai, 2013; Cvitanovic *et al.*, 2015; Meadow *et al.*, 2015; Goggin *et al.*, 2019; Cross *et al.*, 2022), thus highlighting the importance of sustaining participatory processes. Important aspects of joint knowledge production, such as continued engagement amongst participants require significant amounts of time and resource to maintain (Hegger and Dieperink, 2014; Norström *et al.*, 2020; Street *et al.*, 2022). Furthermore, planning for and sustaining long-term participatory processes in the Environment Agency is challenging, given that participants may be working on projects or assignments and often move around the organisation into different roles (discussed in Lesson Learned 1). It is therefore unsurprising that participants felt that more sponsorship and support from senior leadership was required to embed and sustain longer-term participatory processes within the Environment Agency.

Key lessons:

- Identifying ongoing processes or initiatives into which to plug participatory processes for co-production is key to secure interest, commitment, and resources from participants in an organisation.
- If sustaining participatory processes for co-production is defined as a core objective of the research project, it is important that participants are aware and agree with that objective from the beginning of the project. This can help using the participatory research process to co-design the next steps and required actions between participants as a concrete output of the process.
- Several factors such as continuing sponsorship and support from senior management are required to sustain long-term participatory processes initiated in the context of a research project beyond the lifespan of the project.
- Sustaining the participatory process will also depend on commitment from the participants and setting up a formal delivery mechanism (e.g., a working or steering group) to co-lead the process going forward and continue the momentum generated during the research project.

Relevance of participatory processes in the context of knowledge exchange and development: when and for what purposes?

As discussed previously, this project was designed to deliver a participatory co-production process rather than a defined set of outcomes detailing the substance of knowledge (i.e., content) that should be developed and/or exchanged. The openness and flexibility of this approach and dedicated time set aside for discussion helped to create an environment where participants from different teams across the Environment Agency could exchange

knowledge and good practices related to climate change adaptation and where research gaps and priorities could be co-defined.

From the feedback received from participants and the project team, the participatory process was seen as most beneficial in developing relationships and exchanging existing knowledge rather than co-producing ‘new’ knowledge. Most considered that the project objective of strengthening the linkages and collaborative capacity across the Environment Agency to improve climate change adaptation had been achieved, with several participants highlighting that this collaborative research model had enabled them to make new connections with others across different departments. This was viewed as beneficial in advancing participant understanding of the Environment Agency organisational structure, roles, and ways of working within other teams, plus identifying wider research needs and challenges related to climate change, operationalising resilience across the organisation. For example, one member of the IM&R team explained that the process had made them aware of research gaps in the Environment Agency and to whom to speak about future research and development, due to new relationships formed with members of CSG. This participatory process therefore highlights the importance of forming new relationships between people and generating a shared understanding of the data, information, and knowledge available within an organisation. The importance of creating trusting, long-term relationships was reflected in the evidence review, with these relationships perceived as necessary to successfully co-produce usable science (Meadow et al., 2015).

It was hard for participants and the project team to discern whether the participatory process had been successful in enabling participants to co-produce new knowledge and work together in an ongoing initiative relevant for climate change adaptation. Some noted that the process had helped to generate new research ideas and create agreement between individuals, although detail as to what these ideas are was not specified in the feedback forms. The project team highlighted that there was real evidence that teams and individuals who had not worked together before, were collaborating. This was especially evident in the co-design of the third workshop agenda.

Key lessons:

- While co-production of novel knowledge has not necessarily been achieved, the participatory research process was beneficial in promoting collaboration and forming new relationships between participants. This is a relevant step towards knowledge co-production and can potentially lead to generating relevant and usable knowledge in the future between participants (and the teams to which they belong) in this research project.
- Creating ownership and trust between participants has facilitated more expansive conversations, creative thinking and brainstorming of ideas around climate change adaptation to help individuals and teams across the organisation to identify knowledge gaps and prioritise research needs.

- Having a formal mechanism set aside to bring together staff from different teams has helped to advance the knowledge base and shared understanding around climate change adaptation in the organisation.

Recommendations for experimenting with knowledge exchange and development in participatory processes

This final section brings together a series of recommendations for experimenting with knowledge co-production (i.e., knowledge exchange and development) using participatory research methods. Recommendations are drawn from the review of the literature and our learnings during the design and facilitation of a participatory process using a case study. Recommendations highlight the 'conditions for success' and 'key questions to consider' when designing participatory processes for knowledge exchange and development.

Conditions for success

Table 3 synthesises the conditions under which participatory processes tend to work well when experimenting with knowledge exchange and development between different knowledge holders. It is worth considering whether these conditions are already in place before embarking on a participatory process.

Table 3: Conditions for success

Conditions for success	Description
Time and space for reflexive, creative thinking	Two aspects of time are important. Firstly, the same participants having time (or being allowed the time) to meet on several occasions, for an hour or more. Secondly, creating spaces within those times where people can move into a reflexive, creative thinking mode rather than the usual reactive, problem-solving mode of thinking.
Willingness to experiment and learn	The objective of the participatory process (i.e., to exchange and co-produce knowledge for adaptation) carried out for this project was by its nature an experiment, in the sense that it was a new approach, and there was no certainty of the outcome. Experimenting involves taking risks and testing, adapting as you go, and being willing to fail. Learning from others can expose gaps and flaws in our own thinking.
Desire to develop different knowledge networks	Most organisations have an element of “siloed” thinking and working, where different work areas do not need to interact on a daily basis. However, to tackle increasingly complex “wicked problems” such as the impacts of climate change where the interconnections and consequences cross boundaries, working across those siloes becomes more important. Knowledge networks that span traditional boundaries can lead to innovative solutions and whole systems thinking.
Desire to build relationships across different knowledge holders	Relationship building develops and enhances social capital[1], bonds of trust and reciprocity which are vital to enabling large organisations deliver on complex issues. It gives access to different knowledges and resources. Willingness to have open conversations and following the

[1] Social capital after Putnam (1995, p. 67). "social capital" refers to features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit.

	'rules of engagement' can ensure a respectful and inclusive process.
Intentional design and facilitation of process	The design of the participatory process has to be intentional to enable participants to be free to think creatively which may seem counterintuitive. Good design of the process means attending to the questions to be asked, the time given to different sessions, the materials used, and the facilitation style. Sessions without intentional design are likely to be draining and unproductive.

Key questions to consider

The following questions are intended to guide the design of participatory processes aimed at knowledge exchange and development between diverse knowledge holders (e.g., scientists, practitioners, policymakers, etc.). The list is designed to encourage critical reflection on the most appropriate approach depending on the overarching objectives of the process. The questions are organised under the key components of a participatory research process.

1. **Understanding of the context and organisational landscape**

- Who has conceived the original research project?
    - Who is commissioning the research project?
    - Who has defined the overarching objectives of the participatory process?
    - Have 'participants' being invited to collaborate as co-designers of the research project?
- What are the key processes or ongoing initiatives that the proposed participatory process is aimed at influencing and tapping into?
- Are there any previous experiences in the organisation with participatory processes aimed at knowledge co-production and bringing individuals from different departments together?
    - Who led these past experiences?
    - What can be learned from these previous experiences?
    - What has worked well? What have been the main challenges?

NOTE: Consider history and organisational context, so you can build on successes and not repeat failures.

- Who are the key knowledge holders within the organisation in relation to the topic of relevance?
    - What is the relationship between them?
    - How does knowledge flow between them?

- Are there external knowledge holders upon which the organisation relies? If yes, is it desirable to involve them?

NOTE: Think about what types of knowledge you want to bring together, where do they lie within the organisation? Think widely.

2. **Selection and recruitment of participants**

- Who should be involved? Why?
  - Are there key influencers/champions in the organisation that can replicate and/or scale up the process?
  - Are there key knowledge holders that are often ignored and/or misrepresented in discussions and decisions on the topic at hand?
  - Are there key people who are likely to block or distrust the process?
  - Does the selection and recruitment of participants recognise the diversity of views and perspectives, including disruptive voices that can enrich the process?

NOTE: Involving key influencers will help your process have traction. Involving those who are ignored/misrepresented will help challenge organisational myths. Involving "critical" friends will ensure your process is not derailed externally.

- Have participants been given a chance to self-identify and position themselves in relation to other knowledge holders and types of knowledge?
- Are there any power imbalances that should be considered and addressed when bringing participants together during the process?
  - How can these power imbalances be mitigated in the most effective and sensitive manner?

NOTE: Power imbalances need to be addressed throughout the design of the process so that they are not further reinforced by the participatory research . Ground rules, small group work, Chatham House rules, etc. all help.

3. **Role of facilitators and other key individuals / organisations**

- Who are the most appropriate individuals to design and facilitate the participatory process for knowledge exchange and development?
  - Should the process rely on external or internal facilitators? Why?
- Are there other key individuals/organisations who should be engaged in the participatory process (e.g., boundary spanner, boundary organisation, knowledge broker, embedded researcher, etc.)?
  - What should be their role in the process?
- What is the nature of participants – facilitators relationship underpinning the participatory process?
  - To what extent do participants have ownership over the process?

- Are there key moments/transitioning points for facilitators to 'hand over the stick'?

NOTE: External expert support for the design and delivery of participatory processes will help avoid mistakes and create a sense of independence and neutral space. A useful approach is for participants to co-design the content and facilitators to curate the process. Co-production may increase as the process evolves, requiring less design work from external experts.

4. **Curation of the participatory process for interfacing and co-producing knowledge**

- What activities are the most appropriate to achieve the co-defined objectives?
- Are different activities (e.g., format, grouping of participants, etc.) required for different objectives?
    - What is the most appropriate format (e.g., online versus in-person) for each activity?
    - What are the most appropriate criteria for grouping participants (e.g., individual, in pairs, smalls groups or entire group) for each activity?
- What is the most appropriate sequence of activities and of grouping of participants for providing continuity and learning during the process?
    - How can you sustain the enjoyment, interest, and commitment of participants during the entire process?
- Is there flexibility and room for manoeuvre to refine the design of the activities as the process unfolds?
    - Is the process design iterative and adaptive to the needs and preferences of the participants?
- What resources (e.g., people, money, technical infrastructure) do you need for undertaking the various activities of the participatory process?
    - Are these resources available?

NOTE: Ensuring the activities help achieve the objectives is in the detailed design and needs to be attended to.

5. **Reflexivity, learning and ongoing adjustment**

- Are there reflexive moments for facilitators/researchers and participants to pause and critically think about the process?
    - Does the process design incorporate individual and collective moments (e.g., allocated time and guided activities) for reflexivity?
- How are facilitators stocktaking and incorporating learnings emerging from these reflexive moments?
    - Are there specific mechanisms in place to feedback reflections into the participatory process design?
    - Are adjustments being incorporated as part of these feedback loops?

- What are the emotions and feelings of facilitators and participants during the process?
    - Have these emotions and feelings changed over time?

6. Evaluation of the participatory process

- Is evaluation conducted throughout rather than only at the end of the process?
- To what extent have the objectives originally co-defined between facilitators and participants been achieved?
    - Are the objectives being monitored, periodically reviewed and adjusted if necessary?
- What have been the main achievements from a process point of view (e.g., changes in ways of communicating, ways of interacting, ways of knowing)?
- What have been the main achievements from an outcome point of view (e.g., tangible knowledge products or knowledge objects)?
- Are there other core achievements as a result of the process?
- What have been the main challenges that hindered the achievement of certain objectives?

NOTE: Reflexivity and evaluation are a key part of the process and aid learning. Time needs to be made for this to happen.

7. Sustaining the process

- Has the continuation of knowledge exchange and development been discussed throughout the participatory process?
    - Has this been prioritised as one of the core objectives?
    - What methods for that continuation have been considered?
- Has an action plan been co-developed by participants to sustain the process moving forward?
    - Has a list of tasks (e.g., activity tracker) been co-defined by participants to keep track of progress?
    - Have dedicated resources (i.e., people, money, technical infrastructure) been ringfenced to implement the plan of action?

NOTE: It is important to discuss what sustainability might mean for your participatory process. For example, It might not be a continuation of the same process but integrating new knowledge into a wider process.

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List of abbreviations

CSG: Chief Scientist's Group

E&B: Environment & Business

FCRM: Flood and Coastal Risk Management

IM&R: Incident Management & Resilience

IMS: Incident Management Service

LO: Local Operations

SBD: Sustainable Business & Development

SNA: Strategy & National Adaptation

WR: Water Resources

Glossary

Term	Definition
Boundary organisation	An intermediary organisation that sits outside of the other groups but facilitates knowledge exchange or development between these groups.
Boundary spanner	Any individual who works across a boundary to enable knowledge exchange or development.
Boundary spanning	Any process or situation where an individual or organisation crosses the boundary between different groups to enable knowledge exchange or development. 'Groups' could include scientists, researchers, policymakers, practitioners, communities, other stakeholders.
Co-production	A process where representatives from different groups (e.g., scientists, policymakers, practitioners, communities) work alongside each other to produce knowledge. Co-production is resource and time intensive as a strong component involves building and maintaining relationships between the participants. An element of co-production is that there must be a degree of power sharing between all participants involved. A spectrum of co-production exists depending on the balance of power sharing among the participants. Co-production is understood within this report to be iterative and collaborative.
Embedded researcher	An individual from one organisation (e.g., academic institution) who is hosted or positioned within another organisation (for example, a decision-making agency). Similarly, you might have policy fellowships, where policymakers directly engage with scientists around a particular topic.
Joint knowledge production	A term used to refer to research projects in which scientists and policy-makers (or practitioners) cooperate directly to produce actionable knowledge (Hegger and Dieperink, 2014).
Knowledge	Within this report, knowledge is defined as outlined by the Data, Information, Knowledge, Wisdom hierarchy, whereby data becomes information which becomes knowledge.

	Includes all types of knowledge: scientific, academic, practical/practitioner, community and theoretical. Useable knowledge is knowledge that is perceived to be credible, salient and legitimate by those who use it.
Knowledge broker	An individual who transfers knowledge between organisations (across a boundary). A knowledge broker usually comes from within one of the organisations that is involved in the knowledge exchange or development process.
Knowledge exchange and development	Within this report, this term is used to encompass all components of knowledge production, development, sharing, exchange, and use.
Knowledge exchange and development approaches	Within this report, this term is used to encompass all approaches and processes that may be used to enable knowledge exchange and development.
Knowledge products	Knowledge products are defined to include (but are not limited to) ‘worksheets, tools, models, and assessments designed to harness science and technology to link knowledge to action’ (Ernst and Preston, 2020).
Science-policy-practice interface	Any situation where academic/scientific research, policymaking, and practice meet and interact (for example, in problem solving of complex environmental problems such as climate change adaptation).

Annex 1: Evidence Review Report: Knowledge Exchange and Development Approaches and Their Use in Climate Change Adaptation

Note: This annex consists of an evidence review report, which examines what is known about knowledge exchange and development approaches and their use in informing and enable adaptation to climate change. This report is an output from the first phase of this research project as was intended to inform the second phase of the research project (participatory research process)

Contents

Executive Summary

This report explores different approaches to knowledge exchange and development (KED) across the science-policy-practitioner interface and how they have been used to inform climate change adaptation. Academic papers and grey literature were systematically selected, prioritised and reviewed. The use of KED approaches in environmental decision-making contexts is a well-established area of research. Therefore, this report seeks to gain better understanding of how KED approaches could be used to enable effective climate change adaptation, by reviewing existing literature on the use of KED approaches in other environmental and sustainability decision making contexts. We also interviewed 12 experts from academic, policy, and practice backgrounds about their experiences of and thoughts on producing knowledge for enabling climate change adaptation.

What emerged was that co-production, which brings actors from different groups to work alongside each other to produce knowledge can be particularly advantageous to climate change adaptation research. Bringing together different stakeholders and knowledge types can lead to the production of relevant knowledge that is more accepted by decision makers, brings a greater sense of ownership by all parties and tends to be more easily communicated.

Boundary spanning, where an individual or organisation crosses between different groups to enable knowledge exchange or development, was also identified as important for enabling climate change adaptation. In practice, boundary spanning can be taken on by a knowledge broker or boundary organisation or facilitated by an embedded researcher (an individual from one organisation who is hosted within another). The use of boundary spanners was identified as a characteristic and enabler of several successful knowledge co-production projects. Their role in overcoming barriers is also important.

The effectiveness of KED approaches is also influenced by organisational silos and institutional cultures, for example, a lack of openness to change. Barriers to knowledge exchange can include contrasting expectations, differing understandings of uncertainty and a risk averse culture amongst decision makers. Involving multiple stakeholders presents the challenge of integrating different types of often context-specific knowledge. This may mean that decision makers engage in information transfer rather than knowledge co-production. The use of a transdisciplinary approach and increased interaction between scientists and decision makers can help overcome this.

The costly nature of co-production best practice means that resourcing is often a barrier to research projects that use different knowledge exchange and development approaches. This is compounded by the challenges that co-created or practitioner-led projects often

experience in obtaining funding. The inclusion of a boundary spanner can reduce costs by helping the project through early hurdles quickly but requires an initial investment.

Identified knowledge gaps include evaluation of the effectiveness of different knowledge exchange and development approaches in different circumstances, a lack of empirical studies employing knowledge exchange and development approaches in practice, particularly in climate change adaptation, and how scientific evidence feeds into participatory processes and subsequent decision-making.

The findings from this evidence review, including best practices for co-production approaches for knowledge exchange and development will be used to inform a participatory research case study. This case study will bring together scientists, experts in adaptation, and those responsible for the Environment Agency's incident management strategy, to explore what might be needed to ensure the service functions in a changed climate.

Introduction

Background

The is no single approach to climate change adaptation since the risks that we anticipate will be experienced and responded to differently. The breadth of contexts is vast, from local, regional and national scales to societal sectors and types of organisations (for example, government, private sector, or community based). The uncertainties described by climate scientists about how the future might be, alongside uncertainties in how earth systems and people will respond make decision making challenging. Climate change adaptation is an evolving process and thus requires working across the science-policy-practice interface to ensure informed, rigorous, transparent and climate-sensitive decision-making.

The field of climate change in general is dominated by scientific information about how the climate is changing and what the impacts of that will be, which needs to be turned into action for climate change adaptation to occur. However, as work in climate change adaptation progresses it is clear that there is a wide range of knowledge types: scientific, social scientific, practical, local, organisational with different assumptions and levels of credibility which need considering for actions to be effective. This is further complicated by the diversity of people who need knowledge, evidence and data, including national and local policy-makers, public, private and voluntary sectors. Different users will have different perspectives on the validity of different types of climate change adaptation knowledge, and the different capabilities for handling this knowledge is also influenced by their context.

Unsurprisingly, conventional linear approaches to science into policy/practice have been found to be less useful in these types of complex applied areas with a move away from an idealised, linear framing of “science” being produced, handed over to policy/decision makers and somehow “used” within a linear policy/strategy/decision-making process.

Typically, it is in complex transdisciplinary applied areas where a different approach to knowledge production is needed, and climate change adaptation has all those characteristics. Transdisciplinarity (i.e., crossing disciplines, going beyond disciplines and including stakeholders in formulating research objectives) requires the translation and re-presentation of information to different audiences. It also requires having a range of knowledges from different disciplines, some of which might be contested points towards the need to co-produce knowledge. Further, climate change adaptation is focussed on applied problem solving, beyond understanding into action.

Finally, within the social sciences there is a long tradition of research approaches that seem to break the barrier between the researcher and the researched to achieve change.

This takes place under the umbrella of participatory research which engages those who are the focus of the research in the research process in ways that enable meaningful participation (Vaughn and Jacquez, 2020). Researchers work with participants to understand systems and then use that understanding to facilitate improvements in these systems. This has grown out of a desire to go beyond the traditional positivist approach that treats participants as ‘subjects’ to be directed by researchers.

This project looks at approaches for knowledge exchange and development in order to understand how they might be useful in supporting climate change adaptation.

Report outline

Objectives

This report describes the method and results of an evidence review with three objectives :

1. the effectiveness of different knowledge exchange and development (referred to as KED from now on) approaches in enabling the use of scientific data and different forms of knowledge to support climate change adaptation.
2. the barriers and enablers of KED at the science, policy and practice interface and how working across it could be enhanced to support climate change adaptation.
3. the main gaps in the evidence base.

This report provides the methodology used for the evidence review along with specific research questions. This is followed by a presentation of the main findings for each research question, and themes emerging from the literature on knowledge production and exchange to support climate change adaptation. The evidence review also provides an overview of the volume and characteristics of the evidence base and a synthesis of what the evidence indicates in relation to the research questions. This is followed by a discussion of the main evidence gaps associated with the research questions. Finally, this report provides conclusions based on the findings from the literature.

Method

Research questions

To address the objectives of the evidence review, the following primary and secondary questions were selected. The primary research question is: **What has been learnt about developing knowledge for climate change adaptation and how might this inform the way the Environment Agency works in the future?**

For purposes of reporting the primary question was reframed into five more detailed research questions (RQ) each presented in a separate section in this report:

- RQ1: How are key terms (such as knowledge, evidence, data, knowledge development/production tools/approaches, knowledge exchange) defined and used within the literature/evidence? Do definitions vary between users/stakeholders (e.g., practitioners, policy makers, researchers)?
- RQ2: What are the different approaches for knowledge development? How are they defined? Who are the users? What are the needs of different users for knowledge production?
- RQ3: What evidence is there about the effectiveness of different knowledge development/production approaches for enabling climate change adaptation? What barriers/enablers exist in different contexts / for different users?
- RQ4: What evidence/examples are there of where approaches for knowledge development have been used to enable climate change adaptation? Why have they been successful or not?
- RQ5: Is there evidence/are there examples of the different approaches being used around incident management?

Evidence review scope

The scope of the evidence review is defined by the research questions outlined by Environment Agency in the project specification. The scope established the inclusion criteria and exclusion criteria for our search strategy:

- language restrictions: English
- target: public sector knowledge production and exchange and studies that explore interventions and approaches to climate change adaptation and measure the impact of climate change adaptation policies or implementation.
- geographical reference: relevant examples from UK, Europe, North America, Australia, New Zealand and Tasmania
- date restrictions: 2010 to present (except in cases where an older source is important for answering any of the research questions)
- search libraries: Google and Scopus
- type of source: peer-reviewed research and grey literature

Evidence review method

The methodology and process of the evidence review is focussed and follows a logical search strategy outlined in a protocol (see Annex 1). The evidence review protocol describes how the review was carried out, concentrating on the inclusion and exclusion criteria, search string, sources of evidence and approach to prioritisation of documents. The Population Intervention Comparator and Outcome (PICO) approach to organising the search terms was taken drawing on JWEG guidance (Collins et al., 2015). A consultation with the Environment Agency was carried out to ensure the main search string included all the appropriate keywords. Following the approach set out in the protocol, a final list of 39 evidence sources was produced to be used in this review. This included peer-reviewed scientific literature resulting from a search in Scopus, grey literature from a Google search, and further additional literature suggested by interviewed experts, members of team and Environment Agency as well as Steering Group members that fulfilled the exclusion criteria as defined in the evidence review protocol. Both Scopus and Google enabled the use of Boolean search strings. An overview of the method used is presented in Figure 1.

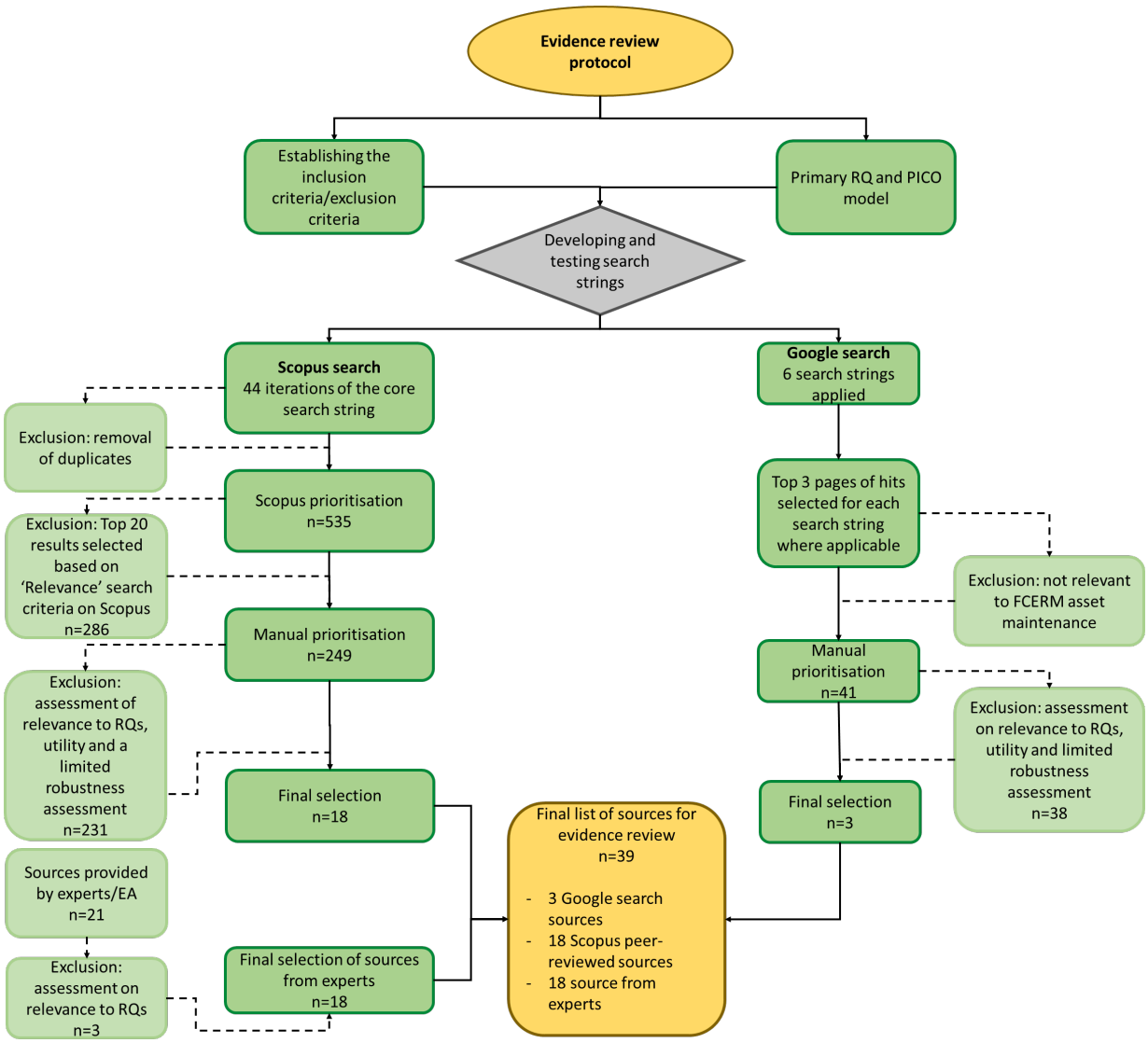

Figure 1: Evidence review process

Interviews

In total 12 experts including academics, national/international policy-makers, climate change adaptation advisors and practitioners working on climate change adaptation were interviewed. The objective was to gain a range of stakeholder views on:

- Definitions of knowledge, evidence and data in the context of climate change adaptation
- Examples of the successful co-production or transfer of scientific knowledge or evidence for climate change adaptation and factors contributing to success

- Challenges for successful knowledge co-production and transfer in the context of climate change adaptation
- Main lessons from knowledge co-production and transfer literature and practice over the past ten years
- Main gaps in evidence about knowledge co-production and transfer in the context of climate change and how these could be filled.

An interview schedule was developed and agreed with the Environment Agency and experts from the Steering Group in advance of the interviews (see Annex 1(i)). Following the interviews notes were written up and checked against recordings/transcripts. The team analysed the interviews using the qualitative data analysis software Dedoose (see section below).

Review methodology

An Excel database was set up and populated with the results from Scopus and Google searches. In addition, the recommended reading by interviewed experts and sources from the project specification were added to the list and any duplicates were removed. This resulted in 249 literature sources. The database was populated with the main information for each piece of evidence (for example, author, source, type of evidence). The origin of the evidence (whether the source came from the literature search or via expert suggestion) was also recorded and is presented in this report as part of the overall assessment of the evidence. The limited duration of the evidence review made it necessary to carry out a further prioritisation of sources by introducing prioritisation criteria including:

- application of exclusion/inclusion criteria
- relevance to research questions (3 - Directly answers the RQ; 2 - indirectly answers the RQ; 1 - Does not provide answers to the RQ)
- a limited or simplified robustness assessment (peer reviewed or not; review or empirical study; number of citations)
- taking the top 20 from each search string using the Scopus prioritisation[2]

[2] Note this was validated by Environment Agency who manually assessed the relevance of a random selection of Scopus prioritised sources and those that were excluded following Scopus prioritisation. The results showed that those sources prioritised by Scopus were also considered to be the most relevant by experts in the Environment Agency.

Based on the total score from the assessment, 39 sources with the highest scores were prioritised and taken forward to the literature analysis and synthesis stage. This involved the development of an Excel spreadsheet where all the information relevant to the RQs was extracted from each of the prioritised sources. Once complete we conducted inductive coding of qualitative data to identify emerging themes that would help to answer the RQs. Inductive coding is a process of reading the information taken from the sources and developing codes and themes from the bottom-up rather than going in with pre-assigned themes. A separate database was developed for the coding task where each code created was presented under the relevant RQ and relevant excerpts across the prioritised sources were inserted that captured the respective code.

The interview analysis used the qualitative data analysis software Dedoose[3] which enabled the application of codes that helped to facilitate the analysis. More than 50 codes were applied across the five RQs that were categorised into high-level thematic codes (such as, types of knowledge, boundary organisations) and more specific codes (such as, relationships between actors, organisational/institutional capacity). This approach enabled the project team to extract the issues from experts and other stakeholder experiences of the use of knowledge in climate change adaptation.

This report compares and combines the findings from the analysis of the interviews and the literature.

Limitations

This evidence review does not provide a comprehensive overview and analysis of all existing evidence compared to a full systematic review. The limited duration of the evidence review only allows a restricted view of the use of knowledge in the research literature available as a more in-depth search for sources could not be done. The time limitations also meant that the results from Google were capped at the top 30 sources and Scopus searches were capped at the top 20 sources for each search string used.

[3] Dedoose is an online qualitative software: www.dedoose.com

Findings

Overview of evidence reviewed

A total of 39 sources were analysed as part of the evidence review, prioritised from the long list of 249 sources identified by external experts, Environment Agency staff, and through systematic Scopus and Google searches. These sources comprised a mixture of peer reviewed academic and grey literature. The overwhelming majority of sources (n=34) were peer reviewed, with the journal 'Environmental Science and Policy' contributing the most sources (6). The five non-peer reviewed sources were published by a range of different institutions, encompassing the Environment Agency, Stockholm Environment Institute, University of Leeds, University of Twente, and University of Oxford. The sources can further be disaggregated by the type of methodology applied. Just over half of the sources (21) were empirical studies based on information generated through observation or experimentation, with the remaining 18 sources review articles.

Approaches applied to knowledge production and exchange are rapidly evolving in the fields of environmental and social science, with applications in the climate change adaptation field only recently emerging in the literature. Therefore, during the evidence review, all sources published prior to 2008 were excluded from the analysis (see Method). The final list of 39 sources analysed covered a date range from 2010 – January 2023, with the majority of the literature assessed published from 2015 onwards (Figure 2).

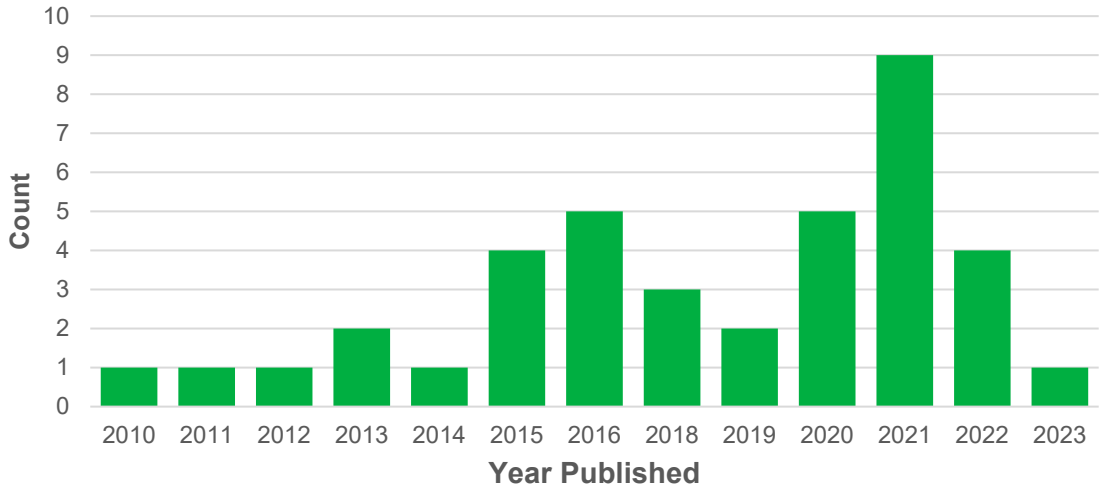

Figure 2: Publication dates of the evidence reviewed

While the focus of this project is on the use of research and knowledge development in climate change adaptation, not all the evidence reviewed explicitly focused on climate

change adaptation. Instead, many focused on related topics such as environmental resource management, sustainability transitions, and environmental governance more broadly while others discussed knowledge production and exchange processes more generally.

Overview of the interviews

A total of 12 semi-structured interviews were carried out with a range of UK experts who work at the science, policy and practitioner interface. The aim of the interviews was to gather a range of perspectives on the topic. Each expert interviewed had experience of developing, sharing, or using knowledge for climate change adaptation. Interviewees were from a range of disciplines as set out in Table 1:

Table 4: List of interviewees

Expert interviewee identifier	Interviewee experience
E1	Climate adaptation expert working primarily within the infrastructure sector
E2	Academic expert in hydrology and climate impacts
E3	Expert knowledge broker in the field of climate mitigation
E4	Academic expert in climate change adaptation in UK and internationally
E5	Interdisciplinary academic expert in climate change adaptation and co-production
E6	Climate science expert from a UK government organisation
E7	Academic expert in the use of climate information in adaptation
E8	Climate change and evidence expert from an environmental NGO
E9	Academic expert in theatre and performance in the context of environmental change
E10	Independent researcher and climate resilience expert
E11	Academic expert in socioecological systems and environmental risk
E12	Interdisciplinary boundary spanner between research, practice and policy relating to climate resilience and adaptation

To support the findings of the evidence review and answer the research questions, the focus of the interviews was on *how* knowledge is or can be developed in practice, and not about knowledge for climate change adaptation itself.

Understanding terminology for knowledge exchange and development for climate change adaptation

It is clear from the volume of evidence identified through this review process that understanding the relationship between the use of knowledge in research and decision-making is an established area of academic interest. However, there does not appear to be widely accepted consensus when it comes to defining some of the terminology. This section conceptualises some of the terminology used within the field of KED and sets out how we use such terminology within this report. To do this, findings from the literature and expert interviews are analysed to understand how key terms are defined within the literature and how they are used in practice. In doing so, this section explores how the definitions and use of terms vary depending on the context and the users/stakeholders involved.

This section answers research question *1. How are key terms (such as knowledge, evidence, data, knowledge development/production tools/approaches, knowledge exchange) defined and used within the literature/evidence? Do definitions vary between users/stakeholders (e.g., practitioners, policy makers, researchers)?*

Understanding what is meant by 'knowledge'

Knowledge, as referred to in the context of the literature reviewed, is developed through various phases. This is referred to as the Monitoring-Data-Indicate-Assess-Knowledge (MDIAK) chain (EEA, 2011 cited by Oliver et al., 2021) starting with monitoring, leading to data, information, assessment and then knowledge. Data are the raw values which, when processed, can become information. Information then needs to be synthesised or assessed in order to become knowledge. Each step increases the usability of the original data. Furthermore, Oliver et al. (2021) refer to '*organisational wisdom*' (p.155) as a step beyond knowledge, using knowledge in a sophisticated and sensitive way, looking at the ethical and social context, taking a long-term perspective and weighing the interest of multiple stakeholders (Rowley, 2006 cited by Oliver et al., 2021).

Within the reviewed literature, definitions of types of knowledge tended to fall into two broad categories: practical knowledge and theoretical knowledge (including 'epistemic' –

knowledge deduced from induction, rather than practical application[4], and 'constructivist' – knowledge constructed through cognitive processes, influenced by individual experiences (Young and Collin, 2004)). Practical knowledge is described as being acquired through practical application such as primary scientific research or manual work, for example, farmers harvesting crops (Sharpe et al., 2016). Cvitanovic et al. (2015) explicitly define primary science as '*knowledge that is generated through formalised processes such as through research and/or the application of scientific methodology*' (p.26). This type of scientific practice has also previously been termed 'Mode 1' model of scientific practice, described as done by scientists '*acting largely on their own*' (Robards et al., 2018, p.204) rather than drawing on context, cultures or other stakeholders to develop knowledge. It may be more difficult to elicit this type of knowledge as it is embedded within the person doing the action (Sharpe et al., 2016).

Theoretical knowledge contrasts with practical knowledge or primary science (Cvitanovic et al., 2015), being developed through logic, not through practice (Sharpe et al., 2016). Fewer papers defined theoretical knowledge, with Cvitanovic et al. (2015) referring to '*constructivist knowledge*' (p.26) as being in contrast to primary science but without providing any further definition of constructivist knowledge. Sharpe et al. (2016) define epistemic forms of knowledge which are logically built up and then applied back to practice. Both constructivist and epistemic knowledge are referred to here as under the broad category of theoretical knowledge, '*often represented as a set of principles or guidelines*' (Sharpe et al., 2016, p.4) which can inform, but not prescribe, action.

Knowledge is often referred to within the reviewed literature without being explicitly defined (André et al., 2021; Cvitanovic and Hobday, 2018; Meadow et al., 2015; Vinke-de Kruijf and Pahl-Wostl, 2016; Westwood et al., 2021; Wickenberg et al., 2022).

Many of the experts interviewed emphasised the need for transdisciplinary knowledge when it comes to dealing with climate change adaptation and the importance of different types of knowledge such as scientific knowledge, practitioner knowledge and community knowledge. Some of the experts interviewed felt that it was less important to define different types of knowledge. For example, one expert said that they interpret knowledge as anything that has data or information that is relevant to what they 'do' on adaptation. Another expert referred to the knowledge hierarchy model (also known as the data-

[4] Stanford Encyclopedia of Philosophy. "Episteme and Techne," 2020. https://plato.stanford.edu/entries/episteme-techne/#Bib.

information-knowledge-wisdom (DIKW) pyramid[5]), whereby data is discrete facts or observations which, when processed, is transformed into information with purpose or context, and becomes knowledge through, for example, experience, organisation, context and structure. Wisdom is then integrated knowledge, or correct use of knowledge.

Knowledge exchange systems

Knowledge exchange is generally defined as the interchange of knowledge among those who produce the knowledge and those who use and apply this knowledge (Cvitanovic et al., 2015; Fazey et al., 2013; Westwood et al., 2021). The concept of knowledge exchange has been suggested to therefore encompass all facets of knowledge production, sharing, storage, mobilisation, translation and use (Best and Holmes, 2010 cited by Cvitanovic et al., 2015).

Previous reviews of the literature have found that historically, knowledge producers and knowledge users were considered as two distinct groups, and under this relationship knowledge transfer occurs in a linear and uni-directional model from the producers to the users (Cvitanovic et al., 2015; Fazey et al., 2013). In this traditional model, science is often conceptualised as a '*place of knowledge production*', policy is seen as a '*place of knowledge use*' and practice is seen as '*a place of adoption*' (Bommel et al., 2016). However, this linear model has been widely challenged within the literature (Cvitanovic and Hobday, 2018; Ernst and Preston, 2020; Fazey et al., 2013; van Bommel et al., 2016).

An alternative model of interdependency has more recently been identified, which recognises high levels of interdependency and interconnectedness among all actors (Contandriopoulus et al., 2010 cited by Cvitanovic et al., 2015). Within this model of knowledge exchange systems, individuals are embedded in systematic relationships in which the production and use of knowledge is mediated by multiple factors including the contexts in which individuals operate and institutional norms and values by which they are constrained (Cvitanovic et al., 2015). This model of interdependency also recognises that all participants involved (producers, users or intermediaries) have their own experiential

[5] Frické, Martin H. "Data-Information-Knowledge-Wisdom (DIKW) Pyramid, Framework, Continuum." In Encyclopedia of Big Data, edited by Laurie A. Schintler and Connie L. McNeely, 1–4. Cham: Springer International Publishing, 2018. https://doi.org/10.1007/978-3-319-32001-4_331-1.

knowledge that can contribute to the process of knowledge exchange (Fazey et al., 2006 cited by Cvitanovic et al., 2015).

Some of the expert interviewees also felt that two-way knowledge transfer between scientific researchers and knowledge users (e.g., decision makers) is important for climate change adaptation. For example, one climate science expert said that:

> *"Thinking about what science we do [includes a] process of engaging with users and spotting what they are going to need in the future. For example, if transferring [knowledge] to specific type of decision making, [then important to understand] what they need to be able to do that. If you get it right, you can get virtuous cycle of increasingly helping that process of adaptation with more and more relevant new science" (E6).*

Another interviewee, who is an academic expert on KED for climate change adaptation pointed out that in their experience, flow of knowledge and information is complex and exists among many actors. For example, interdependencies exist among different infrastructure operators (for example, gas, electricity, water, ICT), so decision-makers within these organisations do not work only with scientists or intermediaries (see section on Boundary organisations), but also exchange knowledge among themselves.

> *"[Models of knowledge exchange] must recognise that that community has to be working together [to adapt to climate change] because of interdependencies [for example, among infrastructure operators]. The decision makers don't work just with scientists, they're working with different organisations. And it's recognising that, for example, not only can you group all the scientists together, you have to also recognise that they're working with consultancies. Consultancies, whether they're engineering or whatever they are, are major players in this." (E4)*

The interdependency model of knowledge exchange also aligns with the concept of knowledge systems referred to elsewhere in the reviewed literature. For example, a knowledge system is defined by Ernst and Preston (2020) as '*a network of actors connected by social relationships, formal or informal, that dynamically combine knowing, doing, and learning to bring about specific actions'* (p.8). The actors involved in these knowledge systems vary somewhat within the literature to include people as well as practices, institutions, and their arrangements. For example, Oliver et al (2020) define knowledge systems as '*the agents, practices and institutions that organize the development, uptake and use of knowledge*' (p.153) and Kirchhoff et al (2013) refer to '*programs and institutional arrangements*' (p.399) as the actors within knowledge systems.

Westwood et al. (2021) identified four main types of knowledge exchange: one-way exchange, solicited exchange, network exchange, and participatory exchange. One-way exchange encapsulates the linear model mentioned previously where knowledge producers independently produce and deliver their knowledge (such as in a report) to the knowledge users. Solicited exchange involves knowledge users requesting a knowledge producer to fill a pre-identified gap. Although there is increased communication, this exchange would still be considered linear. Network exchange involves two or more actors coming together to exchange knowledge that was generated independently from each other, and participatory exchange refers to knowledge that is generated by knowledge producers and knowledge users together (such as co-production, see next section).

Climate Services

An interviewee (E1), who is an expert in climate change adaptation within the infrastructure sector, referred to a standard that defines 'climate services' to *'involve the production, translation, transfer, and use of climate knowledge and information in climate-informed decision making'* (p.3, Climate Sense and JBA Consulting, 2022). This definition was agreed by consensus with the project delivery team that developed the standard, and wider stakeholder consultation. Similar to knowledge exchange systems, climate services have previously been framed as supply-driven, one-way flow of climate knowledge or knowledge products (such as models, maps or reports) from scientists to knowledge users (such as policy makers). However, climate services can be reframed to a process-centric approach (Findlater et al., 2021) which more closely mirrors the interdependency model of knowledge exchange. Findlater et al. (2021) propose deliberately moving towards the process-centric (and transdisciplinary) approach to expand networks and build relationships, using science-informed decision-making and creating climate services with actors working together.

Usability of knowledge / actionable knowledge

The relationship between knowledge and decision-making has become increasingly prominent due to the growing recognition of the need for multidisciplinary approaches to respond to complex environmental problems (Cvitanovic et al., 2015). This is particularly relevant in the field of climate change adaptation. A finding from the literature is that for knowledge or information to be used in climate change adaptation decision-making, it must be perceived as credible, salient and legitimate by those who use it (such as decision makers) (Cash et al., 2006 cited by Briley et al., 2015; Gluckman et al., 2021; Kirchhoff et al., 2013; Oliver et al., 2021; Robards et al., 2018). Furthermore, it must be perceived to 'fit' within the existing context and cultures, therefore, interactions and translation of information between producer and user communities are essential for stakeholders' perception of knowledge as usable (Lemos et al., 2012 cited by Briley et al., 2015).

Similarly, a notable finding from the expert interviews was that, in the experience of one expert, what is useful knowledge for climate change adaptation is context specific and relates to the needs of the specific user.

> *"The knowledge that is needed is that that is required by a particular user to inform their decisions... [It's important to] understand why they need it and how they use it. It's understanding that that will allow you to define what is useful knowledge." (E4)*

The same expert also felt that, in their experience, the types of knowledge that an organisation will need to enable climate change adaptation changes over time depending on where they are in their adaptation journey.

Knowledge products

The concept of 'knowledge products' was also referred to in the reviewed literature. Knowledge products are defined to include (but are not limited to) '*worksheets, tools, models, and assessments designed to harness science and technology to link knowledge to action*' (p.8, Ernst and Preston, 2020). Ernst and Preston (2020) note that knowledge products exist within and across knowledge systems.

Defining terms within this report

Given the range of definitions found within the reviewed literature it is important to be clear as to how we are using terms within this report. Table 2 provides definitions of frequently used terms. Other terms used within the report are defined as they are introduced.

Table 5: Definitions of terminology

Term	Definition
Knowledge	Within this report, knowledge is defined as outlined by the Data, Information, Knowledge, Wisdom (DIKW) hierarchy, whereby data becomes information which becomes knowledge (processed, contextualised, organised information). Includes all types of knowledge: including scientific, academic, practical/practitioner, community and theoretical. Useable knowledge is knowledge that is perceived to be credible, salient and legitimate by those who use it.
Knowledge exchange and development (KED)	Within this report, this term is used to encompass all components of knowledge production, development, sharing, exchange, and use.
Knowledge exchange and development approaches	Within this report, this term is used to encompass all approaches and processes that may be used to enable KED.
Science-policy-practice interface	Any situation where academic/scientific research, policy-making, and practice meet and interact (for example. in problem solving of complex environmental problems such as climate change adaptation).
Knowledge products	Knowledge products are defined to include (but are not limited to) papers, diagrams, videos as well as '*worksheets, tools, models, and assessments designed to harness science and technology to link knowledge to action'* (p.8, Ernst and Preston, 2020).
Climate services	Products and services that involve the production, translation, transfer, and use of climate knowledge and information in climate-informed decision making (Climate Sense and JBA Consulting, 2022).

Approaches for knowledge exchange and development

This section explores the different approaches for KED that are found in the reviewed literature. Specifically, it aims to define and compare different approaches for KED. In addition, all the experts interviewed had knowledge and experience of different approaches for knowledge development and exchange and so this section also draws learning from this experience.

This section aims to answer research question 2, 'what are the different approaches for knowledge development? How are they defined? Who are the users? What are the needs of different users for knowledge production?'

All the experts interviewed had experience of developing and/or using knowledge for climate change adaptation and many of them had experience of using different approaches for KED. Some experts reported that often the approach taken would depend on the stakeholders involved and the objective of the process. One example provided by an interviewee (E6) was the Met Office Hadley Centre Climate programme, within which the process for developing knowledge is focused on who the users are, what they respond to, and what is driving them.

Co-production

What is co-production and how is it defined?

Definitions of knowledge co-production are diverse and often contradictory (Norström et al., 2020). However, co-production of knowledge is generally described in the reviewed literature as a collaborative and iterative process involving actors from diverse areas or disciplines (often from the production side of knowledge such as scientists, and from the 'use' side of knowledge such as policy makers), working alongside each other to produce context-specific and actionable knowledge (André et al., 2021; Costa et al., 2022; Cross et al., 2022; Cvitanovic and Hobday, 2018; Dilling and Lemos, 2011; Ernst and Preston, 2020; Hegger et al., 2012; Kirchhoff et al., 2013; Mach et al., 2020; Meadow et al., 2015; Norström et al., 2020; van Bommel et al., 2016; Vincent, 2022; Westwood et al., 2021).

Based on literature and experiences and perspectives of leading researchers and practitioners engaged in knowledge co-production globally, Norstrom et al. (2020) describe co-production processes as iterative because they find that there is no single approach for success, and 'collaborative' because '*the act of engagement across domains and disciplines can be as important for the pursuit of sustainability as the production of knowledge'* (p.183). Their definition emphasises that '*co-production processes produce more than just knowledge; they develop capacity, build networks, foster social capital, and implement actions that contribute to sustainability'* (p.183, Norström et al., 2020)).

Some of the expert interviewees felt that co-production is becoming a buzzword that is being used increasingly often without clear definition. Some experts interviewed also felt that the term co-production is often understood to mean different things to different people (E12, E9, E5). For example, according to interviewees, some users of the approach view co-production as a participatory workshop in the data gathering phase. However, some of the experts interviewed felt that co-production is about "*power sharing throughout the whole research process*" (E12), from identifying the research question through to the report writing and evaluating at the end. This illustrates the potential difference for depth of engagement between actors across processes labelled as co-production and suggests the importance of understanding how it is being used in specific circumstances.

There are alternative approaches described within the reviewed literature that are similar to knowledge co-production and sometimes explained as belonging to the same cluster of 'participatory' and 'transdisciplinary' research approaches (Norström et al., 2020). For example, '*transdisciplinary knowledge integration*' (p.2, André et al., 2021) and '*participatory (knowledge) exchange*' (p.3, Westwood et al., 2021), are defined in similar ways as co-production of knowledge, with the users of knowledge being involved in its production.

Why is it used?

Research practice, funding agencies and global science organisations suggest that research aimed at addressing sustainability challenges is most effective when 'co-produced' by academics and non-academics (Norström et al., 2020).

The literature suggests that the desired outcomes of using a co-production approach include producing knowledge that is tailored to an identified issue and can fill knowledge gaps across disciplines, rather than driven by a single discipline in a scientific research setting (Kench et al., 2018; Vincent, 2022). Furthermore, Fazey et al. (2013) state that co-production is more likely to produce effective outcomes which last longer as the knowledge is more likely to have been adapted to the environment.

The effectiveness of co-production approaches and the factors that affect this in climate change adaptation research are explored further in the section 'Effectiveness of different knowledge exchange and development approaches at enabling climate change adaptation'.

Co-production approaches in practice

Drawing on their collective experiences of working within diverse sustainability co-production processes, Norstrom et al. (2020) demonstrate that within sustainability research, two broad approaches of co-production have emerged: 'normative' co-production and 'descriptive' co-production. The first regards co-production as a deliberate

collaboration between different people to achieve a goal, while the latter examines how science and society constantly shape each other in expected and unexpected ways (Norström et al., 2020). Similarly, Vincent (2022) also highlights the split between co-production approaches that are focused on outcomes and the production of actionable knowledge, and those that focus on the process and inclusion of multiple voices.

According to the reviewed literature, the co-production cycle (Vincent et al., 2018 cited by Cross et al., 2022;) goes through five steps: '*1) Identify actors and build partnerships; 2) Co-explore decision needs; 3) Co-develop solution; 4) Co-deliver solution; 5) Evaluate'* (p.883) to produce knowledge, with the iterative nature of co-production meaning that these steps can be repeated several times. Other sources in the literature give examples of how co-production processes may look in practice, such as embedding a researcher/scientist in the decision-making process (Cvitanovic et al., 2015; Kench et al., 2018) or the joint production of assessment reports by experts and decision-makers (Weichselgartner and Kasperson, 2010). Communication and collaboration is emphasised as being important throughout each phase (including designing research questions, implementation, and analysis) when co-producing knowledge, with regular interaction between the actors being continuous over time (Cross et al., 2022; Cvitanovic et al., 2015; Goggin et al., 2019; Meadow et al., 2015).

Some needs of users that are mentioned in the literature include creating a trusting space that enables participants to be fully active in contributing as well as recognising the value of multiple disciplines and including the diverse knowledge from these various actors (Costa et al., 2022; Cvitanovic and Hobday, 2018; Robards et al., 2018; Vincent, 2022; Wickenberg et al., 2022). However, André et al. (2021) suggest that the needs of the users will depend on the specific aims of the project.

According to the literature, users of co-production approaches most frequently include scientists and policy makers or decision makers (Cross et al., 2022; Cvitanovic and Hobday, 2018; Hegger et al., 2012; Hegger and Dieperink, 2014; Meadow et al., 2015; Vincent, 2022; Weichselgartner and Kasperson, 2010). However sometimes other actors (such as communities (Mach et al., 2020; Robards et al., 2018; Vincent, 2022) and boundary spanners/bridging agents (Cross et al., 2022; Robards et al., 2018) are also included.

Some of the experts interviewed also shared experiences of co-production approaches in practice. The experience of some expert interviewees was that co-production is often not an equal arrangement in practice, for example the input from the different groups (for example, hazard exposed communities and government institutions) is not equal (E10). This was perceived to be caused by one organisation leading the process by "*going in and asking for a collaboration from somebody else, be it a community or another organisation […] They are very much the authors, so they are just looking for input.*" (E9).

Boundary Spanning

It is recognised in the reviewed literature that ongoing and real physical, social and conceptual differences persist at the boundary between scientific research and policy and practitioner communities (Posner and Cvitanovic, 2019).As such a range of cultural, institutional and personal barriers exist between these actors (see the section '*Barriers and enablers to effective knowledge exchange and development for climate change adaptation*'). The concept of boundary spanning is defined in the literature as '*work to enable exchange between the production and use of knowledge to support evidence-informed decision making in a specific context,*' while boundary spanners are the '*individuals or organizations that specifically and actively facilitate this process*' (Bednarek et al., 2018 cited by Posner and Cvitanovic, 2019, p.141). Boundary spanners can facilitate KED between diverse groups of actors, for example, bridging the knowledge gap between scientists and policy makers to reduce time and effort to produce useable knowledge (Cross et al., 2022; Posner and Cvitanovic, 2019).

The benefits of boundary work include aiding the co-production of knowledge to enable desired changes (van Bommel et al., 2016). This is broken down further by Posner and Cvitanovic (2019) to include improved knowledge exchange, enabling cohesive social networks across boundaries, helping both policy makers and scientists improve their understanding of the other side and improving their communication to diverse audiences.

Boundary spanning is not characterised by any single function or role but instead encompasses a broad suite of activities that can be performed by individuals, teams or entire organisations (Bednarek et al., 2018 cited by Posner and Cvitanovic, 2019). Examples of boundary spanning approaches include boundary organisations, knowledge brokers, and embedded researchers. These are explored below.

Many of the experts interviewed felt strongly about the need for individuals or organisations that operate at the boundary between academia and policy and practice organisations when it comes to climate change adaptation. Many of the experts themselves worked as knowledge brokers at the science-policy interface. This is explored more in the section '*Effectiveness of knowledge exchange and development approaches*'.

Boundary organisations

Boundary spanners can include boundary organisations (Cvitanovic et al., 2015; Oliver et al., 2021; Posner and Cvitanovic, 2019) which are often independent entities who synthesise data and facilitate communication between stakeholder groups (such as scientists and decision-makers), thus contributing to knowledge exchange. Examples of boundary organizations in the context of climate change adaptation include the California

Ocean Science Trust in the U.S. and the Baltic Eye Project at Stockholm University (Posner and Cvitanovic, 2019).

Knowledge brokers

Knowledge brokers and the concept of knowledge brokerage are also referred to within the literature. Knowledge brokers are defined as individuals who communicate information effectively from the producer to the user, tailoring the knowledge and providing guidance, rather than simply relaying the information (Gluckman et al., 2021; Street et al., 2022). In the literature reviewed, individuals who are knowledge brokers tend to be representatives of institutions or research teams (Cvitanovic et al., 2015; Gluckman et al., 2021; Robards et al., 2018) and can act as filters for knowledge users, providing the most important information as needed (Bharwani et al., 2016). Several interviewed experts worked in roles where they acted as the knowledge broker between scientific researchers and climate change practitioners or policy makers (E1, E3, E5). One expert interviewee who identifies as a knowledge broker, discussed their role of taking detailed academic research out to practitioners and policy makers. Therefore, also portraying this as a unidirectional transfer of knowledge from knowledge producers to users.

Bridging agents

Bridging agents are referred to in the literature examined in a similar way to knowledge brokers in that they translate information across stakeholder groups, however this transfer of knowledge is not expressed as being exclusively one directional (Robards et al., 2018).

Embedded researchers

This approach involves positioning or hosting a scientific researcher within a decision-making agency (or vice versa) to facilitate opportunities for knowledge exchange (Cvitanovic et al., 2015).

Models for knowledge exchange and development vs real world knowledge exchange and development processes

Approaches for KED can be defined and demonstrated using simplified models (for example, see p.29 in Cvitanovic et al., 2015), but findings from the interviews suggest that in reality processes are more complex. For example, the model for boundary organisations: according to experts interviewed, realistically there are multiple intermediary organisations that are working as boundary organisations between researchers and decision makers, and these organisations in turn exchange knowledge among themselves. Furthermore, different decision-making organisations are also exchanging knowledge

amongst themselves. Therefore, the idea of a single intermediary actor and separate, distinct groups is not an accurate representation of real-world scenarios.

> *“But it doesn't work with how the real world operates, it’s [not] recognising the complexity of the knowledge and information flows that occur.” (E4)*

Defining knowledge exchange and development approaches within this report

Table 6: Definitions of knowledge exchange and development approaches

Concept / approach	Definition
Participatory research	Umbrella term for research which varies along three axes: 1) the extent to which participants are co-researchers, 2) the extent to which the researcher is a facilitator from within and 3) the extent to which the focus is on applied research that is aiming to change the social world.
Joint knowledge production	A term used to refer to research projects in which scientists and policy-makers (or practitioners) cooperate directly to produce actionable knowledge (Hegger and Dieperink, 2014).
Co-production	Process where actors from different groups (for example, researchers, policy-makers, practitioners, communities) work alongside each other to produce knowledge. An element of co-production is that there must be a degree of power sharing between all participants involved. Co-production is understood within this report to be iterative and collaborative. A spectrum of co-production exists depending on the balance of power sharing among participants involved.
Boundary spanning	Any process or situation where an individual or organisation crosses the boundary between different groups to enable knowledge exchange or development. ‘Groups’ could include scientists, researchers, policy makers, practitioners, communities, other stakeholders.
Boundary spanner	Any individual/organisation who works across a boundary to enable knowledge exchange/development.
Boundary organisation	An intermediary organisation that sits outside of the other groups but facilitates knowledge exchange/development between the groups.

Knowledge broker	Individuals, often a representative of an institution/organisation, who transfer knowledge between organisations (across a boundary). A knowledge broker usually comes from within one of the organisations that is involved in the knowledge exchange/development.
Embedded researcher	An individual from one organisation (e.g., academic institution) who is hosted or positioned within another organisation (for example, a decision-making agency)

Effectiveness of knowledge exchange and development approaches

This section explores the evidence from the reviewed literature and expert interviews about the effectiveness of different KED approaches at enabling climate change adaptation. This section aims to answer the first part of research question 3 '*What evidence is there about effectiveness of different knowledge development/production approaches at enabling climate change adaptation?*'

Evaluating effectiveness

It is understood from the reviewed literature that evaluating the effectiveness of knowledge development and engagement processes in the context of climate change is difficult due to the relative intangibility of some knowledge concepts, long timescales involved, resource availability, and an absence of systematic and comprehensive evaluation methods being implemented by organisations involved (Findlater et al., 2021; Mach et al., 2020; Posner and Cvitanovic, 2019; Street et al., 2022). Meanwhile, fundamental barriers linking knowledge development approaches to climate change adaptation are the tangible difficulties associated with measuring success of adaptation across a range of actors (Charlton et al., 2023; Hegger and Dieperink, 2014; Tuler et al., 2020). Attributing change is particularly hard because actors are likely to hold differing perspectives of climate change risks due to the numerous different factors that influence and conceptualise adaptation as an ongoing process where metrics of success can evolve over time. So although frameworks have been proposed for assessing the use of KED processes, those encountered in the literature have failed to identify processes that have actually been successful in facilitating climate adaptation (Ernst and Preston, 2020; Kench et al., 2018). As such, evaluation of KED approaches in available literature is minimal and has predominantly been demonstrated using case studies.

The use of case studies can be a valuable tool used to illustrate effectiveness of KED approaches, however several experts interviewed recognised that case studies are context specific, and learning is not always transferable.

> *"The problem with a case study, it tells you what they did and how they did it. But they don't tell you why. So, something that works in one place won't work in another because the context is different."- (E4)*

Some interviewees discussed the challenges of evaluating the effectiveness of KED approaches for enabling climate change adaptation. For example, it was noted that it is difficult to know whether climate change information is actually influencing decision-makers because inputs to decisions are not always visible (E6). Another expert suggested that a way to measure effectiveness is whether more informed decisions are being made and resilience is being achieved (E12). Some of the experts interviewed felt that an important measure of effectiveness of the KED process is the level of engagement of those involved. For example, sustained co-production where people build long-term relationships is evidence of an effective approach.

Effectiveness of different knowledge exchange and development approaches at enabling climate change adaptation

This section discusses two distinct but related aspects of the effectiveness of different knowledge development approaches:

- Whether different approaches facilitate better KED.
- Whether knowledge produced or exchanged is more usable and actionable to improve decision making for climate change adaptation.

Co-production

Definition: Process where actors from different groups (for example, researchers, policy-makers, practitioners, communities) work alongside each other to produce knowledge. A key element of co-production is that there must be a degree of power sharing between all participants involved.

Co-production is understood within this report to be iterative and collaborative. A spectrum of co-production exists depending on the balance of power sharing among participants involved.

According to the literature reviewed, co-production approaches can lead to the advancement of better, more policy-relevant or more socially robust knowledge. There is some anecdotal evidence that co-produced research is more likely to be accepted and used by decision makers who are able to obtain a good understanding of research

content, generate a sense of ownership, and better communicate the research within their organisation (Cvitanovic et al., 2015; Meadow et al., 2015). However, there remains limited discussion on the mechanisms for achieving the general principles of co-production (Meadow et al., 2015) and a lack of comparative empirical assessments of knowledge coproduction approaches (Hegger and Dieperink, 2014).

Several studies present examples where a co-production process has been successfully undertaken to inform decision making for environmental management in international contexts, for example, within projects funded under the European Research Area for Climate Services (ERA4CS) and the international climate change adaptation and water governance (CADWAGO) project (Costa et al., 2022; van Bommel et al., 2016). Both an expert interviewee and the literature made specific reference to the Tandem Framework[6] to guide knowledge co-production processes in the context of climate change adaptation. One paper detailed the successful application of the framework as part of a climate information co-production process case study in Lusaka, Zambia[7] (Daniels et al., 2020). The process involved conducting a series of "Learning Labs" with a wide variety of stakeholders, embedding researchers in the local policy and planning context. This format created a safe space for different types of actors and knowledge to challenge dominant or business-as-usual approaches, and to innovate new pathways for societal transformation. Results from a survey completed by stakeholders involved in the process detected that all participants, including both traditional knowledge users and providers, emerged with '*a deeper understanding of climate change and local impacts, increased awareness of the urgency of climate action, an appreciation of the need for collaborative relationships between partners and networks, and increased confidence to ask more informed questions of each other*' (Daniels et al., 2020, p. 13). This observed behaviour shift had a positive impact in increasing the integration of climate information into ongoing projects, plans and policy development in Lusaka.

While the plurality of perspectives is a core element of effective co-production, it has been highlighted that decisions about which stakeholders to include in the process are not necessarily inclusive and can be dependent on inherent bias based on institutional or

[6] https://www.weadapt.org/tandem/home

[7] We acknowledge that this example doesn't meet the original inclusion criteria under geographic range (as defined under Evidence Review scope) but is included in this instance as a useful example of successful co-production for climate change adaptation in practice that has relevance for the report.

political perspectives into the suitability of knowledge from different actors (Vincent, 2022). Such risks are important to consider as knowledge co-production projects are usually initiated and facilitated by researchers themselves which can therefore increase the likelihood of perspectives being excluded if not consciously managed (Vincent, 2022). Additionally, highly interactive and iterative co-production approaches can often result in the lengthening of project timelines due to frequent engagement by producers and users of knowledge and hence delaying the production of usable knowledge (Kirchhoff et al., 2013; Robards et al., 2018). These factors are explored further in the next section.

Some of the experts interviewed felt that co-production is an effective way of enabling knowledge development for climate change adaptation, however expressed awareness of the difficulty of achieving 'true' co-production.

> *"The more successful and enduring [adaptation frameworks] are those that have been developed with the intended users, or representatives of them. The ones that have been developed by [only] scientists aren't successful. The people can't use them, they don't know how to use them, they don't have the capability to use them." – Expert interviewee E4*

The issue of unequal power sharing throughout the process was raised by some interviewees as a barrier to achieving full co-production of knowledge. For example, it was felt that 'co-production' is often used to refer to the process where an organisation asks for collaboration with another group (such as a community or another organisation), but the driving force is the organisation looking for one-directional input. Concerns over unequal power relations were also mirrored in published literature on co-production, where it has been recognised that more powerful actors from formal institutions with are more likely to have the resource, capacity, confidence, knowledge, and skills to actively participate in knowledge development processes and engage with information providers (Findlater et al., 2021; Vincent, 2022).

> *"Co-production is fantastic, but it has to be equal power or really clear what is going on. It goes right the way through the process because, even in report writing it's about the decisions about what's included and what is not included." – Expert interviewee E12*

One academic interviewee (E5) had experience of co-developing climate services by focusing on bringing climate scientists together with planners, disaster risk managers and civil society organisations to understand challenges and how to address them. They felt that a success factor of this approach was that "*the relationships and networks built as part of the process were enduring and functioning beyond the end of the project/case studies themselves*" (E5). Another expert interviewed also highlighted that in practice it can be difficult to sustain dialogue between different actors due to availability of individual

time and resources, with this exacerbated due to the fact most engagement now occurs online rather than in person which has altered stakeholder dynamics (E7).

Some fundamental enablers impacting the success of the climate service co-design processes identified in the literature include the development of a jointly defined question by scientists and practitioners and mutual understanding of needs, capacities, and limitations (André et al., 2021), and close collaboration between both natural and social scientists (Costa et al., 2022). In co-production approaches implemented in practice, social scientists are often responsible for running workshops or interviews with end-users, while natural scientists contribute expertise of a technical nature. This raises the question whether social science expertise in aspects such as social systems remains undervalued within multidisciplinary approaches.

Boundary Spanning

Definition: Any process or situation where an individual or organisation crosses the boundary between different groups to enable knowledge exchange or development. 'Groups' could include scientists, researchers, policy makers, practitioners, communities, other stakeholders. Examples of boundary spanning approaches include: Knowledge brokers, boundary organisations, embedded researchers, bridging agents.

According to the literature reviewed, boundary organisations can stabilise knowledge production by helping to protect against undue influence caused by predisposed values of stakeholders involved (Briley et al., 2015; Gluckman et al., 2021; Kirchhoff et al., 2013). They do this by resisting influence of external factors such as differing expectations between actors, terminology mismatches between scientists and changing political environments, so are generally considered a feature enabling successful joint knowledge production (Hegger and Dieperink, 2014). Several literature sources also provide specific examples of where the use of a boundary spanner (individual or organisation) was instrumental to co-production approaches generating positive outcomes in the context of climate change adaptation:

- The State-wide Habitat Plan produced by the Wyoming Game and Fish Department mentioned "climate" 63 times in 2020 compared to just a single mention in the 2015 version. Interviews, with core team members in the department stated the role of the boundary spanner in the co-production approach taken was pivotal to ensuring climate change was incorporated into the revised plan by translating motivations into actionable steps (Cross et al., 2022).

- Assessment of the Montérégie Connection project[8] in Canada, concluded that a critical factor in the success of the project was the strong relationships formed between the boundary organisation with both researchers and local community stakeholders (Mitchell et al., 2015 in Norström et al., 2020). This enabled the organisation to identify, understand and address potential issues such as power imbalances between actors and political challenges.

Some of the core characteristics identified as a requirement for successful boundary spanners include: knowledge, charisma, an ability to act as a guide by facilitating and asking questions, cross-cultural competencies (for example, understanding both the research and managerial realms), experience translating science into practice, and social capital that supports the involvement of and access to other experts with relevant knowledge and information (Cross et al., 2022). Similarly, one expert felt that the outcome from the use of a knowledge broker to enable climate change adaptation "*depends upon how well the knowledge broker knows the knowledge domain*" (E7). From experience, they felt that this approach worked best when the knowledge broker knew both the area of science, and therefore had the credibility among the scientists, but was also conversant with the applications of scientific information so had credibility among the practitioners or knowledge users. Practical skills associated with facilitation were also deemed as important within the literature. For example, framing an effective workshop, driving a step-by-step approach to climate-informed planning, being able to engage over an extended period of time, and timely follow-through on commitments (Cross et al., 2022).

> *"If there is too generic a structure, more of a liaison person, but they don't know anything about the science it doesn't work too well" (E7).*

Embedded researcher

Definition: An individual from one organisation (e.g., academic institution) who is positioned within another organisation (e.g., a decision-making agency). An example of a boundary spanning approach.

Findings from both the literature review and expert interviews suggest that the use of embedded researchers is an enabler of success in knowledge exchange processes at individual, group, and collective levels as it can help to overcome some of the institutional barriers such as differing cultures and use of language (Fazey et al., 2013; Kench et al.,

[8] Monteregie Connection - PECS (pecs-science.org)

2018) which are explained in more detail in the *Barriers and enablers to effective knowledge exchange and development for climate change adaptation* section below.

Several expert interviewees spoke positively of the embedded researcher approach to KED for climate change adaptation. One interviewed expert had previously been an embedded researcher within the Environment Agency. They said that *"[the opportunity for] two-way communication and learning was really valuable*" (E2) and that it allowed them to better understand existing barriers to the use of scientific climate change data. A different expert interviewee said:

> *"A critical aspect [for success] is having embedded researchers where the host organisation identifies the research…embedded researchers are able to get to know the culture of their host organisation and understand how information is used and how knowledge is used" (E12)*

Working across teams to synthesise information was another strength of the embedded researcher approach perceived by some experts. One expert (E11) said that working within the team enables quicker access to expert insights in different areas of relevance and helps to deliver a synthesised product. Another perception from the experts interviewed was that embedding can help overcome the unwillingness to share data, as from experience, researchers are more willing to share data when physically embedded within an organisation as there is greater trust.

Factors influencing effectiveness of knowledge exchange and development for climate change adaptation

The effectiveness of KED and subsequent learning by individuals, organisations, and communities is dependent on a myriad of relationships between different actors. This section discusses which barriers and enablers exist in different knowledge development contexts across producers and users.

This section aims to answer the second part of research question 3 '*What barriers and enablers exist in different contexts and for different users?*'

Governance arrangements and institutional cultures

Institutional and governance factors are regularly cited in the literature as both barriers to and enablers of effective knowledge development in the context of climate change adaptation (Costa et al., 2022; Dilling and Lemos, 2011; Fazey et al., 2013; Mach et al., 2020). These institutional and governance components may be relevant across the science-policy interface or applicable only to certain sets of individuals or organisations.

There are general governance and institutional barriers that can appear during any KED process, which can hinder efforts to generate knowledge useful to and used in decision-making in the context of climate change. These include organisational silos (the existence of separate departments), (a lack of) openness to change, plus contrasting incentive structures and economic interests between institutions (Fazey et al., 2013; Mach et al., 2020; Norström et al., 2020; Oliver et al., 2021; Vinke-de Kruijf and Pahl-Wostl, 2016). Other institutional barriers identified in the literature include incompatible institutional cultures, differing epistemologies between knowledge producers and users, and contrasts in timescales and spatial scales of research (André et al., 2021; Costa et al., 2022; Dilling and Lemos, 2011; Hegger et al., 2012; Kirchhoff et al., 2013; Lee et al., 2021).

These barriers are often most prominent in situations where linear top-down approaches to knowledge development are employed (i.e., situation where scientists set the research agenda, do the research, and then transfer the results to potential users) (André et al., 2021; Weichselgartner and Kasperson, 2010). This can lead to situations where, for example, scientists research issues that do not assist with applied decision making and/or propose naive solutions to problems without adequately considering institutional or political constraints impacting practical implementation of suggested changes (Hegger and Dieperink, 2014). Instead, joint knowledge production processes generating usable knowledge require extensive collaboration between stakeholders from different backgrounds and should be problem or demand driven, rather than informed by a single discipline (Findlater et al., 2021). The drawbacks of the traditional pipeline model of knowledge development were also highlighted in the expert interviews.

> *"Universities are 'supply-led', whereby they think about what knowledge they have and how they can find a useful application of it to allow further perpetuation of that research. Needs to be demand-led. But this also depends on ability of the customer to articulate exactly what it is they want, which is a challenge." E3*

Alongside these general barriers, peer reviewed sources also demonstrated that institutional barriers specific to scientific or political institutions can impede joint knowledge production approaches. While reward systems increasingly encourage collaboration within and between scientific and policy institutes (e.g., research grants given to work on extensive multidisciplinary projects), some authors have highlighted that researchers may not commit to conducting engagement and outreach activities due to lack of consideration/perceived legitimacy of activities, time and funding (Cvitanovic et al., 2015; Oliver et al., 2021). Scientific research can also be inaccessible for external actors outside of academia due to delays in publishing research results, the fact that research is often behind a paywall and the usability of results for decision makers. These all act as barriers to the use of science in knowledge development (Cvitanovic et al., 2015). Staff continuity

has also been highlighted as a determinant of success in knowledge production processes (Goggin et al., 2019), but it is acknowledged that government departments often suffer from frequent turnover of staff (i.e., knowledge users) and poor inter-departmental communication (Costa et al., 2022; Lee et al., 2021). This was also mentioned by one of the experts interviewed. The integration of boundary organisations in co-production approaches has however been recognised as an opportunity to enable continuity in processes in the face of political and personnel change (Robards et al., 2018).

The findings from the expert interviews broadly mirrored those emerging from the literature analysis. Continuously evolving governance priorities within organisations, and the inability to link together timescales and time horizons, were perceived by some experts (E7, E9) to be the principal barriers preventing changes to enable climate change adaptation and resilience to be realised. This is perceived to be exacerbated by inconsistency of leadership and personnel within organisations (E7, E9) leading to situations where climate change adaptation remains a low priority with organisations instead focused on current rather than future scenarios. Some of the experts interviewed felt strongly that organisational leadership, commitment, and resource are key to enabling climate change adaptation, and that ownership and responsibility for climate change adaptation, rather than a lack of information per se, was also a fundamental barrier to the use of climate change research in policy and practice.

> *"If we are seeking to adapt and improve resilience then I am not convinced that lack of information and evidence is the main barrier…the main gap is the lack of ownership on adaptation and resilience." – E7*

For example, one expert explained that when encouraging conversations about adaptation across council teams, once they had strong advocates in place, they started to see a domino effect across other councils within the region as well.

Several experts (E6, E7, E11) also discussed the topic of compartmentalised working (organisational silos) across government/organisation departments and teams acting as a notable barrier to knowledge production for climate change adaptation. The use of embedded researchers was viewed by some interviewees as an effective way to break down the barriers of siloed working within organisations (E2, E4, E6, E11, E12). Embedded individuals could better understand cultural barriers and hence build trust between knowledge producers and users to facilitate knowledge exchange.

> *"There are silos around physical climate change science, mitigation methodologies, and contribution from different disciplines…[siloing] is not healthy because you don't always get the right science to right person in the right way." (E6)*

"Quite often, it wasn't new research that was needed, but collation and putting evidence in a place so that it's easy to see and access." – (E11)

Methods for standardising and structuring climate change adaptation information cited by experts included the use of knowledge products such as online portals to make it more shareable and discoverable online. One named example was the WeAdapt[9] programme, which has undertaken activities around breaking down silos and avoiding the fragmentation of knowledge (E5). Another expert indicated that when silos are broken down, the results can be very impactful, referring to the example of Defra and Department of Health and Social Care's work on social prescribing of activities in green space (E11).

Characteristics of actors involved

There is consensus in the reviewed literature that effective knowledge development for decision/policy making requires a bottom-up approach driven by the engagement of a broad range of stakeholders from a variety of backgrounds and cross-boundary collaboration (Costa et al., 2022; Cross et al., 2022; Fazey et al., 2013; Oliver et al., 2021; Vincent, 2022; Weichselgartner and Kasperson, 2010). The involvement of boundary organisations that sit outside formal decision making structures has been identified as playing a role in defining which actors should be represented and which expertise is considered relevant (Hegger et al., 2012), as has the presence of leaders acting as knowledge brokers and bridging agents (Robards et al., 2018). Techniques like stakeholder mapping and social network analysis can also help bring in a comprehensive range of relevant perspectives to facilitate effective knowledge production (Norstrom et al., 2020).

Across the literature reviewed, a factor influencing the effectiveness of joint knowledge development is the extent to which existing as well as potential future stakeholders are involved in the process (that is., through frequent interaction rather than only at a single point) (Kirchhoff et al., 2013). An example of this working successfully in practice is that of scientists working with Southern Bluefin Tuna company in Australia to adapt fishing practices to new climatic conditions. Research into process has suggested that a principle for successful science informed practice was the integration of decision-makers as active participants in each phase of the scientific research process (Cvitanovic and Hobday, 2018).

[9] https://www.weadapt.org/knowledge-base/weadapt-guidance/about-weadapt

However, engaging knowledge producers and users in a collaborative process is, in itself, insufficient to ensure that the knowledge produced is inclusive or legitimate or will be used in decision making (Mach et al., 2020). One example is the Dutch research programme 'Knowledge for Climate' which comprised nine regional 'hotspot' teams in which representatives of regional actors and scientists collaborated to produce regional adaptation strategies and policies. However, research into the programme demonstrated that these strategies could lack political legitimacy as administrative representatives were not included in the process (Hegger et al., 2012).

Managing individuals with different experiential and cultural backgrounds in the context of joint KED is recognised as being difficult due to contrasting expectations and methods of communication (Fazey et al., 2013). Several literature sources identified the observed mismatch between scientific researchers and decision makers in their underlying comprehension of uncertainty and technical information, and in what constitutes relevant knowledge, as a barrier to participatory approaches in knowledge production (André et al., 2021; Hegger et al., 2012). These findings were corroborated through the interviews held with experts who also recognised that scientists and decision makers can often speak in "different languages", with one expert highlighting the difference in perceptions and interpretation of risk between research and practitioner organisations in relation to hazard vulnerability and exposure vs likelihood times and consequence (E1). Moreover a prominent culture of risk aversity across decision makers can prevent the use of innovative knowledge development approaches and the implementation of radical policy, in favour of established and tested practices for fear of public criticism (Dilling and Lemos, 2011; Oliver et al., 2021). This has created a situation where a large knowledge base on climate change adaptation exists but has yet to reach its potential in influencing policy and practice (Bharwani et al., 2016).

Differences in understanding and perceptions can create situations where scientific information and its providers can lack credibility, legitimacy, and trust in the eyes of end users or vice versa (André et al., 2021). For example, in the context of climate change adaptation, researchers may construct scientific expertise as having greater legitimacy than other knowledge types and thus struggle to engage with those who are not also highly technical and numerate (Vincent, 2022). They can also generate unrealistic expectations regarding the development of knowledge for decision making in the context of climate change adaptation (Briley et al., 2015). However, it has been recognised that acknowledging uncertainty and limitations in co-production processes can help to build trust between knowledge users and producers and overcome such credibility barriers (Briley et al., 2015; Costa et al., 2022).

The expert interviews also recognised the differing characteristics of stakeholders in joint knowledge production/knowledge exchange, with many emphasising the importance of

facilitating actors (such as knowledge brokers or boundary organisations) acting at the interface between research and practice to translate information. To be effective in a knowledge brokerage capacity, interviewees recognised that individuals and/or organisations needed to possess characteristics such as competence in both the research domain and application area to be credible both with scientists/researchers and policy makers/practitioners. They also need co-production experience: the ability to recognise and bring together different knowledge types through skilled facilitation. Experts who had acted as knowledge brokers noted that successful co-production approaches relied on the open-mindedness of stakeholders involved and on building the capacity and confidence of those involved. One interviewee (E5) indicated that scientists employing a "*humble science*" approach had helped to build a safe space and trust amongst participants, thus encouraging them to step outside their comfort zone and contribute to and question the process.

> *"I don't think researchers and people who are trying to deal with immediate problems, like businesses and local authorities, talk the same language and think on the same time scales. So, the role of somebody like me as a facilitator, a translator at that interface between research and practice is quite an important one." – E3*

Integrating different types of knowledge

There is clear consensus in the literature over the need to integrate a wide range of knowledge types (such as, experiential, traditional, and scientific knowledge) and a range of skills (for example, analysis, translation, evaluation) to ensure bottom-up participatory approaches to knowledge production are effective and subsequent knowledge produced is relevant to many stakeholders (André et al., 2021; Norström et al., 2020; Oliver et al., 2021; Street et al., 2022; Vincent, 2022). The experts interviewed also strongly emphasised the need for a transdisciplinary approach to knowledge development to enable climate change adaptation.

> *"Strong emphasis on the need to blend physical and social sciences together, increase multidisciplinary learning and use participatory approaches. Transdisciplinary approaches have a key role to play." – E11*

One challenge related to integrating different types of knowledge is that relevance of knowledge is context-specific in nature and may be perceived differently depending on the time, place and group involved (Hegger et al., 2012; Mach et al., 2020; Vinke-de Kruijf and Pahl-Wostl, 2016). Another barrier to effective knowledge exchange is that knowledge is not 'values free' and can be influenced by political, institutional, and economic interests, thus careful consideration must be taken by knowledge brokers in recognising potential

biases when synthesising knowledge as evidence (Fazey et al., 2013; Gluckman et al., 2021).

Barriers that inhibit the co-development and exchange of usable knowledge for decision-making in the context of climate adaptation also include the complexity of scientific paradigms and methodologies which can influence interpretation by other stakeholders (Briley et al., 2015; Fazey et al., 2013; Goggin et al., 2019; Norström et al., 2020; Weichselgartner and Kasperson, 2010). As a result, researchers and policy or decision makers primarily engage in information transfer rather than as equal partners in knowledge co-production processes (Weichselgartner and Kasperson, 2010).

Continued facilitation of discussions to understand the types of information stakeholders want has been presented as a method to overcome this barrier (Briley et al., 2015). Additionally, in-depth interviews with environmental scientists and practitioners revealed that overcoming these cognitive barriers could be achieved through increased interaction between scientists and decision makers to explain methods and terminology used (Goggin et al., 2019).

Resourcing

It was apparent from both the reviewed literature and the expert interviews that the availability of sufficient time and resource across all relevant individuals and organisations is an important factor influencing all barriers and enablers to the knowledge development process discussed in the sections above. Ideals in joint knowledge production, such as the input of a broad range of stakeholders, facilitating continued engagement through meetings, and preserving trusting relationships between actors with cultural differences, requires significant amounts of time and resource to maintain (Costa et al., 2022; Hegger and Dieperink, 2014; Kirchhoff et al., 2013; Norström et al., 2020; Street et al., 2022). This was clearly evidenced by a collaborative project focused on improving land-use management for the provision of multiple ecosystem services in Canada. This required the whole first year of the project to be dedicated to working interactively with the community to reach an agreed set of goals for the project (Mitchell et al., 2015 in Norström et al., 2020). Additionally, in the domain of incident management, practical risk assessment is perceived to be limited by budgets for data collection as projects are perceived to be more reliant on the production of scientific information than those in other domains e.g., climate adaptation (Weichselgartner and Kasperson, 2010).

Despite its importance, funding for such approaches may not always be forthcoming with research demonstrating that large-scale co-created research projects achieve lower funding success rates when compared to more traditional academic research (Bromham, Dinnage and Hua, 2016 cited by Kench et al., 2018). The inclusion of boundary spanners in knowledge co-production approaches may help to reduce costs of this resource

intensive process as they enable common barriers in knowledge development (such as mismatches in the terminology used by scientists and other stakeholders) to be overcome earlier in the processes to increase efficiencies and reduce costs (Briley et al., 2015; Cross et al., 2022). But this needs to be balanced with the additional costs required to sufficiently support of boundary spanners (Meadow et al., 2015).

Many of the experts interviewed also felt that the translation of scientific climate change information into useable knowledge lacks funding, and this is a barrier to the use of this knowledge for climate change adaptation. For example, research carried out by one of the experts interviewed has highlighted a lack of applied or translational research funds to support more integration between natural and social sciences. Research councils may fund a proof of concept but then resource and capability to extend and replicate across different geographies is very limited. Another expert interviewed, who is a research practitioner who develops standards for infrastructure resilience, explained that it is difficult to get funding for practitioner-led research. Funding bodies such as the Science Research Council require academic proposals which take a lot of time that practitioners don’t have. Additionally, on the practitioner side, one interviewee highlighted that within the Environment Agency a challenge faced is that operational staff do not have the time or capacity to adequately interact with scientists despite understanding the importance of this interaction.

Examples of approaches for knowledge development used to enable climate change adaptation

The following example is provided to address research question 4 '*What evidence/examples are there where certain approaches for knowledge development have been used to enable climate change adaptation? Why have they been successful or not?*'

Toward successful joint knowledge production for climate change adaptation: lessons from six regional projects in the Netherlands (Hegger and Dieperink, 2014)

The authors undertook a comparative analysis of six climate change adaptation projects funded by the Dutch government as part of the Climate Changes Spatial Planning and Leven Met Water projects which had employed joint knowledge production approaches to better understand the factors contributing to the success of projects in practice. Each project was assessed against an existing framework of seven theoretical success conditions for joint knowledge production (Hegger et al., 2012), with four projects attaining a positive net score.

Interviews with stakeholders involved in the climate adaptation projects revealed two key indicators of success: the presence of the broadest possible actor coalition, and the presence of specific resources. Most successful projects managed to build a large network of actors from science and policy with a coordinating entity functioning as a boundary organisation. This broad coalition was perceived to enable the creation of a 'safe space' for knowledge development that enabled scientists to engage in research they were interested in that was also relevant for policy/decision making. Analysis also indicated that specific resources, including facilities, boundary objects, specific material arrangements such as GIS maps, places to meet), labour, competencies, and finances, should be employed to increase the chance for successful production of usable knowledge for decision making.

Examples of approaches for knowledge development used in incident management

This section aims to address research question 5 '*What evidence/examples are there of the different knowledge development approaches being used in incident management?*'

The Environment Agency are working with their incident management team to explore climate change and the knowledge needed to inform climate change adaptation activities and decisions now and in the future. However, it is not clear what specific research will be

most useful to achieve this. As such, the second stage of this project will initiate a participatory research process involving Environment Agency staff focused on using climate change science to inform practical activities and decision making for incident management. By tapping into institutional knowledge that is not publicly available we might be able to explore and discuss how different knowledge production and exchange processes are used for incident management and the effectiveness of these approaches from the perspectives of practitioners.

Both the evidence review and expert interviews provided very little information on and examples of approaches for knowledge development used in incident management contexts. So, although this evidence review was only able to offer a limited view of the literature available, we conclude that this is a significant gap in existing literature and would need to be further developed. This is likely because current emergency planning practice in the UK has so far rarely explicitly considered climate change, while climate change adaptation plans do not regularly consider the role of emergency planning (Arnell, 2022). However, one interviewee (E10) noted that they do think knowledge and evidence is informing policy change in terms of better integration of communities in emergency planning. An example provided was the Environment Agency's evolution of engaging with communities for flood risk planning at local levels, highlighting that operational teams are more prepared to engage with complex communities rather than just come up with their own plan on how to respond to flood risks.

Gaps in the evidence

This section covers research question 6. '*What does the evidence say are the existing gaps in literature?*'. The evidence gaps identified in this section were identified in the reviewed literature or suggested by expert interviewees. A further synthesis of the overall gaps in the evidence is included in the conclusions section of this report.

A strong theme emerging from the reviewed literature is the need for greater efforts to evaluate the effectiveness of different knowledge development and exchange approaches at enabling the use of evidence in climate change adaptation (André et al., 2021; Cvitanovic et al., 2015; Daniels et al., 2020). It was felt that there is a lack of quantitative evidence of efficacy and effectiveness of knowledge exchange activities (Cvitanovic et al., 2015), and also a lack of tried and tested evaluation methods (Posner and Cvitanovic, 2019).

It is understood that evaluating the effectiveness of KED approaches can help to better understand how knowledge exchange functions in different contexts, which approaches are most effective, and the kinds of skills and processes required to facilitate them (Entwistle & Smith 2002; Dwivedi et al. 2011 cited by, Fazey et al., 2013). This is particularly important for climate change adaptation due to decision-making needing to be

highly context specific, and the breadth of contexts that exist (for example, at different geographical scales) in a changing climate. When considering evaluation of knowledge exchange approaches, it was suggested that it is important to pay attention to both effectiveness (outcome/impact) and efficiency (time/resource it took to deliver impact) of knowledge exchange, and study what affects these two aspects to enable selection of the best approach for a given activity (Cvitanovic et al., 2015).

The reviewed literature also suggests that evaluation and empirical studies are needed to refine the understanding of what specific actions and activities produce the trusting, long-term relationships necessary for co-production of usable science (Meadow et al., 2015). It is argued that identifying specific actions that make co-production most effective will help co-production become a more widely accepted and used approach to creating usable science in climate change adaptation (Meadow et al., 2015). Expert interviewees also highlighted the need to be able to evaluate the engagement between knowledge producers and users, and the implementation of the knowledge, data or information in a meaningful way. One expert suggested the need for co-evaluation of the process to be able to improve what has been done and also to improve the trust of the users (E4).

In aiming to assess the quality of adaptation knowledge produced through co-production and identify the factors in the co-design process that led to this, André et al. (2021) found that their proposed knowledge quality criteria were relevant yet insufficient to fully capture whether and how adaptation knowledge is perceived as actionable by users. Their findings suggest that the criteria did not capture the wider decision-making context that affects stakeholders' perceptions of the quality of knowledge and their ability to apply it to decision-making (André et al., 2021). This highlights the need for additional research into the design of evaluation methods to evaluate the effectiveness of knowledge development approaches. Daniels et al. (2020) also highlight a need for further research into the design and implementation of effective and accountable monitoring and evaluation to enable learning about long-term outcomes and intangible benefits of co-production processes to support long-term use of integrated climate information in decision-making.

Another gap identified, relating to evaluating the effectiveness of knowledge development processes, is the need for analysis of how scientific evidence feeds into participatory processes and then contributes to decision-making processes (Oliver et al., 2021; Posner and Cvitanovic, 2019). Posner and Cvitanovic (2019) suggest the need to explore how policy makers actually '*define, access, and use scientific evidence in decision making'*, including changes in attitudes to scientific evidence (p.149, Posner and Cvitanovic, 2019). One of the experts interviewed also felt that more evidence is needed of how well government and policymakers recognise what the scientists are telling them and how well that has filtered down into organisational process and delivery (E1).

The literature also highlights a lack of empirical studies of applying certain approaches in practice (Gluckman et al., 2021; Hegger and Dieperink, 2014). However, as highlighted in earlier sections of this report (see Effectiveness of knowledge exchange and development approaches) challenges exist around the generalisation of empirical case studies due to the highly contextual nature of adaptation decision-making. The evidence gap around understanding what is effective in a given context was also highlighted in the expert interviews. One of the experts explained that "*context is everything with co-production*" and that there are "*lessons to be learned from psychology about bringing different groups together*" (E6).

The literature also identifies gaps around characterising existing approaches of KED, such as their prevalence and effectiveness (Cvitanovic et al., 2015; Kench et al., 2018; Westwood et al., 2021). For example, there is little guidance and dialogue about research practices and frameworks that underpin co-created research and empirically documented descriptions of co-production processes are also rare (Kench et al., 2018; Mach et al., 2020). The literature also suggests that there remains some ambiguity and variance in the ways co-production is conceptualised and put into practice (Mach et al., 2020).

Conclusion

A number of insights emerge from the evidence review that provide direction for the development of participatory approaches to climate change adaptation research.

Overall, the review found few examples of KED approaches in relation to climate change adaptation and very little information on and examples of KED approaches used in incident management contexts. However, lessons can be gained from the reviewed literature around KED approaches in relation to wider environmental and sustainability decision-making.

The first specific point is that there is inconsistency in use of terms and approaches across the literature and the experts interviewed which means that care is needed when using terms to ensure that they are clearly defined, and definitions are shared and agreed amongst research participants. The term that is perhaps becoming used most without clear definition is co-production. Co-production of knowledge implies an equal input from stakeholders in the development of knowledge, but this varies considerably in practice. Linked to this, no standard processes of KED, such as co-production, could be discerned within the literature. However, the five steps outlined in the co-production cycle (Vincent et al., 2018 cited by Cross et al., 2022, p.883) (*'1) Identify actors and build partnerships; 2) Co-explore decision needs; 3) Co-develop solution; 4) Co-deliver solution; 5) Evaluate'*)

together with cycles of iteration provide a very useful starting point for developing co-production processes.

In terms of the needs for new knowledge on climate change adaptation, the evidence from the literature suggests there is not a 'knowledge gap'. Improved knowledge exchange through brokers or boundary spanning approaches may therefore be required, rather than the co-production of 'new' knowledge, to create trusting and transparent relationships and ensure that the available evidence base is well understood, salient, and useable for policymakers. Bharwani and colleagues note that new technologies are enabling knowledge on climate change adaptation to be communicated through different pathways tailored for intended audiences (Bharwani et al., 2016). These include infographics, animations, interactive features, and videos that can be easily shared online. These hold promise for making complex climate information more accessible and more compelling for a wider range of stakeholder audiences.

Whilst there is discussion of the general benefits of approaches for KED, overall, there are few examples that robustly evaluate effectiveness. Most of the evidence around effectiveness is demonstrated through the use of case studies, which means that enablers of success remain inherently context/project specific. Without being able to test standard approaches in different contexts, it is not possible to say what works better in which contexts. The literature has focussed on "*(i) identifying the barriers that prevent efficient and effective knowledge exchange, and (ii) developing frameworks for overcoming these barriers" (Cvitanovic, 2015 p. 27)* rather than developing generalised approaches and assessments of outcomes.

Barriers that have been identified in the literature can also become facilitators and therefore need to be attended to. For example, institutional and governance factors, specifically organisational cultures and their openness to new ways of working, commitment/involvement from leaders to a process, alignment of timescales for research and practice are all important for establishing whether or not a KED process will be able to flourish or not. Further, characteristics of actors specifically the range of stakeholders included and who has chosen those stakeholders, differences in languages (scientific vs practical), and variation in risk appetite for new ways of working are all important and have been shown to impact on KED processes. Finally, resourcing: time and finances can be very important with KED processes often needing more time than traditional research processes for relationships and trust to develop between participants.

There is little mention of the mechanisms/processes involved in an overall co-production process, for example workshops and the importance of ensuring collaboration, power and knowledge sharing are embedded at the micro level, for example in the way the process is facilitated.

Despite those caveats, there are some general benefits of knowledge development and knowledge exchange approaches that can be drawn out of the literature:

- the production of better, more policy relevant and robust knowledge
- knowledge that is more accepted by decision makers
- an increased sense of ownership of the knowledge by those involved
- knowledge that is easier to communicate by those involved
- specifically for climate change adaptation, bringing together a range of knowledges is a clear benefit

Overall, many of the main barriers faced in linear KED processes can be addressed using joint knowledge/co-production processes that engage a wide range of stakeholders holding equal power in the process. This last point is key: power relations must be surfaced and rebalanced between stakeholders otherwise processes can remain superficial and prone to institutional capture. Boundary spanning, including embedding of researchers, can play a key role in these participatory approaches. For boundary spanners to be successful they need to be knowledgeable about both science and practice and have skills in participatory processes. Embedded researchers can gain organisational credibility (by being ‘one of us’) which facilitates knowledge exchange and access to data.

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Glossary

Term	Definition
Boundary organisation	An intermediary organisation that sits outside of the other groups but facilitates knowledge exchange/development between the groups.
Boundary spanning	Any process or situation where an individual or organisation crosses the boundary between different groups to enable knowledge exchange or development. 'Groups' could include scientists, researchers, policy makers, practitioners, communities, other stakeholders.
Boundary spanner	Any individual/organisation who works across a boundary to enable knowledge exchange/development.
Climate services	Products and services that involve the production, translation, transfer, and use of climate knowledge and information in climate-informed decision making (Climate Sense and JBA Consulting, 2022).
Co-production	Process where actors from different groups (e.g., researchers, policy-makers, practitioners, communities) work alongside each other to produce knowledge. An element of co-production is that there must be a degree of power sharing between all participants involved. Co-production is understood within this report to be iterative and collaborative. A spectrum of co-production exists depending on the balance of power sharing among participants involved.
Embedded researcher	An individual from one organisation (for example, an academic institution) who is hosted within another organisation (such as a decision-making agency)

Joint knowledge production	A term used to refer to research projects in which scientists and policy-makers (or practitioners) cooperate directly to produce actionable knowledge (Hegger and Dieperink, 2014).
Knowledge	Within this report, knowledge is defined as outlined by the Data, Information, Knowledge, Wisdom (DIKW) hierarchy, whereby data becomes information which becomes knowledge. Includes all types of knowledge: scientific, academic, practical/practitioner, community and theoretical. Useable knowledge is knowledge that is perceived to be credible, salient and legitimate by those who use it.
Knowledge broker	Individual, often a representative of an institution/organisation, who transfers knowledge between organisations (across a boundary). A knowledge broker usually comes from within one of the organisations that is involved in the knowledge exchange/development.
Knowledge exchange and development	Within this report, this term is used to encompass all components of knowledge production, development, sharing, exchange, and use.
Knowledge exchange and development approaches	Within this report, this term is used to encompass all approaches and processes that may be used to enable KED.
Knowledge products	Knowledge products are defined to include (but are not limited to) ‘worksheets, tools, models, and assessments designed to harness science and technology to link knowledge to action’ (Ernst and Preston, 2020).
Participatory research	Umbrella term for research which varies along three axes: 1) the extent to which participants are co-researchers, 2) the extent to which the researcher is a facilitator from within and 3) the extent to which the focus is on applied research that is aiming to change the social world.

Science-policy-practice interface	Any situation where academic/scientific research, policy-making, and practice meet and interact (for example, in problem solving of complex environmental problems such as climate change adaptation).

Annex 1(i): Evidence Review Protocol

Introduction

The evidence review protocol describes how the evidence review will be carried out, focussing on the inclusion/exclusion criteria, search string, sources of evidence and approach to prioritisation of documents. The draft protocol is largely based on the structure laid out in the JWEG guidance (Collins et al, 2015).

Research question(s)

The Primary Research question for the project is:

What has been learnt about developing knowledge for climate change adaptation and how might this inform the way the Environment Agency works in the future?

To clarify a bit further the research question we have used the PICO approach which details which population is to be studied, what the intervention is that we are looking at, what comparators we are interested in and what outcomes we are investigating. The table below presents the PICO elements for this evidence review.

Table 1: PICO elements

Element	Definition	Key words
Population	Actors involved in the science, policy and practice interface	scientists – policy makers – decision makers – practitioners – operators – regulators – advisors – users – networks – institutions – forums – organisations – commissions – programmes – academics
Population	Actors involved in the science, policy and practice interface	scientists – policy makers – decision makers – practitioners – operators – regulators – advisors – users – networks – institutions – forums – organisations – commissions – programmes – academics
Intervention	Knowledge production and knowledge exchange tools/ approaches and the (social) processes through which they are delivered	Data – knowledge – information – research – science – evidence – knowledge production tools/approaches – co-production – co-creation – embedding – knowledge brokerage – knowledge exchange – knowledge sharing – knowledge transfer – boundary spanning – open science – translation – communication – engagement – cooperation – competition – assimilation
Comparator	Exploring what works for whom and in what context The differences in conceptualising knowledge, evidence and data by different actors in climate change	Needs – ambition – conceptualisation – connectivity – effectiveness – enablers – barriers

	adaptation, e.g., scientists, policy-makers, practitioners. The effectiveness of different tools/approaches to ensure the use of scientific data and knowledge leads to better climate change adaptation. The different needs (among the users) for knowledge production and exchange.	
Outcome	The use of knowledge in adaptation	adaptation – decision making – policy making – action – practice – use*(user/useful) – usage – maladaptation

Other relevant key words: UK, adaptation, knowledge, evidence, data, climate risks

Ten sub-questions were developed to further guide the focus of the REA

- Who are the users of knowledge, evidence, and data on climate change adaptation and what is their ambition for use of evidence in adaptation? What are the needs of different users for knowledge production?
- What different types of approaches and tools to knowledge production and exchange are there?
- How effective are they at developing the knowledge needed to enable adaptation to climate change?
- In the context of climate change adaptation, what social processes [ways of working] are needed to effectively develop knowledge and enrich decision making?
- What is working well/less well in the current approaches and processes, in what contexts and for which users?
- What are the enablers and challenges/barriers to the effective use of these approaches and tools?

- How are knowledge, evidence and data conceptualised by different actors in climate change adaptation, for example, scientists, policy-makers, practitioners? What typologies have been developed to understand these conceptualisations?

- To what extent is evidence available about the application of approaches to knowledge production for climate change adaptation and what are the challenges for making evidence available?

- How robust is the evidence? What are the challenges for producing robust evidence?

- What key evidence gaps remain in the evidence base and how could they be filled?

The sub-research questions were then reframed into five simpler research questions to aid better processing of information in the analysis and synthesis stages:

RQ1: How are key terms (such as knowledge, evidence, data, knowledge development/production tools/approaches, knowledge exchange) defined and used within the literature/evidence? Do definitions vary between users/stakeholders (for example, practitioners, policy makers, researchers)?

RQ2: What are the different approaches for knowledge development? How are they defined? Who are the users? What are the needs of different uses for knowledge production?

RQ3: What evidence is there about effectiveness of different knowledge development/production approaches at enabling climate change adaptation? What barriers/enablers exist in different contexts / for different user?

RQ4: What evidence/examples are there of where approaches for knowledge development have been used to enable climate change adaptation? Why have they been successful or not?

RQ5: Is there evidence/are there examples of the different approaches being used around incident management?

What does the evidence say are the existing gaps in literature?

The scope establishes the inclusion criteria/exclusion criteria for our search strategy.

Table 2: Exclusion and inclusion criteria

Exclusion criteria	Comment
Exclude studies not in English	
Exclude any research that is not relevant to use of data and knowledge across the science, policy, and practice interface	
Exclude studies outside the UK, Europe, North America, Australia, New Zealand, and Tasmania.	If there is an explicit comparison with the UK or there is direct relevance suggesting the transferability of the findings of the study to a UK context – those will be kept.
Exclude studies with a focus on individual adaptation.	
Exclude studies purely on technological or engineering measures that look solely at climate change adaptation and do not examine how that adaptation has been arrived at.	
Inclusion criteria	**Comment**
Include studies carried out in the UK, Europe, Africa, North America, Australia, New Zealand, and Tasmania (see relevant exclusion).	
Include focus on public sector knowledge production and exchange.	
Include studies that explore interventions and approaches to climate change adaptation.	

Include studies that explore the effectiveness of different models and approaches for producing or transferring knowledge.	
Include studies that measure the impact of climate change adaptation policies or implementation.	
Include studies from 2008 to date	

Process of prioritisation

Only the most pertinent articles will be reviewed in full. To facilitate this process, a rating will be given to each of the sources identified as meeting the inclusion criteria according to:

1. Simplified robustness assessment (this includes. the quality of the source - methodology used to conduct primary research; peer reviewed or not; and the number of citations)
2. The extent to which the source answered the main research questions (its relevancy to research questions)
3. Taking the top 20 from each search string using the Scopus prioritisation

Key search string(s)

The proposed search string that will be used in an iterative process to develop additional strings is the following:

In curly brackets insert one of – climate change, disaster risk management, incident management, environmental management {XX} AND (Organisation OR initiative* OR network* OR scientist* OR "policy maker*" OR "decision maker*" OR practitioner* OR operator* OR regulator* OR advisor* OR user* OR network* OR institut* OR forum* OR commission* OR academic* OR programme* OR {science-policy interface} OR {science-practice interface}) AND (needs* OR ambition* OR conceptualis* OR connectivity OR effective* OR enabl* OR barrier) AND (knowledge OR evidence OR data OR information OR research OR science) AND (communicat* OR engage* OR cooperat* OR compet* OR*

assimilate OR participat* OR practic*) AND adaptation AND ((knowledge W/2 (development OR production OR exchange)) AND tools OR approaches)*

To substitute after last AND -

OR co-production

OR co-exploration

OR co-creation

OR embedding,

OR translation

OR "knowledge brokerage",

OR "knowledge exchange",

OR "knowledge sharing",

OR "knowledge transfer"

OR "boundary spanning",

OR "open science"

Potential source locations

Table 3: Source locations

Locations for peer reviewed evidence (e.g., bibliographical databases)	Scopus
Locations for grey literature (for example, websites of organisations)	Google (which scans grey, government and commercial sources) EA website IPCC website UK Resilience programme – relevant insight papers to be made available end March Knowledge exchange platforms, e.g., weAdapt https://en.unesco.org/themes/social-transformations/most Place-based Climate Action Network Climate Change Committee Grantham Research Institute (at LSE and Imperial) ISO standards (Adaptation to climate change – Principles, requirements, and guidelines (ISO 14090:2019), Climate Services - Principles, requirements, and guidelines)
Locations for unpublished data	Consult experts from Project Steering Group, project team and interviewed experts.

Will other reviews and secondary reviews be considered?	Yes
Will theoretical or conceptual studies be considered?	Will be considered on a case-by-case basis

Annex 1(ii): Interview Guide

About the research

As part of the Environment Agency commissioned project *Use of research in climate change adaptation*, the project team, led by Eunomia, is carrying out an Evidence Review. To support the evidence review, we are conducting up to 18 expert interviews. The objectives of the interviews are:

- to assist in the identification of the most pertinent evidence to be included in the review
- to contribute to the team's understanding of the different approaches to knowledge production, development and sharing
- to help to identify evidence gaps in the field of knowledge production, development and sharing for climate change adaptation

The focus for these interviews is on *how* knowledge is or can be developed and not about knowledge for climate change adaptation itself. This is explained in more detail in the next section.

Research question(s)

The Primary Research question for the project is:

What has been learnt about developing knowledge for climate change adaptation and how might this inform the way the Environment Agency work in the future?

More detailed research sub-questions have been developed.

For the purpose of this interview, we have grouped the themes covered under three main headings:

- Framing
- Tools, techniques, approaches, and ways of working
- Exploration of the evidence gaps

We are also hoping that interviewees will help us develop definitions for key terms such as 'knowledge' and 'evidence'.

The interview

Depending on your responses, we expect the interview to take 30-45 minutes.

With your permission we would like to record the interview. The recording will only be used to assist with notetaking and will not be shared outside of the project team. Information about how we will use the data provided in the interview can be found in the information and consent form already provided.

Do you have any questions before we start the interview?

Interview schedule

1. [*Ask the interviewee to talk about one or both of the bullet points below, depending on their role/experience*.] **Using examples, please could you tell me a bit about:**
   - **Your research into developing/sharing/using knowledge for climate change adaptation**
   - **Your experience of developing/sharing/using knowledge for climate change adaptation:** How and when did you first get involved? In what role(s) have you worked? With what kinds of organisations (e.g., public, private, voluntary; professional, community, academic; international, national, sub-national, local; etc) and in what places (UK, Europe, other?)

2. **Briefly, what do you think is the relevance of using research/scientific knowledge alongside other types of knowledge for achieving climate change adaptation? Is the current status quo different to what it should ideally be?**
   - Is the current status quo in relation to use of knowledge for climate change adaptation different to what you think it should ideally be? In what ways (is it or isn't it) and in what areas?

Framing

3. **What types of knowledge and evidence have you used for your own work on climate change adaptation?**
   - Are there any useful definitions of 'knowledge' or 'evidence' that you could share with us?
   - Where do you generally find the knowledge or evidence you use? How do you assess whether it is fit for your purposes?

4. **With this research, we are interested in exploring the way knowledge is developed and how knowledge flows between scientists, policy makers and practitioners (often referred to as the science-policy-practitioner interface). To what extent do you use a model or models for conceptualising this interface? Are there any models that you find particularly useful that you could describe?**

5. [*Share figures showing different types of knowledge production from the ITT].* **We find these figures described by Cvitanovic useful illustrations of the different kinds of interface. Could you talk through your understanding of and response to these illustrations, and whether or not you are familiar with or have used them?**
    - Are there any other main ways in which knowledge, evidence and data are conceptualised by different actors in climate change adaptation, for example, scientists, policy-makers, practitioners?

Tools, techniques, approaches, and ways of working

6. **Now looking at different approaches and tools for knowledge production and sharing in high-income countries, to what extent have you used/researched any specific tools or approaches in the past?**
    - Could you share any relevant examples and describe what worked well or less well?
    - Could you suggest any key references/sources/case studies that would inform our evidence base?

7. **How effective are the different approaches you have described for enabling adaptation to climate change?**
    - How do / would you measure their effectiveness?[10]
    - To what extent are there enablers or challenges/barriers to the effective application of these approaches and tools? Could you describe any key ones?

8. **From your research/experience, which ways of working or organisational processes are needed to effectively develop and share knowledge for climate change adaptation?**
    - To what extent has the nature / content of the knowledge in question influenced these working processes?

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[10] For example, we might apply the following four categories of impacts to assess the effectiveness of knowledge production/sharing for climate change adaptation:
• Instrumental – direct impact on climate change adaptation
• Conceptual – influences how stakeholders think about climate change adaptation
• Strategic – evidence used for promoting climate change adaptation
• Process – improved working processes in some way

- Could you give an example of where any of these ways of working have been effective or less effective?

Evidence gaps

9. **Thinking about the way that knowledge is currently developed and shared, what are some of the evidence gaps that remain to be filled?**
   - What do you think would change if they were examined and addressed? What would you be able to do differently?
     What are the challenges for producing robust evidence about developing and sharing knowledge?

Are there any other comments or observations you would like to make regarding ways of developing knowledge to support climate change adaptation that we have not covered sufficiently in the interview?

Annex 2: Participatory Research Methodological Note

Note: This annex consists of a note outlining the progress made in the development of the methodological framework for the participatory research programme as of March 2023.

Introduction

This report outlines the development of the methodological framework for the second phase of the *Use of research in climate change adaptation* research project. The core of the methodology gravitates around the ethos of participatory research and has been jointly designed with the Environment Agency project managers who are embedded in the everyday work of the organisation. In the light of the nature of participatory research, it is important to highlight that this is a suggested approach that delineates the principles of engagement with participants in the research process and proposes an overarching roadmap with core milestones to be informed and shaped by the values and aspirations of participants.

The report is organised in six sections. It begins with a brief introduction of the rationale for participatory research in the context of this research project (Section 2) and related criteria for unpacking our understanding of participatory research (Section 3). Section 4 synthesises the methodological framework that is proposed for interfacing and co-producing knowledge for climate change adaptation across the Environment Agency and expands on the details of the case study on which it will be piloted. Section 5 translates the methodological framework into a series of suggested methods and a timeline. Finally, a set of preliminary criteria are proposed to evaluate the impact of the participatory research during the timeframe of the project and beyond (Section 6).

Rationale for Participatory Research

The overall project has an overarching research question:

What has been learnt about developing knowledge for climate change adaptation and how might this inform the way the Environment Agency works in the future?

By responding to this research question, the project will:

1. Consolidate new knowledge, good practice and expert opinion;

2. Identify opportunities to enhance the suggested research approach(es) and build consensus on further research priorities;

3. Learn by doing and co-create principles and other requirements for climate service or services[1] with Environment Agency team(s).

To answer the main research question and achieve the three above mentioned objectives, the project is structured around two phases. Phase 1 focuses on the first part of the research question (i.e., *What has been learnt about developing knowledge for climate change adaptation?*) by using a combination of evidence review and expert interviews. Phase 2 addresses the second part of the research question (i.e., *How might this inform the way the Environment Agency works in the future?*) through participatory research. It is relevant to highlight that, although distinctive, both phases inform each other.

The participatory research follows an action-oriented approach towards encouraging critical reflection and change in the ways of working across the Environment Agency. In so doing, this research is aimed at promoting learning by doing and co-creating requirements for climate service(s) across different teams in the organisation (Objective 3). The participatory research builds on, and further complements, the methods being deployed in the first phase of the project (i.e., evidence review and expert interviews). It also contributes to consolidating knowledge, good practices, and expert opinions from members of the Environment Agency themselves (Objective 1), and to opening up a space where research approach and priorities can be co-designed between scientists and practitioners across the organisation (Objective 2). Ultimately, the participatory research contributes simultaneously to advancing new scientific knowledge (i.e., by filling evidence gaps in the literature with new empirical examples) and catalysing change by addressing issues that are prioritised by participants.

Importantly, while the participatory research represents an end in itself in the context of this research project (with clear objectives, outputs and associated timeframes), it is considered part of a longer-term process to be sustained by those individuals who engage in this experimental phase. Core principles are delineated to provide guidance as to how this can be achieved (see Section 3).

[1] Incident management (IM) is defined as a climate service by the Environment Agency. Other climate services are linked to a broad range of data services including data archives and repositories, data dashboards, climate risk indicators, collaborative adaptation platforms, among others.

Defining Participatory Research

There are three core elements to consider when designing methodological approaches for participatory research:

1. level or degree of engagement of participants in the research,
2. role of researchers, and
3. intentionality of the research process (Blaikie, 2010; Wittmayer & Schäpke, 2014; Sellberg *et al*., 2021).

In practice, each of these core elements spans across a continuum of possibilities that coalesce as to delineate different approaches to participatory research. Figure 1 graphically represents this idea.

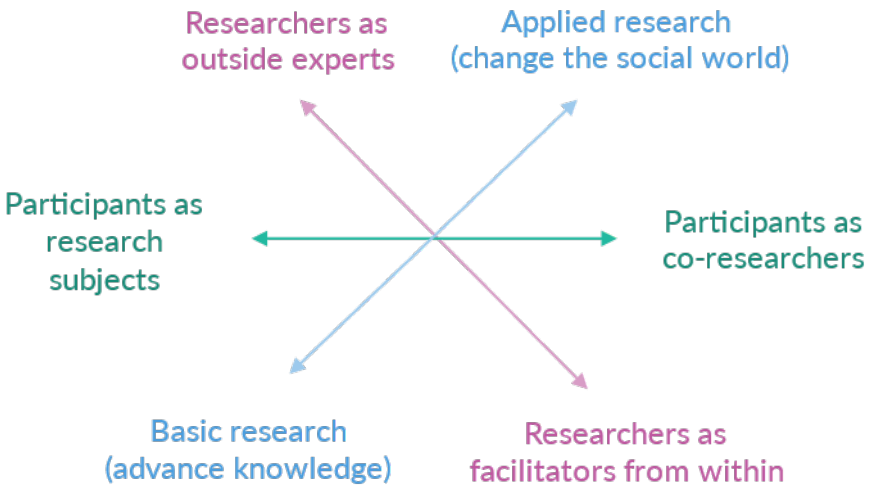

Figure 1: Axes of participatory research

The **level or degree of engagement of participants** can vary from being subjects in a research project minimally or superficially involved, through participating in the research process to becoming co-researchers (Brown, 2022). This is tightly connected with the **role of researchers**: whether they see themselves as outside experts who adopt a top-down approach when defining research objectives and leading the entire research design or as facilitators who are immersed in a research process in which participants are recognised as co-researchers, rather than research subjects (Lewin, 1946). Finally, the **intentionality of the research process** mainly expands from basic research (i.e., advancing scientific knowledge and addressing purely scientific concerns) to applied research (i.e., trying to change the social world and addressing social or political concerns). The 'action research' tradition, which largely builds on the legacy of participatory action research (PAR), has the joint purposes of advancing knowledge and changing some aspects of the world at the same time (Blaikie, 2010).

Drawing on the core elements of participatory research, a series of principles can be defined to orient the design of the methodological framework. Table 1 synthesises the principles that underpin the methodology for this research project.

Table 1: Core elements and principles of participatory research

Core elements	Principles
1. Level or degree of engagement of participants in the research	i. Careful selection and commitment of participants who can then sustain and leverage the initiated processes of change.
	ii. Attitude to listening to others, respecting diversity of opinions and openness to questioning own assumptions and ways of doing. Willingness to engage in constrictive and challenging dialogue. Feeling comfortable with the uncomfortable.
2. Role of researchers	iii. Joint delineation of priorities, objectives and steps between researchers and participants.
	iv. Clarity of research journey and management of expectations (what is possible and what is not).
	v. Reflexivity along the process (individually and collectively), with moments to share learning and adjust while doing.
3. Intentionality of the research process	vi. Build on existing processes or initiatives.
	vii. Leverage existing relationships, socio-technical networks, and formal/informal spaces.
	viii. Encourage lasting commitment to operationalising or implementing research outputs or outcomes, according to agreed research goals and objectives.

The selection of strategic and influential individuals who can then champion what they learnt throughout the process (i), build on existing processes or ongoing initiatives (vi), and leverage existing relationships, socio-technical networks and formal/informal spaces within and across the organisation (vii) are key principles for the legacy of the project. An example can be the creation of a Task force or Working group that keeps working after the research project finalises. An attitude to listening and respecting others' opinions and openness to question and revise assumptions and practices when expose to others' views and experiences (ii) applies to both participants and researchers and can be exercised through reflexivity (v) to critically think about our positionality or standing in relation to the topic or issue under consideration.

Methodological framework: participatory research for interfacing and co-producing knowledge

Figure 2 illustrates three models of science production and related science-policy interactions (Dilling & Lemos, 2011). The main difference between the models pertains to the directionality of the agenda setting process for science production. Our methodological approach will focus on the third model (Model C) with the aim of encouraging interactivity between scientists/researchers and potential users of information (policymakers/practitioners) and co-producing knowledge for climate change adaptation.

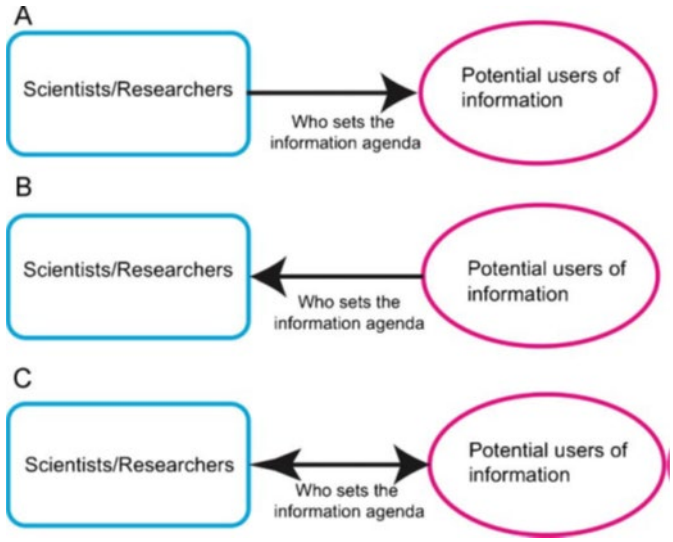

Figure 2: Three models of science production and science-policy interactions (*ibid*)

Science-policy-practice interfaces and knowledge co-production have been at the centre of the research and policy agendas in the field of climate change, broadly, and adaptation, specifically, over the last decade.[2] This has stimulated an exploration of relevant methods for encouraging these processes in a more meaningful and substantive manner, including participatory approaches to knowledge co-production for climate change adaptation. This methodological exploration has led to the identification of enablers and barriers to co-production, but it has also called for a more critical understanding of power imbalances (e.g., derived from the value and legitimacy of different types of knowledge) and recognition of the nuances across a diversity of cases.[3] In this regard, ethical

[2] See emerging findings from REA.

[3] Power imbalances usually derive from the intersection of multiple factors, including income, class, gender, age, race, migration status, among many others. In the case of

considerations and context specificity should not be overlooked when designing methodological frameworks for knowledge co-production.

Objectives of Participatory Research

- **Interfacing**: To strengthen the linkages and collaborative capacity between and among science-policy, science-practice, and science-policy-practice interfaces across the Environment Agency for improving climate change adaptation.
- **Co-producing knowledge**: To co-design and work together in an ongoing process/initiative relevant for climate change adaptation.
- **Sustaining an ongoing process to enable implementation and continued learning**: To commit participants to build on this pilot and sustain the co-production approach and interfaces drawing on identified good practices or ways of working.

Case Study: Bringing together scientists and incident management practitioners in the Environment Agency

A case study is proposed to experiment with different models of science production for climate change adaptation within and across the Environment Agency (EA). Specifically, the case study aims to bring together EA scientists and Incident Management (IM) staff to explore climate change and the knowledge needed to inform climate change adaptation decisions and activities in the future.

Taking the three models of science production and science-policy interactions as a reference (Figure 2), we delimit the scope of our case study and group of participants as illustrated in Figure 3.

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knowledge co-production, the value and legitimacy of different types of knowledge and knowledge holders play a critical role in the research process and outcomes. Specifically, it has crucial implications in terms of framing the research agenda (i.e., what is deemed relevant to be researched) and influencing how different types or sources of data or evidence are recognised or marginalised.

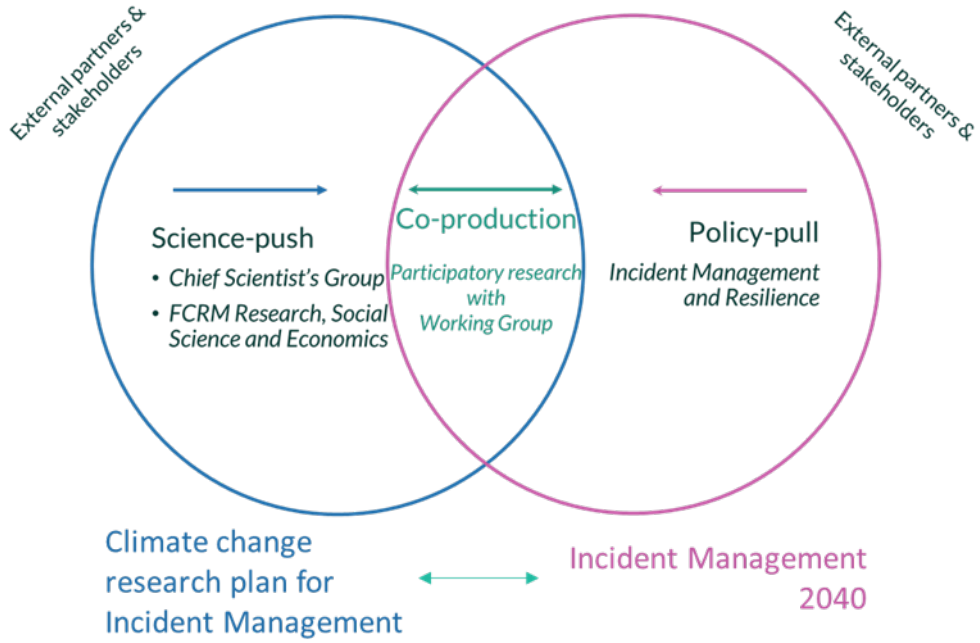

Figure 3: Interfacing and co-producing knowledge for climate change adaptation within the Environment Agency

Model A refers to the 'science-push' model where scientists lead the definition of the research agenda, under the assumption that policymakers and practitioners will automatically uptake the generated new knowledge. Model B or 'policy-pull' describes a situation where research priorities and objectives are defined on the basis of what policymakers and/or practitioners consider to be relevant or useful for the work that they undertake. In both cases, the production of scientific knowledge is unidirectional. On the contrary, Model C brings together scientists, policymakers and/or practitioners to jointly identify research problems and questions that are of relevance for all of them.

In the context of the Environment Agency, our case study brings together scientists working on climate change-related issues across two broad teams (i.e., Chief Scientist's Group and FCRM Research, Social Science and Economics) and practitioners from Incident Management and Resilience. With the intention of building on existing processes and leveraging existing relationships, exploratory conversations were organised with staff working in these areas. From these initial conversations, two core processes have been identified:

1. The Chief Scientist's Group is in charge of developing the *Climate Change Research Plan for Incident Management*.

2. Incident Management and Resilience is currently drafting *Incident Management 2040*, the new long-term strategy for managing future incidents.[4]

Therefore, there is an opportunity to design the participatory research in a way that contributes to align these two processes and inform each other:

1. To make research applicable or useful for practitioners (e.g., scientific knowledge can improve IM's prevention, response, and recovery from future climate change impacts).

2. To allow scientists to inform the delineation of IM's programme of work according to the state-of-the-art advancements in the field (e.g., what might be feasible in the following years based on available technology, models, and data).

Selection of participants and development of a Working Group

The selection of participants becomes crucial for the sustainability and impact of the entire research process. Furthermore, the development of a Working Group is recommended for the purposes of gathering the same participants together on an iterative basis and building a sense of group belonging and identity. This lies at the core of experimenting with interfacing and co-production endeavours.

The initial selection of members of the Working Group has been guided by the embedded experience of the EA project manager together with the advice of other members of the project team for securing an appropriate balance across knowledge types, educational background / professional expertise, job positions and gender representation. Noteworthy, the EA project manager is a principal scientist in the Chief Scientist's Group, which entails she also represents scientists across the organisation. She still needs to decide on her role in the participatory research, whether as a member of the Working Group or as a wider observer. To keep self-awareness of her positionality and acknowledge potential biases in the approach and results, reflexivity is encouraged across the research process (see Section 5).

The Working Group will be composed of 8-10 colleagues from the Environment Agency representing climate change physical and social scientists (x5) and IM practitioners (x5) (see Table 2). This group of participants will be working with the project team in all planned activities of the participatory research. It is anticipated that each member of the Working Group will be expected to commit approximately 17 hours between July –October

[4] Incident Management 2040 will replace the current Incident Management Strategy 2020-2025.

2023. This calculation is based on a tentative allocation per planned activity: interview (1 hour), three workshops of 3.5 hours each (10.5 hours), two in-between workshop activities (4.5 hours) and two dedicated moments for self-reflection (1 hour). Section 5 provides full details of the activities and timescale of the approach.

Table 2: List of suggested Working Group members

Participant	Gender	Science / Practice	EA Team	Educational / Professional background	Interview
1	F	Science	Environment and Business > Chief Scientist's Group	Physical scientist	No
2	M	Science	Environment and Business > Chief Scientist's Group	Physical scientist	Yes
3	F	Science	FCRM	Physical scientist	Yes
4	M	Science	Environment and Business	Social scientist	Yes
5	F	Science	FCRM	Social scientist	No
6	M	Practice	Local Operations > Incident Management and Resilience		Yes
7	F	Practice	Local Operations > Incident Management and Resilience	Interdisciplinary	Yes
8	M	Practice	Local Operations > Incident Management and Resilience		Yes
9	F	Practice	Local Operations > Incident Management and Resilience		No
10	M	Practice	Local Operations > Incident Management and Resilience		No

Ethical considerations

Ethics should underpin all research undertakings, but there are special considerations when designing and doing participatory research. These include:

- Guarantee informed consent and data protection for all participants (see Appendix 1).
- Secure commitment of participants while being transparent about what they will get in return for their contributions. Management of expectations.
- Encourage participants to reflect on their positionality, especially in relation to the value of different knowledge types and hierarchy of roles in the organisation.

Consider power imbalances and vested interests among different groups and anticipate and carefully manage potential conflicts.

Milestones of participatory research

The participatory research combines different methods, including exploratory interviews and review of relevant organisational documents, workshops, asynchronous engagements to stimulate the crossing of boundaries between EA scientists and IM practitioners and moments of self-reflection throughout the research process. Figure 4 illustrates the journey of the participatory research with the proposed milestones and timeline.

Each milestone is designed to build on the evidence emerging from preceding stages and informing the subsequent ones, and feedback mechanisms are incorporated to provide room for manoeuvre (i.e., flexibility and refinement) as the research progresses.

Figure 4: Milestones and timeline of the participatory research journey

Exploratory interviews and review of organisational documents

Exploratory interviews were conducted with six colleagues from the Environment Agency who were identified as key individuals to share their knowledge and experiences as scientists (three interviewees) or practitioners in the Incident Management & Resilience team (three interviewees). These individuals were also suggested as potential members of the Working Group in charge of driving the subsequent activities of the participatory research. Thus, these interviews were also aimed at confirming their interest in participating in the research process and gathering their suggestions on the ways in which they would like to get involved moving forward.

Interviews were designed as open and informal conversations to grasp:

- roles and work routines of different participants, and the extent to which they consider their everyday job connected to climate change and adaptation;
- key questions or knowledge gaps about climate change and adaptation they think it would be relevant to address or further explore in the future;
- awareness of other teams/individuals across the EA when generating or using knowledge for climate change and adaptation and current patterns of interaction;
- existing good practices and what needs to change.

The interview guide is included in Appendix 2(i). Insights from the exploratory interviews are collated in Appendix 3 and contributed to inform and refine the scope and focus of the case study.

Together with the exploratory interviews, relevant documents from the Environment Agency have been reviewed as to have a better understanding of the organisational context in which climate change knowledge is being produced, shared, and used in the organisation. The list of documents has been consolidated by the EA project manager and shared with the wider project team. The list covered organisational charts, strategies, reports, and annual reviews, among others. Some of these documents can be saved in a shared repository for later reference in the activities with the Working Group.

Workshops

The three proposed workshops bring together the same group of participants over time to build a sense of belonging to the Working Group and a shared perspective on the topic being investigated. Specifically, the objective is to encourage conversations and interactions between EA scientists and IM practitioners on the basis of a set of defined and clear objectives for each of the workshops. Importantly: the overarching theme for each workshop is proposed here, but it will be discussed and refine with participants in Workshop 1.

Workshops will be held online and facilitated by project team members.[5] Workshops (and asynchronous engagements) will be programmed in advance so that all participants are aware of dates and can plan their time to be available. During workshops, notes and recordings will be taken to ensure that all contributions are captured and can be later analysed by the project team.

A short workshop record will be written up as an aide memoire following each event. This will provide an audit trail of the development of new ideas and knowledge through the workshop process, as well as allowing any group members who were unable to participate to keep updated with the process.

Workshop 1: Where are we standing?

- Online workshop in Microsoft Teams.
- Duration: 3.5 hours
- Who are involved? Working Group members (x10) and facilitators (x3)
- What are we doing?
    - Preliminary agenda:
        - Introduction to the research project and sharing core findings from the REA.
        - Presentation of the 'journey of participatory research' (timeline, planned activities and level of commitment).
        - Discussion of expectations and co-definition of expected outcomes (i.e., measures of success for this short-term research project and beyond).
        - Activity**: Where are we standing?**

          In this activity, participants will co-map the system across three dimensions:

          1. Understandings: What do climate change and adaptation mean in the context of your work? Why do they matter for your everyday job?
          2. Relationships: In the context of climate change, what are the existing flows of data/information/knowledge across the EA? What are the existing relationships between EA scientists and IM staff? Are there

[5] The possibility to hold one of the workshops in person will be discussed with the EA project manager.

any boundary objects mediating these knowledge flows and relationships?

3. Best practices: What is working well? What is not working so well and can be improved?

Workshop 2: Linking Climate Change Research Plan for IM and IM 2040 Strategy

- Online workshop in Microsoft Teams.
- Duration: 3.5 hours
- Who are involved? Working Group members (x10) and facilitators (x4)
- What are we doing? Preliminary agenda:
    - Group reflexive exercise (drawing from Self-reflection 1)
    - **Activity: Linking Climate Change Research Plan for IM and IM 2040 Strategy[6]**

    In this activity, participants will experiment with knowledge co-production for climate change adaptation by tapping into two ongoing processes:

    - EA scientists introduce the Climate Change Research Plan for IM (draft)
    - IM colleagues present the IM 2040 Strategy (draft)
    - Participants work together to align and integrate these two processes by co-defining priorities, objectives, approach, ways of working and tools. Outcomes of the system co-mapping (Workshop 1) will be re-introduced to inform this co-production activity.

Workshop 3: The way(s) forward

- Online workshop in Microsoft Teams.
- Duration: 3.5 hours
- Who are involved? Working Group members (x10) and facilitators (x4)
- What are we doing? Preliminary agenda:

[6] These are two ongoing initiatives, so revisions of the drafted research plan and strategy should be expected as a result of the discussions.

- Group reflexive exercise (drawing from Self-reflection 2)
- **Activity: The way(s) forward**

In this activity participants co-delineate the way(s) forward by:

- Taking stock of the participatory research process and identifying lessons learnt that can be disseminated or scaled-up for future climate-related research ideation, design, and delivery.
- Discussing how to sustain the initiated process and relationships (e.g., maintaining the Working Group; working together to operationalise research plan and IM 2040 in an integrated manner).

Planning next steps for co-writing a peer-reviewed journal article that consolidates the experiences and learnings of the participatory research.

Asynchronous engagements for boundary crossing

It is suggested that the workshops bring together EA scientists and IM staff with the objective of encouraging interactivity and conversations. However, for these interactions to be meaningful, it will be important that participants familiarise themselves with the perspectives and everyday work of their peers. The idea of 'boundary crossing' is intended to contribute to this exploration and deeper understanding of others by flexing one's boundaries and discovering other ways of thinking and working. This links back to the principle of 'feeling comfortable with the uncomfortable' (see Table 1).

The suggested boundary-crossing activities described below are labelled as 'asynchronous engagements' since facilitators from the project team will not be mediating these encounters.

Crossing boundaries 1: interviewing a colleague from another department/team

- In person or online (via Microsoft Teams pre-defined channels), depending on location of participants.
- Duration: 1 hour
- Who are involved? Working Group members (x10) split into scientist – practitioner pairs (x5).
- What are we doing?

Working in pairs, participants interview each other to find out more about the specificities of the work of his/her colleague and how it is linked to climate change and adaptation. Each participant will role play half an hour as an interviewer and half as an interviewee.

Upon completion of this activity, participants are encouraged to dedicate 30 minutes to self-reflection (see Reflexivity).

Crossing boundaries 2: shadowing (½ day in another department/team)

- In person
- Duration: 3.5 hours
- Who are involved? Working Group members (x10) are split into scientist – practitioner pairs (x5). Keep the same pair structure as in the first activity.
- What are we doing?

Working in pairs, each participant invites his/her colleague to their workplace for a half-day immersion into their everyday job. After having heard from their peer in the one-to-one interview, this is the time to experience first-hand what those work routines and practices entail. This activity allows participants to understand the nature of the work of their colleagues, including their concerns and priorities.

Upon completion of this activity, participants are encouraged to dedicate 30 minutes to self-reflection (see Reflexivity).

Reflexivity

Reflexivity can be defined as a continuous self-interrogation of our positionality in research practice (Markham, 2007; Sellberg *et al*., 2021). It applies to both researchers and participants, especially in the context of participatory research where participants are deeply immersed in the research process to the extent of becoming co-researchers.

The proposed participatory research journey incorporates reflexivity as an individual and collective exercise:

- **Self-reflection after each boundary-crossing activity**. Participants are encouraged to pause and take a moment to contemplate their first impressions, feelings and thoughts emerging from these engagements. Specifically, they are invited to focus and critically think about their role (and the role of their knowledge) in the organisation and the extent to which this relates to the work of others. A personal diary is suggested to write down personal reflections throughout the entire process.
- **Group reflection at the start of Workshop 2 and Workshop 3**. Self-reflection is personal and for internal introspection. Yet, it is important to leverage on this individual process towards collective reflexivity as a group. Thus, participants are

invited to share some of their personal reflections by posting them on Mural[7] (online whiteboard) ahead of Workshop 2 and Workshop 3. A Mural canvas will be designed to collate participants' reflections and frame the group reflexive exercise at the beginning of these workshops.

The project team will propose a list of guiding questions to prompt these moments of individual and collective reflexivity.

Finally, reflexivity is of special relevance for the EA project manager given her stand in the research process wearing two different hats (as a project manager and member of the project team and as an EA scientist and potential member of the Working Group). It is advised that she also keeps a diary with her personal notes about the process, motivation, and expectations, anticipated and unexpected challenges, questions, ideas for the future, among others.

Evaluating the participatory research

How do we measure the impact of the participatory research?

The evaluation of the participatory research needs to be proportionate to the short timeframe (three months) and pilot nature of the approach. This implies that the evaluation of the participatory research per se will be relatively light touch and mostly driven by the feedback provided by participants after each of the planned activities (e.g., workshops). Online feedback forms will be circulated to gather the opinions of participants about (1) the format of the activities, (2) suggestions for improvement and (3) learning.

However, it will be important to consider another key aspect as part of the evaluation which pertains to the changes (i.e., impacts) that might be observable only after the participatory research finalises. In other words, how do we know if changes have happened after a certain period of time? Furthermore, many of these changes will also depend on the 'legacy' of the project and the extent to which the initiated processes and relationships are sustained over time. The Working Group will take the lead in delineating the next steps (see Workshop 3: The way(s) forward) and the EA project manager can oversee the post-project evaluation with a focus on:

- mainstreaming of identified best practices into ways of working;
- scalability of the Incident Management pilot and replicability across other operations/services in the Environment Agency;

[7] https://www.mural.co/

delineation and review of interfacing and co-production KPIs to build continuous improvement.

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Annex 2(i): Information and Consent Form

Eunomia Research & Consulting Ltd, together with Prof Nigel Watson, Dr Candice Howarth and Middlesex Flood Hazard Research Centre, have been commissioned by the Environment Agency to undertake a project to explore the *Use of Research in Climate Change Adaptation*.

The Primary Research question for the project is:

What has been learnt about developing knowledge for climate change adaptation and how might this inform the way the Environment Agency work in the future?

In order to answer this research question, the project is using a combination of evidence review, expert interviews and participatory research. By engaging with Environment Agency staff working in Incident Management and scientific teams, the participatory research phase of the project has the overarching objectives of:

- Exploring what enables a good conversation and working relationship between scientists and practitioners in the field of climate change adaptation;
- Experimenting with co-production methodologies in the elaboration of the Environment Agency Climate Change Research Plan for Incident Management.

You have been invited to take part in this introductory conversation to help us better understand the work that you do, what climate change / adaptation questions you may have related to your work and how you feel these may be usefully explored. We also want to understand how and who you work with across the EA, and with partners and wider stakeholders. We will use this information to help us develop the initial approach to the participatory research. We are keen to develop a core working group to guide and develop this work and would also like to explore how you would like to be involved in the work going forward.

The interview will last 30-45 minutes.

Before we start, we will ask you to sign this consent form to confirm that you are happy to take part. Things to note:

- The interview is entirely voluntary, you can stop at any time, and you can withdraw your data up to 2 weeks after taking part by getting in touch using the details below.
- Notes will be taken during the interview and, only if you provide consent, the interview will be audio-visual recorded to make sure we have captured information correctly.

- Your personal data (name, role and contact details), and the notes and recordings from the interviews will be stored securely and will be used only for the purposes of this project.
- Anonymised data from the interviews may be seen by the public as part of the final reporting. No participant will be personally identified in the final reporting.
- Three months after completion of the project, any personal data collected will be destroyed. The processing of all personal data will comply with the provisions of the General Data Protection Regulation.

If following the interview you decide you would like to withdraw from the process, it is possible for you to withhold your consent and ask for your data to be deleted. In this event, please contact Rebecca Jones at Eunomia.

Your Consent

Please tick all boxes that are applicable to you:

☐ I agree to voluntarily participate in an interview**.** I understand that I am free to withdraw my consent at any time without giving a reason.

☐ I agree to the interview being audio-visual recorded as data for the research project.

☐ I agree that the information I provide as part of this interview may be used in reports, publications and other outputs for this research project. This information will be presented anonymously so that I will not be personally identified.

☐ I understand that any personal data I provide for this project will be destroyed three months after the project is completed.

☐ I agree that my organisation's name can be identified in the final report and any other final outputs.

Signed
……
……

Full name (please print) …… Date
..……..……

Thank you for taking the time to read the information sheet and for your valuable contribution to the research project.

For further information on this project, please contact Rebecca Jones or Clare Twigger-Ross at Eunomia.

Privacy Notice

The Environment Agency has commissioned Eunomia, in partnership with Prof Nigel Watson, Dr Candice Howarth, and Middlesex Flood Hazard Research Centre, to undertake a project to explore the Use of Research in Climate Change Adaptation. As part of this project, we are undertaking a series of interviews. This Privacy Notice outlines our responsibilities in relation to your data.

Only the project team and the EA Project Manager will have access to the interview data. The information will not be passed on to any third parties or used for any other purposes than this research. Participants will not be identifiable in any publicly shared research outputs.

These interviews are being conducted as part of a contract with the Environment Agency. You can read more about your Data Protection rights here: www.gov.uk/data-protection.

Data protection responsibilities

The Data Controller is: Sam Lumb, Data Protection Officer, Environment Agency, Horizon House, Deanery Road, Bristol BS1 5AH

The Data Processor for this project is: David Gibson, Eunomia Research & Consulting, 37 Queen Square, Bristol, BS1 4QS. Direct dial: +44 (0) 117 917 2263

If you would like to see a copy of the data we hold, you would like to update our records or you have any queries regarding this Privacy Notice, please contact: **Data Protection Officer, Eunomia Research & Consulting, 37 Queen Square, Bristol, BS1 4QS.**

Annex 2(ii): Interview Guide

Eunomia Research & Consulting Ltd, together with Prof Nigel Watson, Dr Candice Howarth and Middlesex Flood Hazard Research Centre, have been commissioned by the Environment Agency to undertake a project to explore the *Use of Research in Climate Change Adaptation*.

The second phase of the project draws on participatory research, using Incident Management as a case study, with the overarching objectives of:

- Exploring what enables a good conversation and working relationship between scientists and practitioners in the field of climate change adaptation;
- Experimenting with co-production methodologies in the elaboration of the Environment Agency Climate Change Research Plan for Incident Management.

A set of preliminary interviews are scheduled to help us understanding the roles and everyday work of different participants across the organisation, the questions they have in relation to climate change impacts and adaptation, and how they currently work and interact within the EA and externally. Specifically, interviews are designed as open conversations to grasp:

- work routines (including in relation to adaptation);
- data and information used on a regular basis (specially, in relation to adaptation);

- awareness of other areas/departments/teams within the EA when generating or using data/information/knowledge for climate change and adaptation;

- data/information/knowledge flows about climate change and adaptation across the EA.

Upon consent from participants, interviews will be audio-visual recorded, and a transcript will be generated for internal purposes only. For details about informed consent and data protection, please refer to Information and Consent Form (see Appendix 1).

Guiding questions for an exploratory conversation

A) With practitioners (EA Incident Management Strategy team)

1. Can you begin by telling me about your educational / professional background and your experience within the Environment Agency (e.g., for how long you have been working in the organisation and in which areas / roles?

2. I understand that you are currently part of the Incident Management Strategy Team. Can you tell me a bit more about your current role? What does it entail in terms of functions and responsibilities?

3. Can you give me some examples of the work that you do day to day?

    - What data / information / knowledge do you usually rely on and use?

    - What tools (e.g., software, platforms, databases, etc.) do you regularly use to access, share and exchange data / information / knowledge?

4. Do you think that the work that you do is connected to climate change impacts? How? Do you think that your work contributes (or has the potential to contribute) to climate change adaptation? How?

5. Thinking specifically about climate change impacts and adaptation, what questions or knowledge gaps do you think it would be relevant to address or further explore to improve the impact of your job?

6. Within the Environment Agency, do you work with researchers from Research (Climate Change, Air-Land-Water, Floods) and Futures – Social Science – Economics teams? How often do you interact with them? For what purposes? Probe: to help you think about climate change impacts and adaptation.

7. Can you expand a bit more about how you work / have worked with researchers from these teams? What is the relationship like? What works well / less well within your exchanges? What needs to change to improve climate change adaptation? Probe: frequency / amount of time for interactions, ways of communicating, understanding each other, personal relations, etc.

8. Do you think it would be helpful to involve external partners or wider stakeholders when doing work about climate change impacts and adaptation? Why? Who would you suggest?

9. We would like to develop a working group for the participatory component of the research. How would you like to be involved as part of this process? What are your preferences for participation (interviews, workshops, on-the-job interactions with colleagues, etc.)?

B) With scientists (EA Chief Scientist's Group; Flood and Coastal Risk Management Research, Social Science and Economics):

1. Can you begin by telling me about your educational / professional background and your experience within the Environment Agency (e.g., for how long you have been working in the organisation and in which areas / roles?

2. I understand that you are currently part of the [Chief Scientist's Group / FCRM Research, Social Science and Economics]. Can you tell me a bit more about your current role? What does it entail in terms of functions and responsibilities?

3. Can you give me some examples of the work that you do day to day?

    - What kind of research do you do?

    - How are research priorities usually defined? By whom?

    - What type of data / information / knowledge do you generate? For whom?

    - How do you share / socialise the data / information / knowledge that you generate?

4. How is your research connected with climate change impacts and adaptation? Can you provide a few examples of the most relevant research you have conducted in the field?

5. What research questions and knowledge gaps should inform the Environment Agency research agenda on climate change and adaptation? Why?

6. Within the Environment Agency, have you ever worked with colleagues from Incident Management (IM)? For what purposes?

    6.1 If yes, can you expand a bit more about how you work / have worked with them?

    - What data / information / knowledge have you shared with IM colleagues?

    - What is the relationship like? What works well / less well within your exchanges?

    - What needs to change to improve climate change adaptation? Probe: frequency / amount of time for interactions, ways of communicating, etcetera.

    6.2 If not, do you think that your work could be connected with the work that IM colleagues do? How?

    - What data / information / knowledge do you have that could be useful to them?

7. Besides Incident Management, do you share data / information / knowledge about climate change impacts and adaptation with other teams within EA? If so, could you tell me more about how these interactions work? Probe: do you discuss with them how data/information/knowledge shared might be relevant to their work?

8. Do you think it would be helpful to involve external partners or wider stakeholders when doing research about climate change and adaptation? Why? Who would you suggest?

9. We would like to develop a working group for the participatory component of the research. How would you like to be involved as part of this process? What are your preferences for participation (interviews, workshops, on-the-job interactions with colleagues, etcetera)?

Annex 3: Participants list and workshop agendas

Participants and attendance

Characteristics of participants and activities in which they participated

Participant	Directorate	Team (Director level)	Gender	Workshop 1	Café sessions	Workshop 2	Participants' self-led meeting	Workshop 3
1	E&B	CSG	M	✓	✓	✓	✓	✓
2	LO	IM&R	F	✓	✓	X	X	✓
3*	LO	IM&R	F	✓	X	X	X	X
4	E&B	CSG	F	✓	✓	✓	✓	✓
5	E&B	WR	F	✓	✓	✓	X	✓
6	E&B	SBD	M	✓	✓	X	X	✓
7	LO	IM&R	M	✓	✓	X	X	✓
8	LO	IM&R	M	✓	✓	✓	✓	✓
9	LO	IM&R	M	X	✓	✓	✓	✓
10	FCRM	SNA	M	X	✓	X	✓	✓
11	E&B	SBD	M	X	✓	✓	✓	✓
12	FCRM	SNA	F	X	✓	✓	X	X
13	FCRM	SNA	F	X	X	X	X	✓

* Left the process due to a change in job role

CSG – Chief Scientist's Group (E&B)

IM&R – Incident Management & Resilience (LO)

SBD – Sustainable Business & Development (E&B)

SNA – Strategy & National Adaptation (FCRM)

WR – Water Resources (E&B)

Workshop 1 – Agenda

Session/activity	Format	Timing
Welcome and introduction	Plenary session (with slides)	5 mins
Project overview	Plenary session (with slides)	10 mins
Roundtable introductions	Plenary session	15 mins
Session 1: Getting to know each other		
Positioning yourself Participants locate themselves on a Venn diagram of scientist-practitioner-advisor based on their main role and explain their positionality.	Plenary session (with mural board)	30 mins
Session 2: Where are we standing?		
Co-mapping the knowledge system Participants map actors, boundary objects, and information flows onto the Environment Agency organisational chart.	Plenary session (with mural board)	25 mins
Research gaps and challenges Participants collectively identify research gaps and challenges	Plenary session (with mural board)	25 mins
Break (10 mins)		
Session 3: What would we like to co-produce?		
A roadmap for action Participants prioritise research gaps and challenges identified through voting	Plenary session (with mural board)	15 mins
Delineation of solutions Participants identify solutions that can help gaps and challenges identified, organise these based on the temporal scale of their implementation.	Plenary session (with mural board)	20 mins
Blockers and enablers Participants identify possible blockers and enablers for solutions identified	Plenary session (with mural board)	15 mins
Finish: Wrapping up and next steps		
Thanks, next steps, and close	Plenary session	10 mins

Workshop 2 – Agenda

Session/activity	Format	Timing
Welcome and introduction	Plenary session (with slides)	10 mins
Session 1: Collective reflection about Café session conversations		
Collective reflection (part 1) Participants reflect on the process of taking part in the café session conversations	Plenary session (with mural board)	15 mins
Collective reflection (part 2) Participants reflect on what was discussed around challenge 1 (investment in preparedness versus response) and challenge 2 (data and information sharing)	Plenary session (with mural board)	25 mins
Break (10 mins)		
Session 2: Addressing gaps and challenges for specific climate related hazards		
Introduction	Plenary session	5 mins
Breakout group activity Participants discuss what this challenge means for flooding and drought, how it relates to their work, what actions need to be taken to address it, and what may block progress. Groups swap facilitators and hazard after 20 mins.	Breakout groups (x2)	40 mins
Reporting back Facilitators report back on discussion from each group.	Plenary	10 mins
Break (10 mins)		
Session 3: Moving forward. What would you like our final workshop to be?		
A roadmap for action Participants reflect on co-production and participatory approaches. Facilitator explains self-organising activity.	Plenary session (with mural board)	10 mins
Self-organising Participants experiment with self-organisation and start taking ownership of the process and outcomes by designing final workshop. Participants to identify objectives and choose content and activities for the third workshop	Plenary session (with mural board)	15 mins
Sharing of discussion Participants feedback to the facilitators	Plenary session (with mural board)	15 mins

Finish: Wrapping up and next steps		
Thanks, next steps, and close	Plenary session	10 mins

Workshop 3 – Agenda

Session/activity	Format	Timing
Welcome and introduction	Plenary session (with slides)	10 mins
Session 1: Understanding challenges to resilience within the Environment Agency/IMS		
Setting the scene Discussion to set the scene on thinking around resilience	Plenary session	15 mins
Carousel activity In breakout groups, participants explore challenges to resilience (i) IMS and (ii) the wider Environment Agency during incidents and how ways of working could be adapted to increase resilience. Participants swap facilitator and topic after 20 mins.	Breakout groups (x2)	50 mins
Report back Facilitators feedback on discussion to the group	Plenary session	5 mins
Break (10 mins)		
Session 2: Exploring external influences on IMS residual risk		
Introduction	Plenary session (with mural board)	5 mins
External influences on IMS risk Participants discuss the external factors that influence the risk that IMS has to deal with for 1. Flooding (20 mins) **2.** Drought (20 mins)	Plenary session (with mural board)	40 mins
Break (10 mins)		
Session 3: Moving forward. Where do we go next?		
What do you want going forwards? Participant led activity. Participants discuss and prioritise preferences for the future leading from this process.	Plenary session (with mural board)	10 mins
What is needed in the next 3-6 months to make this happen? Participants discuss what support and resources is needed to proceed and what they can do as individuals to stay committed.	Plenary session (with mural board)	15 mins
Finish: Wrapping up and next steps		
Thanks, next steps for the project, and close	Plenary session	5 mins

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