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University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Better together: knowledge co-production for a sustainable society

White Paper

Acadamh Ríoga na hÉireann
Royal Irish Academy

About

This Royal Irish Academy white paper, 'Better together: Knowledge co-production for a sustainable society', provides an overview of knowledge co-production for sustainability and environmental research in Ireland; highlights the benefits and challenges of co-production approaches; and identifies key levers for building capacity and capability for knowledge co-production. The paper draws on almost 50 case studies of co-production research for sustainability, along with the outputs from the online Royal Irish Academy symposium and workshop 'Better together: Knowledge co-production for a sustainable society', which took place on 3 June 2021. Short summaries of the case studies are included in this white paper.

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Executive summary

There is a growing international momentum for transformative action at multiple levels to address key sustainability crises such as climate change, biodiversity loss and creating a circular and resource- efficient society. Despite the health impacts and global economic-societal disruption caused by the COVID-19 pandemic, the transition towards more sustainable pathways remains one of the greatest challenges facing society.

Responses to sustainability challenges over the last few decades have been too slow and faltering, partly due to the 'wicked' nature of the problem, i.e. that they are characterised by complexity, uncertainty and contested values. For many sustainability challenges, additional scientific knowledge about the underlying problem is not necessarily the limiting factor in the development of more sustainable outcomes. Instead, a combination of social values, political and institutional contexts, and technological diffusion often impede effective action. While scientific knowledge may be required, an equally important task is to link the production of this knowledge with actions where it matters. The sheer complexity of societal challenges combined with the specialisation of science can mean that universities often struggle to mobilise their unique capacities in ways that effectively link knowledge with action. One response of universities and funding bodies to this issue has been to re-focus research strategies around societal challenges, e.g. using the United Nations' Sustainable Development Goals as an overarching framework.

More responsive modes of knowledge production

Many academics within the sustainability research community, along with policymakers and research funding agencies, recognise that the unique and urgent challenge of sustainability requires the exploration of more responsive modes of knowledge production to produce actionable and usable information. Research approaches involving co-production are often suggested as an appropriate means to meet the requirements posed by real-world problems. These approaches bring actors from outside academia into the research process in order to integrate the best available knowledge, reconcile values and preferences, as well as creating ownership of solution options. Knowledge co-production is part of a wide family of transdisciplinary and engaged research methods that have emerged in recent decades. The methods can include a spectrum of engagement with stakeholders that ranges from informing, consulting, collaborating and empowering; knowledge co-production resides between collaboration and empowerment.

Knowledge co-production can enhance research quality, deepen the understanding of the research question, produce more usable knowledge and increase the likelihood of its use in practice, along with building trust amongst stakeholders. In general, co-production is valuable where research questions are at the intersection of academic and non-academic/societal domains, where understanding and solving a problem requires cooperation among a range of disparate stakeholders, and where norms or values have to be included in solutions that have real or perceived impacts on stakeholders.

Despite its potential benefits, the costs of co-producing research can be high. It carries significant risks for academics who are required to adopt practices far from those traditionally recognised or rewarded by universities. It equally carries risks for non-academics and practitioners, and there are many examples of participatory approaches to environmental management that fail to deliver desired beneficial environmental or social outcomes for participants, resulting in alienation and distrust amongst stakeholders.

Demand for greater collaboration between academia and societal actors

Within Europe and Ireland there has been a notable increase in interest in transdisciplinary and engaged research, with many academic institutions and research funding agencies calling for amplified stakeholder and societal participation in research, along with enhanced interdisciplinary and transdisciplinary approaches within research programmes. The Horizon Europe programme launched in 2021 is focused on mission-oriented research where large, complex problems are addressed through interdisciplinary academic work, and through new forms of partnerships between academia, the public sector, business and civil society organisations. The programme recognises that the genuine participation of civil society organisations and the public in projects is crucial to facilitating open dialogues on expected outcomes and practical applicability of solutions. One of the most notable recent initiatives in this area in Ireland has been Campus Engage based at the Irish Universities Association (IUA), which aims to promote civic and community engagement as a core function of Irish higher education, recognising that research generated in partnership with knowledge users is likely to be more impactful.

Royal Irish Academy call for case studies and 'Better together' symposium and workshop

It has been suggested that a key lever to help integrate the practice and scholarship of co-production for sustainability is to improve the reporting on the process itself through the collection of more case studies on knowledge co-production and its implementation. In response to this, in early 2021, the Royal Irish Academy issued a call for case studies on knowledge co-production in the areas of environmental and sustainability research in Ireland. The initiative sought to get a snapshot of knowledge co-production within the environmental and sustainability research community in Ireland, along with the nature of the process, its benefits and challenges. Almost 50 case studies on research co-production across Higher Education Institutes and research bodies on the island of Ireland encompassing a wide variety of sustainability and environmental research were received. The non-academic co-production partners within the case studies were from industry, government departments, local authorities, NGOs and community groups. Short summaries of the case studies are included in Appendix 1 of this white paper.

The call for case studies was proceeded by the RIA 'Better together: Knowledge co-production for a sustainable society' online symposium and workshop on 3 June 2021. The symposium and workshop further explored how the Irish research system can respond to the demand

for increased levels of co-production knowledge, and improve its use in decision-making and practice. The event enabled a sharing of experiences of the reality of co-production within the Irish environmental research community and how to address key challenges.

Co-production for environmental and sustainability research in Ireland

The case studies provide comprehensive details on why Irish academics are co-producing research with non-academic stakeholders, and the resultant benefits of these approaches. The vast majority of case studies indicated that non-academic stakeholders were involved in framing and designing the research agenda and goals. The four main categories of co-production benefits identified were: (i) production of shared knowledge in partnership with non-academic stakeholders, (ii) access to expertise, knowledge and data for both partners, (iii) ensuring research meets user needs and acceptability and (iv) creating buy-in and building capacity for action.

The key barriers and challenges to research co-production identified within the case studies were: (i) different approaches and goals of partners, (ii) lack of resources for sustained engagement, (iii) long or mismatched timescales required for co-production, (iv) communication and different language and culture of partners and (v) ensuring equality, trust and respect.

Participants within the case studies and 'Better together' workshop proposed that some of these challenges can be addressed by: (i) agreeing goals, roles and processes at the outset, (ii) managing relationships and maintaining trust, (iii) engaging early to co-design and build a shared understanding, (iv) communicating and sharing knowledge regularly, (v) hiring project managers and facilitators and (vi) providing adequate resources and time.

Accelerating and building capacity for knowledge co-production for sustainability in Ireland

The case studies and accompanying RIA symposium/workshop reveal that there is a diverse community of academics and researchers in Ireland who are deeply committed to co-producing knowledge with non-academic stakeholders. However, the challenge remains to move beyond these individual exemplars of good practices to scale up and build capacity for knowledge co-production, and create a research ecosystem that encourages, rewards and recognises co-production. This is a shared challenge for the Irish science and research system, including HEIs, research funding agencies and relevant government departments. The case studies and RIA symposium/workshop highlight a number of critical levers for advancing co-production approaches within the research ecosystem, including:

- *Enhanced funding flexibility*, particularly to reimburse non-academic partners and to allow for changes of direction as the co-produced project evolves.
- *Better recognition and broader metrics*, recognising deliverables that have value to non-academic stakeholders, especially those that encompass local knowledge and that produce changes that enrichen communities.

- *Improved networking and opportunities for identifying stakeholder issues*, such as match-making events, industry open days, databases of expertise and forums where research questions of importance to non-academic partners can be identified.
- *Providing training and toolkits for co-production practice*, as successful research co-production requires additional skillsets to deep academic disciplinary expertise; non-academic partners may also benefit from training in the appropriate research tools and techniques.
- *Enhancing capacity in non-academic partners*, by setting aside specific tranches of funding for non-academic partners, focusing on non-academic partner needs, and use of more secondments into stakeholder organisations, and vice-versa.

Co-production costs more for all stakeholders. Assessing and understanding whether, and under what conditions, co-production is the best way to achieve better sustainability outcomes in a particular context is vital. For academics and researchers it is important to avoid using co-production becoming an end in itself or because it is required to win proposal funding.

Ireland's relatively small size and population, our traditionally close connections between academia-policy-industry, and our strong civic base within towns and villages gives us a unique advantage in creating knowledge co-production communities. Embedding co-production approaches within our research ecosystem in the coming decade will increase our capacity and capability to produce more impactful and usable knowledge to enable our ambitions to create a zero-carbon and resource-efficient economy, and catalyse the necessary transition to a sustainable society.

SECTION 1

Introduction to knowledge co-production for sustainability

1.1 A growing momentum for action on sustainability challenges

There is widespread consensus that we are at a critical juncture for action on key sustainability challenges, such as climate change, biodiversity loss and creating a circular economy. Despite the health impacts and global economic-societal disruption caused by the COVID-19 pandemic, the transition towards more sustainable development pathways remains one of the greatest challenges facing society. The climate emergency is accelerating more rapidly than most climate scientists anticipated; the latest data shows that the decade 2011–20 is the warmest on record, and the global temperature in 2020 was approximately 1.25°C above pre-industrial levels (World Meteorological Organization, 2020). The Intergovernmental Panel on Climate Change Working Group 1 Report released in August 2021 confirmed that no corner of the earth is now unaffected by climate change, and called for immediate cuts for greenhouse gas emissions to avoid catastrophic global warming. The World Economic Forum (World Economic Forum, 2020) has reported that for the first time ever all the 'top long-term global risks by likelihood' in their Global Risks Report were environmental. Growing protests from the younger generation, together with increased public awareness and concern over environmental sustainability, are pushing organisations to integrate sustainability into their strategies and operations.

Countries and economies are responding to these sustainability challenges, albeit much too slowly and at insufficient scale. The European Union, through the EU Green Deal, will mobilise €100 billion over the period 2021–7 to transform the European Union into a resource-efficient and competitive economy. The Green Deal provides an action plan to boost the efficient use of resources by moving to a clean, circular economy; restore biodiversity and cut pollution; and ensure a just and inclusive transition. The Irish government has called climate crisis the 'defining challenge of our time', and in March 2021 published the ambitious Climate Action and Low Carbon Development (Amendment) Bill, which will support Ireland's transition to a net-zero and climate-neutral economy by no later than 2050 (with an interim target of 51% reduction in greenhouse gas emissions by the end of the decade). Ireland will need to rapidly scale up investments in low-energy building renovations, renewable energy, sustainable mobility, sustainable agri-food production and processing, and an industrial manufacturing system based on circular economy models. The investment to restart the economy after the COVID-19 pandemic will provide an unique opportunity for Ireland to shift to zero-carbon and circular-economy pathways, transforming our country into a sustainable and climate-neutral society.

Europe's and Ireland's ambitions for a zero-carbon and climate-resilient economy bring significant opportunities to the Irish research community. There will be a need for radical technological innovations, different business models and new competences and skills. The transition to sustainable development pathways will also require an unprecedented and urgent scale of contributions, cooperation and collaboration between academia, policy-makers, NGOs, business, political leaders and civil society (Hart *et al.*, 2015). It necessitates inter- and transdisciplinary approaches, combining and considering technological, economic, social, managerial and environmental aspects of the transition.

Aligning knowledge and action for global sustainability is essential to addressing sustainability challenges. An examination of the role of science and its relationship to society will be critical as we confront the magnitude of societal change needed to achieve socio-ecological sustainability. Producing actionable science to inform decisions on sustainability is an important opportunity for science to serve society and fulfil expectations that come along with public financial support.

'There is a need to involve communities in shaping future developments in response to climate change. In particular, when citizens have a greater say in future planning about their local environment, this can lead to better decision-making about adaptations to climate impacts.'

From: Coastal Communities Adapting Together (Case Study 7)

1.2 From knowledge to action

> *'Too much potentially valuable knowledge produced by committed researchers languishes in libraries, unused by society; and too many of society's greatest needs for new knowledge remain relatively unexplored by researchers.'* (Clark *et al.*, 2016)

The unique challenge of creating a sustainable society can be catalysed by new modes of knowledge production and decision-making; there have been many appeals to revise the social contract for science to a more responsive system of research production for societal problem-solving (Arnott *et al.*, 2020). Ostrom *et al.* (2007) points to a concern amongst politicians, business and the public about the failure of science to provide operational solutions for addressing the sustainability challenges. Ostrom and colleagues call for the knowledge acquired in the separate disciplines of biology, engineering, sociology, economics, geography, law, political science and psychology to strengthen diagnostic and analytical capabilities of the stakeholders who are directly confronted with practical sustainability problems. It has also been considered important that scientific research on sustainability takes a wide view of decision-making to include economic and political considerations (DeFries *et al.*, 2012).

An editorial in the journal *Nature* in 2018 highlighted that much research done in the name of society is not used by societal stakeholders; instead it is paid for, produced and recorded, and left waiting for someone to come along and use it (*Nature* editorial, 2018). A transition toward sustainability therefore requires not just more knowledge but more usable knowledge. Knowledge matters for sustainability transitions, but only if it gets taken up in ways that users and stakeholders can engage with and put to use. Clark *et al.* (2016) state that, to produce usable knowledge for sustainable development, researchers need to:

- listen to the potential users who they hope will act upon their discoveries.
- adjust their research agendas to reflect user needs rather than the enthusiasms of academia or funders.
- adapt their research in an iterative manner to fit local contexts.
- understand that new knowledge is more likely to become usable when it is shaped to 'fit' within the system of existing ideas, technologies and governing institutions.

'To untangle and attempt to understand the many influences acting on the river, an appreciation of the river's story seemed a necessary first step. Local people gave me a lens through which I could view and appraise the technical data on the river by sharing their insights and memories with me.'

From: Restoration of the River Camac (Case Study 41)

Producing actionable and usable knowledge to address large-scale sustainability challenges requires deep and genuine engagement with the users of the knowledge. Many funding agencies understand this requirement; grant applications and research assessments now routinely ask for explanations of the research's technological, policy or societal impact; some funding calls now include requirements for scientist–stakeholder engagement and co-production. Likewise, universities have generally begun to recognise the value of transdisciplinary research as a way to generate new scientific knowledge, but also as a mechanism to link their research mission with their so-called third mission to promote societal benefit (OECD, 2020). Many higher-educational institutes are now articulating their research strengths and priorities around societal challenges rather than disciplines.

In early 2021, the Royal Irish Academy and the Irish Research Council jointly hosted a series of webinars on Research for Public Policy and Society to support and enrich the dialogue among key stakeholders; a discussion paper for the webinars (Doyle, 2021) suggests that, in order to make progress on the improved alignment between science and policy, action is needed in the research community, government departments and by research funders to build an 'architecture for dialogue' between the various stakeholders, drawing on both national and international experience and practice.

1.3 The need for knowledge co-production

> *'Addressing sustainability is more than an academic exercise. It is a vital response to a rapidly evolving crisis and should be at the top of our research agendas. Science itself needs to be fully engaged in this challenge.'* (McMicheal *et al.*, 2003)

> '*Without understanding social and political dynamics, aspirations, beliefs and values, and their impact on our own behaviour, we can only describe the world's physical, biological and chemical phenomena, observe and document their changes at different scales and apply technology to secure access to resources, but would ultimately fail to ensure sustainability.*' (Ignaciuk *et al.*, 2012)

The co-production of knowledge is seen by many academics working in the area of environmental and sustainability research as critical for the advancement of theory, knowledge and governance for global sustainability (Miller and Wyborn, 2020). Co-production research is often suggested as an appropriate means to meet the requirements posed by real-world problems through the involvement of actors from outside academia into the research process in order to integrate the best available knowledge, reconcile values and preferences, as well as create ownership for problems and solution options (Lang *et al.*, 2012). Universities, 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, 2020); they highlight that new structures and mechanisms are needed to foster knowledge for sustainability that is deeply integrated across disciplines and non-academic stakeholders (Irwin *et al.*, 2018).

'The co-production approach has been beneficial as traditional approaches to problematising and making recommendations for reform in the context of environmental justice on the island of Ireland have not been successful in achieving meaningful change.'

From: Environmental Justice Network Ireland (Case Study 19)

Co-production is at the core of the emerging discipline of Sustainability Science, which emphasises that 'science must be created through the processes of co-production in which scholars and stakeholders interact to define important questions, relevant evidence, and convincing forms of argument' (Kates *et al.,* 2000). Sustainability Science focuses at least as much attention on finding solutions as on generating new knowledge; it attempts to position scientists as not just generators of knowledge but also as knowledge brokers, dialogue enablers, solution generators and change agents (Miller *et al.*, 2014; Hart *et al.*, 2016).

There are four main arguments for co-production in the literature (Cash *et al.*, 2003; Oliver *et al.*, 2019; Clark and Miller, 2020; Lang, 2012; Norström *et al.*, 2020; Carmen-Lemos, 2018; Pohl, 2005; Carew and Wickson, 2010), as follows.

It improves research quality: Co-production can enhance the quality of research and improve understanding of an issue. Global environmental challenges such as climate change and biodiversity loss have multiple layers of complexity that resist simple solutions. Co-production enables researchers to acquire a deeper understanding of the problem context by engaging with stakeholders who 'own' the problem; stakeholders know their decision context, what information they have used in the past and what information might support decisions in the future. In the process of co-production, stakeholders and researchers often have complementary and overlapping knowledge and skills. The interface between researcher and practitioner enables societally relevant problems to trigger new scientific research questions and facilitates mutual and joint learning processes between science and society.

It produces more usable knowledge: Co-production can be a powerful way to make scientific knowledge more relevant, actionable and impactful. Within environmental and sustainability research arenas, scientists, along with research funders and stakeholders, increasingly believe that collaborating to co-produce knowledge will increase its use in policy, decision-making and practice. Collaboration with users ensures that the knowledge generated will be salient, credible, legitimate and owned by practitioners; these knowledge users can help to nurture research findings into action at larger scales.

It provides social and political context: Understanding research as a social and political process, and not just a process of discovery, helps to highlight the moral and ethical dimensions of working with the people whose lives are affected by sustainability decisions. Knowledge co-production goes beyond problem analysis to consider practitioner goals, norms and values. It is an effort to afford equal weight to various knowledges, and prompt academics to share decision-making power within the research process with the non-academic stakeholders. Co-production can make practitioners feel empowered, and has the capacity to reduce conflict and build trust amongst stakeholders, who are then more likely to support project goals and implement decisions in the long term.

It has intrinsic value: Co-production, and its associated engagement with relevant non-academic stakeholders, may simply be of intrinsic value, and fosters social capital. Many commentators focus on the accountability of the public university and funding bodies to serve public interests. Flinders *et al.* (2016) characterise this view as the belief that co-production can be 'transformative not solely in research terms but in social terms: the engagement of citizens and social groups nourishes the renewal of democracy'.

1.4 Knowledge co-production: context and process

> *'As part of a new social contract for science not only would science speak the truth to power but society would speak back to science in identifying relevant topics and research priorities, questioning the relevance of specific methodologies and assumptions, validating the results in terms of their social robustness, and make normative commitments explicit.'* (Dedeurwaerdere T., 2014)

Knowledge co-production is part of a wide family of transdisciplinary and participatory research methods that have emerged in recent decades and which are seen as essential for a transition to a sustainable society (Lang *et al.*, 2012; Byrne *et al.*, 2017). Transdisciplinary research emerged from the concept of 'transcending' the traditional boundaries of university-based research to include the participation of extra-academic stakeholders. These approaches favour more interactive arrangements between academic and non-academic actors to enable science to have greater impact on research outcomes (Norström *et al.*, 2020).

While terms such as 'co-creation', 'transdisciplinarity' and 'participatory research' have become increasingly common in research, there is a wide spectrum of interpretation of what they mean, and there is a large number of other descriptors for co-produced research (see Bammer *et al.*, 2020, for an overview of terminologies). When the audience at the 'Better together: Knowledge co-production for a sustainable society' symposium was asked what words they use to describe approaches where knowledge is co-produced between the academic community and external stakeholders, there was a wide diversity of terms and nomenclatures, as shown in Figure 1 below.



Figure 1: Word cloud representing terms/words used by 'Better together: Knowledge co-production for a sustainable society' symposium audience to describe approaches where knowledge is co-produced between the academic community and external stakeholders

One much-cited approach to understanding the extent to which non-academic actors are involved in research is Arnstein's 'ladder of participation', as shown in Figure 2 (Arnstein, 1969). Although originally designed to describe citizen participation in local decision-making, it equally can be applied to how non-academic actors are empowered within research, with the higher rungs on the ladder corresponding with high stakeholder involvement in the research process. The ladder of participation is a simplification, but it helps to recognise that there are significant gradations and intensities of participation and interaction between practitioners and scientists.

Brandt *et al.* (2013) and Rowe and Frewer (2005) distinguished the different types of scientist and practitioner engagements as ranging from:

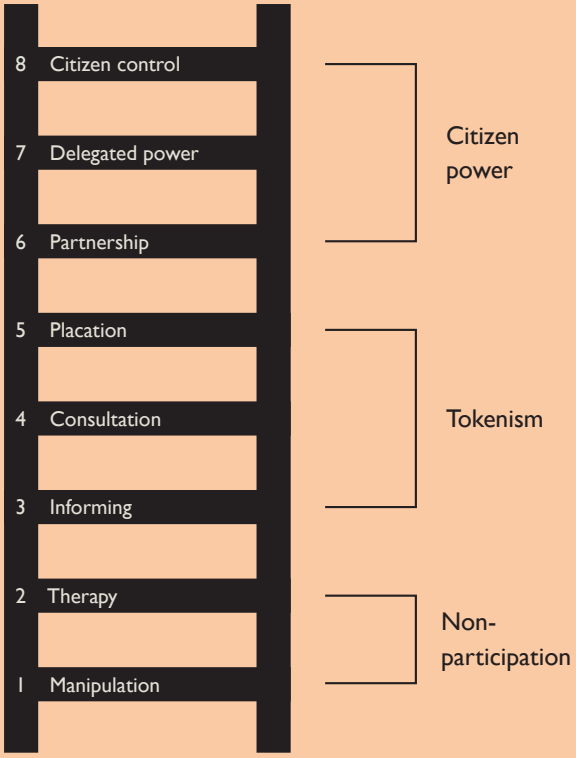


Figure 2: Arnstein's Ladder of participation (Arnstein 1969)

'KelpRes would not be possible without co-production. The collaboration with recreational divers and Seasearch Ireland enabled discoveries such as the presence of L. ochroleuca (the warm-water, European kelp) in Belmullet, Co. Mayo, which was the first record of this species in Ireland.'

From: KelpRes (Case Study 29)

(i) **Informing** – involving one-way communication of information from scientist to practitioner
(ii) **Consulting** – equally demanding closer communication, including responses from practitioner to scientist
(iii) **Collaborating** – requiring that practitioners have notable influence on the outcome
(iv) **Empowering** – where the authority to decide is given to the practitioners

The co-production of knowledge resides somewhere between (iii) and (iv), i.e. collaborating and empowerment. Although empowerment may be a goal of co-production, it remains unclear to what extent this is, or can be, achieved within traditional research frameworks led by scientists (Brandt *et al.*, 2013). It is also noted that the degree of interaction with, and empowerment of, non-academic stakeholders may vary throughout the lifetime of a co-produced research project.

In the context of sustainability research, Norström *et al.* (2020) defined co-production as 'iterative and collaborative processes involving diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future'. Co-produced research has a number of inherent components which set it apart from traditional research approaches (Dedeurwaerdere, 2014; Boyce *et al.*, 2016):

- **Building a collaborative research team composed of academic and non-academic actors**: This includes identifying and involving those who will benefit from the research in order to understand the problem from the beginning, and developing knowledge and solutions together throughout the research process. There may also need to be people with facilitation skills who can strengthen the team's ability to co-innovate and act as translators or brokers between the researchers and stakeholders.

- **A collaborative framing of the research questions, problems and goals**: Knowledge co-production for sustainability is problem-focused and benefits from clearly defined and meaningful goals shared among participants. A co-production approach means putting the problem to be solved at the centre; it is important to take a broad view of the problem system and consider the technical, social, cultural, economic, market and political aspects of the problem and solution.

- **Joint knowledge production through collaborative scientific research:** Non-academic actors are continually engaged in the research process. Research results are shared early and often rather than waiting until the end of the research supporting understanding on how the results fit with non-academic knowledge, identifying new questions and checking that the results are meaningful to users. There should be built-in monitoring and evaluation activities with a focus on reflection and learning to enable a 'Plan-Do-Observe-Reflect' action learning cycle.

- **The integration of scientific results into practice:** The production of more actionable and usable knowledge that better informs and enables more rapid decision-making to help society address large-scale sustainability challenges is a key element of research co-production.

Norström *et al.* (2020) and Miller and Wyborn (2020) draw together important lessons for the processes and practice of co-production.

- **Be goal oriented:** Shared goals and meaningful milestones facilitate learning, increasing the likelihood of achieving the desired outcomes, and reduce the potential for hidden agendas to undermine progress and the legitimacy of co-production processes.

- **Be pluralistic and inclusive:** There must be an accommodating of diverse participants and their knowledges within science processes. Co-production of knowledge must explicitly recognise the multiple ways of knowing and doing.

- **Be attentive to the power accorded to diverse participants:** A failure to sufficiently engage with power imbalances lessens the quality of the engagement and process outcomes.

- **Be interactive, reflexive and iterative:** Processes should have genuine and frequent interactions among participants, avoiding token participation, passive engagement and one-way communication flows. The amount, timing and type of interactions have a significant influence on the quality of knowledge co-production processes.

- **Be sensitive to the context of the research:** As co-production processes are situated within particular social, economic and ecological contexts, participants must take into account the different needs, interests and beliefs of the various social groups who are invested in, or affected by, the challenge at hand.

'A co-production approach was considered vital for this project to ensure good working relationships with data holders, and feedback and buy-in from policymakers and communities that will make use of and benefit from the accounts.'

From: INCASE (Case Study 27)

WHO ARE THE STAKEHOLDERS?

The term 'stakeholders' in the context of knowledge co-production is used to describe organisations and individuals invested in and/or affected by the issues and problems that academics study. These include policymakers, decision-makers, public officials, practitioners, community members and individuals whose livelihoods are informed by environmental science knowledge (Carmen-Lemos, 2018). For the purposes of this white paper, stakeholders are those outside the academic system who are not routinely involved in research but have a 'stakeholding' in how the knowledge from the research is used. It is fully appreciated that not all environmental and sustainability research in Ireland is produced within Higher-Education Institutes, and that there is substantial research capacity and output within government departments and advisory bodies, including Teagasc, National Economic and Social Council, Economic and Social Research Institute, Met Éireann, Marine Institute and the Environmental Protection Agency, amongst others. It is also noted that a number of the aforementioned bodies are also funders of research, and active practitioners on sustainability and environmental issues.

1.5 When should knowledge co-production be used?

Generally, co-production is required when information and consultative approaches are intrinsically unable to generate the requisite insights, and/or when the involvement of non-academic stakeholders is essential to successful implementation of research outputs. Co-production and transdisciplinary approaches are valuable in several contexts (OECD, 2020):

- Where problems fundamentally involve the intersection of academic/technological and non-academic/societal domains.
- Where understanding and management of a system or problem requires cooperation among a range of disparate stakeholders.
- For scientific/technological issues in which ethical norms or value judgements have to be included in the problem-solving, and/or where solutions have real or perceived impacts on some stakeholders.
- In evaluating the societal impacts and/or best implementation strategy for a new technology or policy intervention, particularly as they relate to a specific place or region.

Co-production may not always be the most appropriate means of engagement with stakeholders. For certain purposes and contexts, informing and consultation approaches may be more suitable modes of engagement with non-academic practitioners. Co-production may also not be appropriate in situations where there is little scope for delegation of decision-making power, insufficient resources, no culture of participation or previous unsuccessful attempts.

'The co-production approach has not only been beneficial but essential. The collaborative approach has ensured that researchers have supported the community, and contributed positively to the development of increased societal capacity. This project has enabled a far more significant reach than would have been achieved by the researchers alone.'

From: Dingle Peninsula 2030 (Case Study 16)

WORKSHOP SPOTLIGHT 1:

When is co-production needed and most appropriate?

The RIA hosted a national symposium and workshop titled 'Better together: Knowledge co-production for a sustainable society' on 3 June 2021 to explore how the Irish research system can respond to the demand for increased of co-production (see Section 3.1 for details). Break-out groups at the 'Better together' workshop were asked to respond to the question, 'When is co-production needed and most appropriate?' The main themes for when co-production is needed and appropriate are outlined below:

For addressing problems that interface with society and communities: It was strongly felt that research which interfaces with, and which may have an impact on, communities requires co-production approaches. This was particularly the case if the research involves implementation of policies within a community. Co-production is needed for 'societal challenges that involve a diverse range of actors where their buy-in is needed for action' and 'when the challenge we are facing requires not just insights but actions with communities'. Some workshop participants considered that 'researchers should be available to community to help them solve community issues'.

For uptake of a solution, technology or policy measure: Co-production was seen to be necessary for solutions-focused research where the expected output of the research is to be taken up by a user-group, i.e. 'to validate an idea or technology', 'make it ready for society', 'get the buy-in of the end-users by tailoring the solution to their needs' and 'If user groups are expected to deliver outcomes they need to be involved in the preparation and decision of what the actions will be.' This was particularly evident for the development and deployment of new technologies for industry, but was also identified for research projects that seek to inform policies and legislation 'to accelerate policy development and adoption'.

For complex and 'wicked' problems: To address 'wicked' problems and challenges, more structured processes of co-design and co-production are needed. These include 'issues that are socially contested' and 'where change is needed', along with 'complex challenges that affect a wide range of stakeholders'. Societal challenges with 'multiple contested solutions' and that 'cover areas that are very different' require multiple different knowledges, and are not 'solvable in silos'.

When non-academic stakeholders have critical knowledge on an issue: It may be appropriate to use co-production approaches when particular expertise is required (whether scientific or other) but is not available within the project team, and 'when there are other stakeholders who have key insights to address the research questions'.

To give voice to those most affected by research: Co-production can help 'to ensure those most affected by a problem are involved in creating the solutions' and in particular 'gives an opportunity [to hear] marginal voices' and 'challenge power relations'.

For projects attempting to create behaviour change: When a research project has 'a mix of technical and behavioural issues' and is attempting to implement a change in attitudes and behaviours, non-academic participants should be centrally involved in project co-design and delivery.

1.6 Barriers and challenges to knowledge co-production

The costs of co-producing research can be high compared to conventional research approaches, and there are a significant array of barriers that potentially hinder research co-production (Carew and Wickson, 2010; Haugaard Jakobsen C. *et al*., 2004).

Co-production is an attempt to link two processes of knowledge creation: (i) a scientific process in which scientists design and conduct research on a particular issue and (ii) a societal process in which actors try to understand and tackle the issue. Pohl *et al*. (2017) emphasise that researchers and practitioners may be motivated by different questions and thought styles. The researcher is driven by questions about how things are and how they function (truth and rigour), while practitioners may be more interested in whether a solution is the right approach to the issue, i.e. whether it works and is better than other options.

The sheer scope and complexity of attempting research that aspires to an array of goals (e.g. transcending, integrating, evolving, negotiating and problem-solving) represents an early barrier. Co-production of research requires more time, money, facilitation expertise and personal commitment from participants compared to conventional modes of knowledge production (Lemos, 2018). Oliver *et al*. (2019) highlight that co-production is 'time-consuming, ethically complex, emotionally demanding, inherently unstable, vulnerable to external shocks, and subject to competing demands and expectations'.

'The co-production approach has been decisive in terms of its commercialisation power, market pull and overall industry implementation. The feasibility of the performance reports and the dashboard were made possible through the continuous feedback from supply chain stakeholders, particularly farmers, food processors, policy makers and quality assurance organisations.'

From: Food Futures (Case Study 15)

Co-production carries significant risks for academics, who are required to adopt practices far from those traditionally taught, adopted, recognised or rewarded by universities. It equally carries risks for non-academics and practitioners. There are many examples of participatory approaches to environmental management failing to deliver the envisaged beneficial environmental or social outcomes, which causes distrust and loss of faith in participation (Reed, 2017; Cooke and Kothari, 2001). The constant requests by academics for participation in co-production may also lead to fatigue among stakeholders repeatedly sought out as partners.

Carew and Wickson (2010) outline the challenges of carrying out a research project involving co-production, to include:

DECREASING THE COST OF CO-PRODUCTION

There is an additional cost in time and resources to both academics and stakeholders, with increasing levels of non-academic participation in research, i.e. in graduating from a process of informing to consulting to collaborating to empowering. A cautious approach to co-production might include an assessment of the costs and benefits to all involved, and an agreed decision on the most appropriate level of participation.

Oliver *et al.* (2019) suggest a two-step process when initiating a research project involving potential co-production:

- First, considering whether co-production is likely to be useful in helping the research meet its aims and selecting strategies accordingly.
- Second, considering whether other approaches are as, or more likely, to help achieve those aims.

Creating boundary organisations or brokers that bridge the production of scientific knowledge with its use has been proposed as an effective way of reducing the costs of co-production on academics and stakeholders (Lemos, 2018).

- conceiving and designing the initial research approach.
- attracting funding and institutional support.
- planning and management of such projects.
- making clear statements about what such research might produce.
- explaining how the products of co-production might be documented and evaluated.

Carew and Wickson emphasise that all of these barriers link to, and have implications for, one fundamental problem: a lack of clarity on the hallmarks of good-quality co-produced knowledge and transdisciplinary research. There is an urgent need for better ways to analyse and measure the success of co-produced research (*Nature* editorial, 2018), or else co-production risks becoming a tokenistic method of stakeholder engagement rather than a means for more-effective knowledge use in decision-making, and in building capacity for action in stakeholder communities.

1.7 Enhancing capacity for knowledge co-production

> *'Future knowledge systems need to support a science for all that goes beyond producing knowledge about our world to also generating wisdom about how to act within it.'* (Fazey *et al*., 2020)

Best practices and approaches for transdisciplinary and co-produced research have been developed and refined over the last number of decades, and are now widely available. Examples include Pohl *et al*.'s (2017) *Ten reflective steps for rendering research societally relevant* and Campus Engage's comprehensive *Framework for Engaged Research – A How To Guide* (Campus Engage, 2017a).

However, awareness of research co-production remains relatively low amongst the academic community and within higher-education institutions. Deepening awareness and understanding of co-production across diverse stakeholders and contexts is critical to effectively transitioning from assessing sustainability problems to identifying and deploying effective sustainability solutions. Distinct approaches to communication, engagement and competency-building must be developed through practice and experience, as well as knowledge of theory. In particular, it is critical to understand how and why co-production works under certain circumstances, and to avoid highly prescriptive approaches that mostly focus on the process rather than on achieving desired sustainability outcomes (Lemos, 2018).

Work by Cash *et al*. (2003) emphasises that there is a great need to strengthen the 'demand' side of the dialogue between experts and decision-makers to address the challenges posed by sustainability. Understanding what makes knowledge usable for sustainable development is of limited value unless there is the capacity to transform such understanding into practice; this 'capacity' includes the capability of non-academics to act, and the competence to do so effectively (Fazey *et al*., 2020).

Increasing the capacity for co-production also requires different approaches from a range of institutional actors: from funders who need to find flexible ways to include and pay for people who work outside academia, to government and local authorities who may need to appoint dedicated staff to negotiate and champion the partnerships required, to universities who need to provide better incentives that recognise that co-production work takes more time and resources and doesn't necessarily lead to high-profile papers and other conventional types of academic success.

The 2020 OECD report on *Addressing societal challenges using transdisciplinary research* (OECD, 2020) outlines a set of recommendations for promoting, and enhancing capacity for, transdisciplinary research (TDR) for key actors including governments, funding agencies, universities and science associations (see Inset Box 3). The recommendations within the OECD report strongly reflect the recommendations of higher-education institutions, policy-making bodies, and funding organisations within the *Engaged Research: Society and Higher Education Addressing Grand Societal Challenges Together* report (Campus Engage, 2017b).

Extract of key recommendations for promoting and enhancing capacity for transdisciplinary research from OECD report on *Addressing societal challenges using transdisciplinary research* (OECD, 2020)

Governments

- Providing dedicated resources for transdisciplinary research (TDR), particularly in relation to science for societal challenges and the sustainable development goals.
- Facilitating and supporting the engagement of public sector actors – including policy-makers – in TDR activities, and making the relevant public sector data available for use in these activities.
- Incentivising other actors, including the private sector, to support and participate in TDR to address societal challenges.

Research funders

- Provision of dedicated long-term funding for TDR to address societal challenges, along with individual support, e.g. fellowships for outstanding individuals who can lead transdisciplinary work.
- Experimentation with different mechanisms to support the development of rigorous TDR projects, including sand-pit processes and training workshops for researchers.
- Implementation of proactive management and monitoring of TDR programmes recognising that flexibility is required to accommodate the evolving goals that are inherent in the projects.
- Changes to peer review and evaluation processes, including the use of multi-disciplinary and multi-stakeholder review processes and selection of peer-reviewers with experience in TDR.

Universities and public research institutions

- Introduction of challenge-based approaches in research strategies and organisational structures.
- Establishment of structures and mechanisms to build long-term trusted relations with external stakeholder communities, including creation of formal interfaces with civil society, private and public sector entities.
- Allocation of core resources, including personnel to build long-term expertise in TDR methodologies and practice, including introduction of learning modules and postgraduate training.
- Changes to promotion criteria for individuals who engage in TDR to include evaluation on research outputs that are of value to stakeholders outside of science.

Academic community and science associations

- Development and recognition of new inter- and transdisciplinary research fields such as sustainability science and planetary health, including the promotion of relevant scientific journals.
- Support for and participation in new research management approaches, including innovative peer review and evaluation processes that would promote transdisciplinary research.
- Development of strategies and assessments of the needs and potential for TDR to address societal challenges and contributing to the development of new science indicators and measures that value multiple research outputs.

SECTION 2

The context for knowledge co-production for sustainability in Ireland

> '*Knowledge generated in partnership with policy-makers, product and service users, and civil society is more likely to be useful to society and have impact.*' (Campus Engage, 2017b)

There has been a notable increase of interest in transdisciplinary and engaged research in Ireland in recent years, with many academic institutions and research funding agencies calling for amplified stakeholder and societal participation in research. This reflects international and European trends. The European Commission's Horizon 2020 research programme strongly promoted societal engagement within its Societal Challenges programmes and within the cross-cutting themes of Responsible Research and Innovation, and Science with and for Society. Following suit, the Horizon Europe programme that commenced in 2021 will focus on 'research missions' with more attention being given to the ways in which scientific issues interact with socio-economic and political issues (big science deployed to meet big problems); Horizon Europe also calls for new forms of partnerships between academics, the public sector, the private sector and civil society organisations (European Commission, 2019; Mazzucato, 2018).

A key recommendation in Ireland's National Strategy for Higher Education to 2030 is that 'engagement with the wider community must become more firmly embedded in the mission of higher-education institutions' (Department of Education and Skills, 2011). The strategy challenges higher-education institutions to 'ensure a balance between different types of research from fundamental to strategic and applied, and from single investigator to large multi-disciplinary teams working in partnership with other relevant players'. Ireland's strategy for science, technology, research and development (**Innovation 2020**) recognises that citizen engagement in research is 'essential in some instances and increases the richness and applicability of the findings'; it includes a number of key actions to support collaboration between academia, public, private and civil society actors.

Mobilising communities and citizen engagement to tackle the climate emergency is a central feature of the **2019 Climate Action Plan** for Ireland, along with the recently published **Climate Action Bill.** This legislation is a significant step up in Ireland's commitments to tackle climate disruption, with an ambitious target of an average 7% reduction per year in overall greenhouse gas emissions and a 51% reduction by 2030. The plan outlines the need to support communities and voluntary groups to 'enhance their capacity and understanding in the area of climate action ensuring that the local champions who act as catalysts for action have the knowledge and capacity to do so'. Knowledge co-production can be a powerful means of connecting up the knowledge within the Irish education and research system with the experience and networks of community groups and voluntary organisations to build capacity and direct actions to where they can have most impact.

One of the most significant recent initiatives in relation to research co-production in Ireland has been **Campus Engage** based at the Irish Universities Association (IUA). Campus Engage promotes civic and community engagement as a core function of Irish higher education, and aims to embed civic engagement across staff and student teaching, learning and research. It defines engaged research as research that aims to improve, understand or investigate an issue of public interest advanced *with* community partners rather than *for* them. The *Engaged Research: Society & Higher Education Addressing Grand Societal Challenges* report published in 2017 (Campus Engage, 2017b), involved contributions from 320 stakeholders, and outlined sets of recommendations for policy-makers, higher-education institutions and funding bodies to enhance engaged research, along with an Engaged Research Impact Framework for Ireland. It is noted that improved stakeholder engagement is also a central part of the Irish Civil Service Renewal Plan; for example, the Department of the Environment, Climate and Communications have developed **Stakeholder Engagement Guidelines** to help build internal capacity to engage effectively with stakeholders.

There are multiple other examples of activities and initiatives to increase awareness, and deepen understanding, of co-production approaches in Ireland in recent years. A Future Earth Ireland workshop held in 2016 (Future Earth Ireland, 2016) provided an opportunity for an exchange of views on the challenges and opportunities when embarking on transdisciplinary research in the area of sustainability/environmental research. In their book *Transdisciplinary Perspectives on Transitions to Sustainability*, Byrne *et al*. (2017) highlighted how a university can be re-envisioned through a transdisciplinary informed framework to create more meaningful deliberation, understandings and options for action in relation to sustainability-related crises. The current EU-funded **SHAPE ID** project led by Trinity College Dublin is addressing the challenge of improving inter- and transdisciplinary cooperation between the Arts, Humanities and Social Sciences (AHSS) and other Sciences to establish a comprehensive knowledge base covering the different understandings of inter- and transdisciplinary research and a set of success criteria for meaningful AHSS integration.

Funding agencies are key mediators in managing the social contract for science, acting as guardians of public values and playing a key role in supporting and embedding actionable science in research. Arnott *et al*. (2020) identify four areas where funding agencies can influence how science solves societal challenges: (i) incentivising engagement through solicitation conditions and criteria, (ii) facilitating appropriate expertise and user input into proposal review, (iii) providing implementation support and (iv) fostering learning through evaluation. Irish research funding agencies are to a greater extent calling for inter- and transdisciplinary approaches within their research programmes. Within the sustainability and environmental areas, these include:

> ‘There was a history of difficult relations between [Anon] and local farmers which was limiting potential for sustainable farming practices. The project succeeded in creating a safe place for both and provided a common aim.’
>
> From: A Vegetation Management Strategy for the Wicklow Uplands (Case Study 1)

- Inter- and transdisciplinary collaboration is encouraged with the Sustainable Energy Authority of Ireland (SEAI) **National Energy Research Development and Demonstration** funding. Co-funding partnerships are an active component of the programme, enabling SEAI to support targeted interdisciplinary research projects; 2021 call topic areas encouraged academia applicants to consider forming a project consortium that could include local authorities, communities, utilities, businesses and industry.
- The **Irish Research Council** has a range of funding programmes to encourage transdisciplinary approaches with stakeholder partners, including: (i) Enterprise Partnership Schemes, where an enterprise mentor works with a researcher and provides a placement for the awardee at its facilities, (ii) the IRC COALESCE calls and CAROLINE fellowships, which invite research proposals that are interdisciplinary and inter-sectoral and (iii) the IRC New Foundations Call, which specifically calls for a partnership between academic and civic society organisations.
- Science Foundation Ireland (SFI) research centres are required to provide evidence of engaged research activity as part of their key performance indicators. SFI have recently introduced the **SFI Future Innovator Prize**, which supports 'close collaboration between researchers and solution beneficiaries so that relevant, meaningful and important challenges can be identified and validated'. **The SFI Public Service Fellowship** introduced in 2020 recognises the importance of connecting the Irish research community with public sector organisations to help inform new policy and improve the services that they deliver; the initiative offers researchers an opportunity to be seconded to government departments, agencies and the Library & Research Service of the Oireachtas.
- The Environmental Protection Agency's ten-year high-level framework for research programming (**EPA Research 2030**) calls for more 'multi-disciplinary, cross-sectoral and multi-stakeholder partnership projects'; interdisciplinary and transdisciplinary research approaches have been required on many research call topics in past research calls.
- The Department of Agriculture, Food and Marine **2021 Research Call** requires applicants 'to engage through partnerships with other departments and agencies and to encourage relevant collaboration, partnership and multi/inter-disciplinary approaches in research and innovation through the call process, across research participants, institutions, all academic disciplines and market sectors'.

While this emphasis on co-production within research funding calls is very welcome, it is important that it does not just become another box for researchers to tick and one additional demand on the part of the funding agency. The best starting point for research co-production is not eligibility for a funding call but rather a genuine meeting of minds and goals by academic and non-academic actors. Given the requirements for interdisciplinary and transdisciplinary research within research proposals and projects and the wide variation in interpretation of these concepts, it is important that there is clarity and consistency in how these elements of research proposals are evaluated and scored within research funding calls.

SECTION 3

Knowledge co-production for environmental and sustainability research in Ireland

3.1 Royal Irish Academy call for case studies and 'Better together' symposium and workshop

It has been suggested that a key lever to help integrate the practice and scholarship of knowledge co-production is to improve the reporting on the process through the collection of studies of environmental knowledge production, and its use in being implemented and disseminated (Lemos, 2018). The collection of case studies enables improved insights on how academics and stakeholders are approaching research co-production, and how stakeholders are using results from co-produced research. It also enhances understanding of when and how to co-produce, and what strategies can be used to scale up and increase impact.

In January 2021, the Royal Irish Academy Climate Change and Environmental Sciences Committee issued a call for case studies on knowledge co-production in the areas of environmental and sustainability research in Ireland. The call sought research case studies that involve academic and non-academic stakeholders in co-producing research; have clearly defined and meaningful goals that are shared among participants; and have frequent interactions among participants throughout the project (from collaboratively framing and designing the research agenda to conducting the research and jointly using the knowledge generated). The call for case studies was distributed through Royal Irish Academy networks to all Irish HEIs and research bodies.

Case studies were submitted via an online questionnaire with seventeen questions (see Appendix 2). Details were sought on:

- why co-production approaches were adopted
- what type of non-academic stakeholders were involved
- the nature of the co-production process, i.e. how and when partners were selected, partner involvement in project design, goal setting and research process, and frequency of engagement between academic and non-academic partners
- the benefit of the co-production approach as compared with traditional research approaches
- challenges during the co-production process and how they were addressed
- the main lessons learned and recommendations for other researchers seeking to pursue co-production
- how the use of co-production in research could be better supported

Almost 50 case studies on co-production in the area of sustainability and environmental research were received. Short summaries of the co-production case studies are included in Appendix 1.

The case studies received were from across HEIs and other research-performing bodies on the island of Ireland, encompassing a wide variety of sustainability and environmental research areas, such as water, climate change, energy, agri-food, waste, built environment and sustainable development. The non-academic co-production partners within the case studies were from industry, government departments, local authorities, NGOs, community groups and the public. Almost all case studies indicated that non-academic stakeholders were involved in framing and designing the research agenda and goals.

The call for case studies was followed by the RIA 'Better together: Knowledge co-production for a sustainable society' online symposium and workshop, which took place on the morning (symposium) and afternoon (workshop) of 3 June 2021. The aim of the symposium and workshop were to further explore how the Irish research system can respond to the demand for increased levels of collaboration amongst academics and non-academics to co-produce knowledge and increase its use in decision-making and practice. The symposium and workshop also allowed a sharing of experiences of the reality of co-production within the Irish environmental and sustainability research community.

The symposium was an open event widely disseminated across the Irish research system and amongst groups and communities interested in environmental issues in Ireland; it was attended by 210 people drawn from HEIs, funding agencies, community groups, non-governmental organisations, government departments and local authorities. The symposium featured keynote addresses from Professor Christian Pohl (ETH Zurich) and Carthage Smith (OECD), along with eight case study presentations on research co-production with government departments, industry, NGOs and communities (see Appendix 3 for full programme).

The afternoon workshop (facilitated by Barncat Consulting) comprised a deeper-level analysis and discussion of the key challenges and opportunities for co-production of knowledge for sustainability in Ireland. Academic and non-academic members of 25 selected case studies within this paper were invited to the workshop, along with key stakeholders within Irish research funding bodies and relevant government departments. The workshop was attended by 80 people, almost half of the attendees coming from outside academia. The key questions addressed in the workshop are shown below (see Appendix 3 for full workshop programme):

- When is co-production needed?
- How can we increase capacity for co-production in non-academic stakeholders?
- How do we manage differing goals and expectations within a project?
- How do we strengthen our evidence base on the impact of co-production?
- What kind of incentives and policies are required to promote co-production?
- How can co-production be better supported within research funding calls?

An analysis of the case studies and workshop outputs in relation to the benefits and challenges of research co-production, recommendations for researchers pursuing co-production approaches, and how to better support and enhance capacity for research co-production in Ireland is provided in Sections 3.2–3.4 and Section 4.

3.2 Benefits of research co-production: Irish case studies and RIA symposium

The case studies provide rich insights on why Irish academics are co-producing research with non-academic stakeholders, and the resultant benefits of these approaches. Four main categories of benefits emerge from the data for co-producing research.

Production of shared knowledge in partnership with non-academic stakeholders: Many case studies identified that sustainability issues are highly complex and interconnected, requiring an understanding of a wide range of viewpoints. Case studies highlighted that there is a need to involve stakeholders, particularly communities, in creating shared knowledge and shaping future developments in response to issues like climate change. The case studies emphasised that an approach that developed shared knowledge can lead to better decision-making about environmental issues and more informed plans for the future.

Access to expertise, knowledge and data: The case studies recognise that critical relevant knowledge for research on environmental and sustainability issues can reside in both academic and non-academic communities. In some cases, non-academic partners reached out to HEIs to access expert knowledge to address environmental challenges that they were facing. In other cases, it was the academic community that was seeking to tap into knowledge within local authorities, communities, industry and policy-making. Some case studies highlighted that local knowledge within communities helped the researchers to view scientific and technical data through a wider lens and perspective.

Ensuring research meets user needs and acceptability: A common benefit of co-production, particularly for research focused on producing technological solutions for industry, was that the approach facilitates the assessment of the market pull and added value of the product or technology to the end users. This ensures more rapid and successful commercialisation of new products and novel technologies, and a higher research impact.

> 'The co-production approach has been beneficial as given the multi-dimensional nature of the problem and the project, it would simply not have been possible to integrate the different perspectives required to inform system-wide change to achieve improved water quality, without taking a non-traditional multi-actor and multi-disciplinary approach.'
>
> From: WaterMARKE (Case Study 49)

Creating buy-in and building capacity for action: Many research projects that work with community stakeholders highlighted that the project was important for strengthening public participation in policy-making and governance, along with enhancing public trust in local governance. In some cases, the project created a 'safe space' for stakeholders, particularly where there had been a history of mistrust and poor relations, to come together to work on common goals and chart a way forward, i.e. the process of engagement within the project was more important than the project outputs in building understanding and ownership.

At the 'Better together' workshop, the audience were asked to select from one of the four options above for the single most important benefit of co-production of research. The results are shown in Figure 3 below. The two most important benefits of co-production perceived by the audience were ensuring research meets user needs and acceptability (43%) and creating buy-in and building capacity for action (35%).

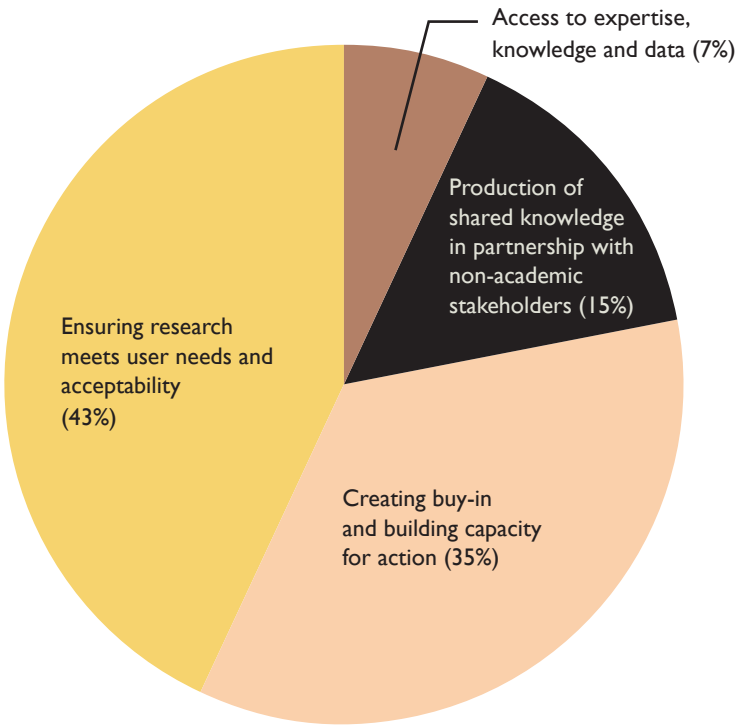


Figure 3: Most important benefits of co-production as identified in audience poll at Royal Irish Academy 'Better together' workshop (n=108)

3.3 Key challenges of research co-production: Irish case studies

The responses to the RIA case study survey outlined the challenges encountered by academic and non-academic stakeholders in co-producing research. The key challenges are outlined in Figure 4 and discussed below (including quotations from case studies).

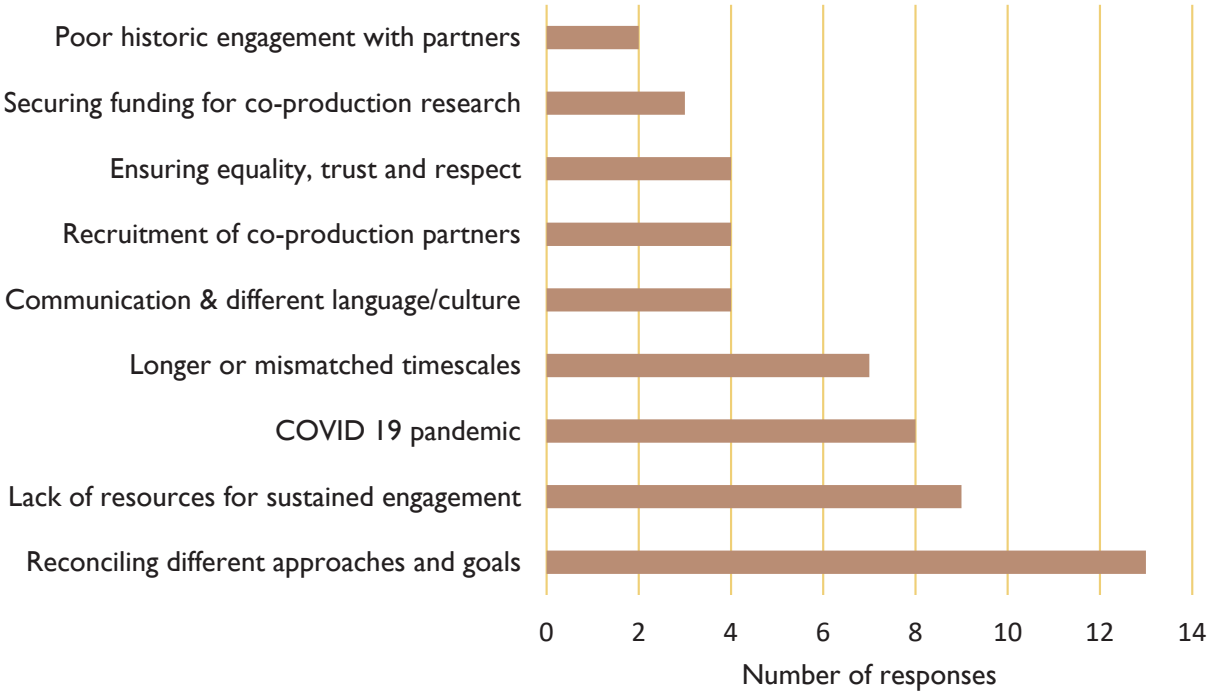


Figure 4: Key challenges of co-producing research as identified in Royal Irish Academy survey on co-production for knowledge for sustainability

Different approaches and goals of partners: One of the main challenges of co-production identified was reconciling different approaches, interests and goals of diverse partners, along with managing expectations. Non-academic partners can come into a research project with significantly different priorities, perspectives and ways of working to academic partners, and may be unfamiliar with research methodologies and tools; likewise, academic partners may need to commit significant time to understanding the goals and motivations of their co-production partners.

> '*Collaborating with groups and individuals from diverse backgrounds inevitably leads to disagreements about how to frame problems and differences in opinion about solutions.*'

> *'The main challenge was to align our priorities with the environmental activism associations. It was challenging to align the priorities and balance what would be ideal from a research perspective with what would be feasible with volunteers.'*

'Bringing together a number of non-academic partners was a challenge particularly given different roles, philosophies and approaches.'

Lack of resources for sustained engagement by non-academic stakeholders: A significant proportion of projects identified challenges around lack of funding and resources to maintain a long-term commitment of non-academic partners to the project. The involvement of non-academic partners frequently relied on the 'goodwill and personal motivation' of participants; participation in the project by non-academic partners was usually done alongside a full-time job, i.e. non-academic partners are rarely released from other commitments to participate. The voluntary quality of participation can result in sporadic engagement in the project. Even in situations where funding may be available to pay non-academics for their time, there is usually little capacity and scope for non-academic partners to take up part- or full-time roles in a project.

'Key challenges expected relate to engaging and sustaining public engagement as co-researchers in a voluntary process which may conflict with the realities of their daily life commitments.'

'The main challenge I foresee during the co-production process is partner buy-in. Potential participants may not have sufficient capacity or motivation to engage in co-productive processes.'

'Deliberative engagement processes tend to be long processes that place significant demands on people's time. Current research practices and protocols have limited options for compensating participants for their time.'

Longer or mismatched timescales (compared to conventional research projects): Genuine co-production of research takes longer than conventional research projects. Non-academic partners have to be recruited, more meetings are required to overcome differences in approaches and to align goals, time may be required for training, and project outputs need to be reviewed by more parties.

'The project timescales need to be longer when there are more people contributing and this needs to be made clear at the outset to the many stakeholders.'

'While academia is often perceived as working at a different pace to industry, a significant delay was the difficulty in engaging industry and scheduling meetings and activities.'

'The need for multiple drafts to be reviewed at each stage, feedback from multiple representatives of the different NGOs, and then long meetings to discuss the various issues arising at each review stage and how they should be dealt with, meant that the process of finalising the research was cumbersome.'

Communication and different language and culture of partners: A frequent challenge to co-producing research is the effort required by partners to understand each other's discipline and work, and to bridge cultural barriers. While these barriers mostly relate to different culture and languages within workplaces and social groups, in one co-production case study there was the additional challenge of spoken language and national culture to be overcome.

> *'The greatest challenge I encountered was related to the different cultures associated with academic and non-academic institutions. Often there is an ivory tower dimension to academia, making it hard for us to communicate and relate to non-academics.'*

> *'Communication issues and language barriers between partners were overcome thanks to bilingual researchers. Cultural barriers between partners and communities were faced locally, e.g. local artists created indigenous-inspired designs to help technological immersion.'*

Ensuring equality, trust and respect: Due to the imbalanced nature of power in terms of knowledge and resources between partners, particularly when working with communities, the co-production of research requires special attention to be given to ensuring that there is equality and respect for all partners, and that marginalised voices are included and heard.

> *'It is essential that non-academic partners are respected and trusted as vital stakeholders in the research and implementation. This helps to ensure full buy-in to the co-production process.'*

> *'Groupwork presents issues of inherent hierarchy which impact the dynamics of groupwork, often generating conflict and exclusion of other voices.'*

Covid-19 pandemic: The Covid-19 pandemic presented unprecedented challenges to all research, but particularly to co-production with non-academic stakeholders. The pandemic mostly had a negative impact on research co-production by making it more difficult to recruit partners and hold face-to-face events, particularly in communities. However, a number of projects indicated that the pandemic offered opportunities for innovative online engagement, resulting in potentially wider participation.

> *'Covid-19 introduced significant unanticipated challenges. The requirement for community members and academics alike to home-school or care for relatives meant that engagement levels (even for remote events) were much lower than expected, with a narrower cohort of community groups represented at meetings.'*

'Covid-19 is the main challenge. The aim of the project is to build community participation and to encourage connections and activities in nature, and to train and engage people in citizen sciences methods to monitor water quality, and this has been hampered by Covid restrictions.'

'The Covid-19 pandemic has "fast-tracked" the adoption of digital tools to engage and empower citizens, in some cases out-performing traditional methods. This required relatively small adjustments to the project and is generally seen as an opportunity to potentially broaden participation in co-production of knowledge and co-design.'

Other challenges: Other challenges include recruitment of co-production partners, securing funding for co-production research and poor historic engagement with partners.

'One of the main setbacks early on has been contacting and receiving a response from some key stakeholders. We were very easily able to have face-to-face conversations with those working in industry, but getting the same level of enthusiasm and response from policy-makers has been more challenging.'

'Research funding mechanisms (and university systems) make paying [non-academic partners] to participate in such activities hard to administer, often taking longer than the co-design events themselves and again placing extra demands on the initiatives.'

'Certain stakeholders are wary of getting involved as they feel that they have given time, resources and expertise to past projects that have not translated into tangible benefits for them. Personal trust, open communication and evidence that all outputs will be freely available have helped with this.'

3.4 Recommendations for improving the quality of research co-production: Irish case studies and RIA symposium

Participants in the RIA case study survey, and in the 'Better together' workshop, were asked to suggest recommendations for how the practice of co-production could be enhanced. The main themes in the responses are outlined below.

Agree goals, roles and processes: Non-academic stakeholders may work in radically different ways to those employing traditional academic approaches. Many case studies highlighted that involving non-academic partners from the outset in the development of processes and approaches sets the right tone in terms of sharing of power, and can be valuable when/if disagreements occur. Workshop participants suggested that it is vital to identify everybody's goals at the outset, and to 'work out which ones can and cannot be met'. Agreement on these goals should be documented. 'Compromise with flexibility on the goals' may be needed, and

'every party should be allowed the right to withdraw if the project isn't able to meet their goals'. All partners should be clear on their roles and what is expected of them, and should benefit from involvement in the project.

Case studies emphasised that co-production 'must be adopted consciously', requiring a 'dynamic approach' and 'learning-by-doing', and that academic partners need to regularly 'check in' with non-academic partners to ensure that processes are working and that goals remain aligned. Academic partners need to give consideration to the 'ethical practices' they bring to the co-production process.

> *'Develop egalitarian, respectful and democratic systems of decision-making in order to ensure no one perspective becomes dominant.'*

> *'Have clearly defined goals and outcomes and find win-win activities that do not require too much compromise.'*

> *'To work collaboratively, particularly with non-academic actors, one must be willing to reflexively reflect on and interrogate the assumptions they bring to the co-production space so as not to impose harm on those with whom you work, particularly if you are in the position of power.'*

Manage relationships and maintain trust: As co-production presents unique challenges in terms of differences of approaches, goals and imbalances of resources and power, managing relationships can be critical. Many of the case studies emphasised the importance of ensuring that partnerships are founded on trust, mutual respect, openness to understanding new and different perspectives, and the benefits of academics being humble, enthusiastic and good listeners.

> *'Co-production is complex and requires time, patience and sensitivity to all partners involved, but also to the context within which we are working. There is a need to actively manage the relationship between partners.'*

> *'Projects like these are a trust-building exercise … and this trust is likely to be tested as this project matures and some collaborators may not wish to compromise to the necessary degree.'*

> *'My recommendation to other researchers would be to enter with an open mind. Also, be willing to give and receive. Learning from others is an important part of the approach.'*

RIA workshop participants emphasised that honesty, transparency and openness need to be established through meaningful engagement at the outset, and participants need to 'value different perspectives to their own' and 'be attentive power and privilege'. It was recognised that differences may sometimes need to be 'held and managed', and that not having consensus may be useful.

Engage early to co-design and build a shared understanding: The recruitment of non-academic partners and their early involvement in the project was emphasised within the case studies. This early engagement ensures that all partners have a sense of ownership of the project, and have agency in setting the direction of the objectives and work programme.

> *'I think it's important for stakeholders to contribute to the project design and the writing of the proposal. This means that the question posed is meaningful and relevant.'*

> *'The main lesson learned from this process is that it is of the upmost importance that you talk to stakeholders, end users and beneficiaries at the earliest stages of the project.'*

> *'Early contact with the community and stakeholders, to canvass their views on the project aims and to listen to their concerns, is a crucial first step in any engagement process. This helps to ensure that the research project is perceived as fair and part of trust-building.'*

RIA workshop participants indicated that building a shared understanding of interests and the problem at the outset is crucial. The research team should create time for an 'exploration piece' at the project inception stage to understand the 'key interests of researchers/partners' and 'the value proposition for each stakeholder group', along with establishing a 'shared understanding of problem, objectives and metrics for success'. There is a need for 'clarity about scope of project from the start', and academics should be 'up front and specific about what is involved, when, and by whom'. It may be helpful to write a 'how to work and what we want from the project document'.

Communicate and share knowledge regularly: Many case studies emphasised the importance of 'establishing a space for communication and exchange of ideas', and that 'regular communication is needed to keep everyone up-to-date and identify collaboration opportunities'.

> *'Regular, constant and honest communication where problems are immediately identified and solutions implemented. It was vital that a high degree of trust existed to enable this level of communication.'*

> *'The main lesson learned was about the importance of continuous engagement and communication with the various non-academic partners to guarantee the alignment in expectations and priorities.'*

RIA workshop participants indicated that high-quality communication 'can be just as vital as the research being conducted', and that listening is more important than talking. Academics should 'have humility', 'talk the language of their stakeholders' and 'go at the speed of the slowest stakeholder'.

Consider project management and facilitation: Co-production can be a daunting prospect for academics who are new to the process, have not developed the required skillsets or have a lack of time to manage the additional demands of a project involving non-academic partners. A number of case studies highlighted the value of a skilled project manager in a co-production project; such a role can be particularly helpful in developing relationships and trust within a community setting. Case studies also highlighted the importance of expert facilitation in enabling open and candid discussions, particularly in groups or areas where there is likely to be disagreement that harms the project.

> *'Coordinating the project is a full-time job; a project manager role is key either from within the research team or outside.'*

> *'Some people like to talk more than others. Having someone who can moderate the discussions from a neutral standpoint has been helpful for us in ensuring all voices are heard and taken into account.'*

> *'Projects need to identify a key individual who will be the bridge/conduit between the various partners, as relationship management is a key element of success in co-production.'*

RIA workshop participants also agree that a complex co-production project can benefit strongly from 'skilled project managers who can manage the team and the skills', and 'it may be worth having one person whose job or part of their job is relationship management'.

Provide adequate resources and time: Both the survey and the workshop suggested that co-production project participants should carefully assess the resources available to different stakeholder groups ('don't assume'), and to recognise stakeholder constraints, capacity, timeliness and commitments, and that 'people can't always be as flexible as they want to be'. Non-academic partners such as local authorities 'need to know specifics to see if they have resources to participate, e.g. requirements, how many meetings, where will they take place?'. The project team should 'be mindful of seasonal deadlines for the different participants'.

> *'For a co-production approach to be successful, consideration should be given to the different timing and funding restrictions of the academic and non-academic project partners. While a delay may be manageable for the non-academic partner, the academic partner may be restricted to a fixed-duration contract.'*

SECTION 4

Building capacity for knowledge co-production for sustainability

The case studies in this paper illustrate that there are a substantial number of academics and non-academics engaging in the co-production of research in Ireland. A considerable body of experience and expertise has been accumulated to support and enhance capacity for the co-production of research. To gather together this knowledge, academics and non-academics who submitted case study questionnaires, and those who attended the RIA 'Better together' workshop, were asked to reflect on what might be critical levers for advancing co-production approaches within the research ecosystem, how can we build the capacity for collaboration that is needed to support the crafting of usable knowledge, and what kind of incentives and policies are required to further promote co-production work in Ireland. There was considerable correlation between the responses from the case studies and the workshop as outlined below:

Increased flexibility in funding allocation: A large quantity of suggestions for how research co-production could be better supported focus on research funding and the need to experiment with innovative funding mechanisms to encourage and support academic and non-academic partners. The suggestions from the case studies and workshop include:

- Co-production to be stipulated as an essential element of the research proposal. For example, the Dutch Diamond Model, which involves co-creation between government, industry, society and knowledge institutions, was identified as a model of good practice.
- Simpler and flexible mechanisms for reimbursing, paying or 'agile hiring' of non-academic stakeholders.
- Allowing more scope for a change of direction within projects involving co-produced research, e.g. enabling research to evolve with the project or 'adaptive project programming'.
- Funding frameworks that allow for idea co-creation between academic and non-academic communities.

'Policy-academic co-production requires different individuals, different funding arrangements, different timescales and different metrics for success when compared to traditional research. The challenge remains as to how to scale up the current project to further build capacity for planning and implementing the transformations towards a more sustainable economy and society which Ireland urgently needs.'

From: Co-production for Sustainability, enabled by an Open, Extended, Policy–Academia Secondment Arrangement (Case Study 12)

- A more joined-up approach across the funders to address societal challenges, including bringing research funders and community/rural development funders together to experiment with jointly funded co-production projects.
- Enhanced scoring for end users being part of a consortium as part of proposal evaluation.
- Researcher funders to allow for the 'messiness' of projects co-produced with communities, particularly in relation to deliverables.
- Funding for a facilitator or a 'bridging person' to make connections between academics and citizens.
- More funding initiatives for research co-production with NGOs.

> *'Specifying on funding applications that collaboration with non-academic partners is a criterion for successful award would promote such collaborations.'*

> *'More flexible funding structures; allowing research to evolve with the project, covering costs for non-academic stakeholders, adequate funding for engagement activities covering both the coordination of the research and also more formal processes like workshops or surveys.'*

> *'Flexibility within institutional structures and understanding of the role of non-academic partners by funding agencies is really important. Our different partners all had to be set up and funding transfers made in different ways.'*

> *'I think non-academic partners are doing beautiful work in my discipline of natural sciences/marine ecology but there is not a lot of funding to aid them. More incentives for their volunteerism would foster the work and the relationship with academia in general.'*

Better recognition and broader metrics: The case studies identified enhanced recognition and broader metrics as key to giving academics and non-academics greater confidence to engage in research co-production. Universities and funding agencies need metrics that recognise deliverables that have value to non-academic stakeholders. These metrics would explicitly acknowledge the additional resources and time required for co-produced research, and place value on non-academic knowledge and 'grey literature' held outside academia. Within HEIs, this needs to include recognition of co-produced research in promotion and tenure. It would be beneficial to have more exemplars of research projects that resulted in societal change in the past, and of the resultant benefits for stakeholders.

> *'New metrics to complement traditional metrics (journal papers). Transdisciplinary research requires greater support and valuing within academia.'*

> *'Standard sets of deliverables by funding agencies can often be alien to non-academic partners, and the innovative deliverables that arise from co-production projects need to be appropriately valued by both funders and institutions in terms of their potential for greater impact.'*

'Provide a mechanism to value and support the development of communities of practice for all stakeholders, including social partners.'

'There is no value placed on local knowledge within formal research structures or funding programmes. In general, though, I think that my immediate research environment is very supportive of this approach.'

'We need better protocols to acknowledge and valorise the work carried out by research participants in the co-creation of knowledge. This means perhaps finding new ways of compensating people for their work, supporting actionable strategies or contributing to existing grassroots-led initiatives. It also means allowing for broader-spectrum criteria for evaluating research outputs other than metrics associated with publications in academic journals.'

The development of a wider evidence base for the impact of knowledge co-production was a key focus question within the 'Better together' workshop (see Workshop Spotlight 2).

Enhanced networking and opportunities for identifying stakeholder issues: Although finding non-academic partners was not identified as a significant challenge for the co-production of research (see Section 3.3), a common suggestion for supporting co-production within the case studies and workshop was improved mechanisms for networking and creating transdisciplinary spaces and communities of practice to enable non-academics to meet with academics, and brainstorm the framing of problems and ideas for research, e.g. match-making events, industry open days or databases of expertise.

A number of case studies suggested a forum where research questions of importance to non-academic partners are identified as a potential means to address issues of concern and establish relationships. Policymaker-academic workshops may also be useful to identify key policy issues that would serve as 'pathfinders' to build relations between policy-makers and the research community, e.g. workshop participants highlighted that 'it would be useful to have a structured line of sight on policy priorities on a regular basis'. Environmental Justice Network Ireland was identified as an exemplar of a successful NGO-academic network; the 'Better together' conference was highlighted as a good example of an event that is 'really recognising what is being done'.

'A dedicated network to help people to identify potential project partners for funding applications both on the academic and non-academic sides. Enhanced formal connections between educational institutions, community groups and the staff of public bodies.'

'Foster, maintain and improve connections and understanding of needs between non-academic and academic partners through a variety of mechanisms, e.g. seminars such as "meet the researchers", "meet the applied research commissioners" and short documents outlining key factors that may constrain one or other of the parties.'

'A reliance on personal (and fortuitous) contacts between the community and academia may lead to poor representation of communities in projects or fundamentally hinder project establishment. As such, a mechanism for incubating these connections is required, perhaps at the local authority level, or through "Business in the Community" or "Social Enterprise Ireland", where prominent research questions in the community are identified and matched to existing knowledge and capacity in the academic and NGO sector. The brokerage tool "Ecobroker", used to match ecological expertise with community research requirements, could be used as a model for this kind of marketplace facility.'

'Finding an existing umbrella group within the community was key to the initial success of this research. We would recommend that future projects identify similar groups in the target area, who maintain connectivity and/or representation within the community and therefore can appropriately represent a cross-section of the community in early design and strategy phases.'

Training and toolkits for co-production practice: The co-production of research requires additional skillsets to deep academic disciplinary expertise. Even though many academics and researchers in the natural sciences and engineering work with communities, they may have no formal training in social science methodologies and ethical stakeholder engagement. It was also suggested that non-academic partners would benefit from training in the appropriate research tools and techniques. Another suggestion was that professional representative bodies include co-production in Continuing Professional Development.

'More training opportunities, workshops and resources/toolkits (in engaged research, co-creation/co-production processes, stakeholder engagement and collaboration.'

'Drawing on previous experience of collaborative work, I feel the most important supports for co-production in research is to build praxis groupwork modules into further and higher education centred on emancipatory democratic co-operative thinking, not only to support those engaged in co-production but to also lay down foundations for collaboration as a normative research practice going forward.'

'Basic research skills training for staff in non-academic bodies would empower and enable them to meaningfully and confidently establish and collaborate in research relationships. A formalised mentoring approach from those who have already successfully completed projects could support new initiatives and provide practical guidance to organisations new to research.'

Enhancing capacity in non-academic partners: A number of suggestions were made for supporting not only co-produced research for the researchers to be based outside of academic institutions, but also opportunities for non-academic partners to be seconded into university. It was suggested that research projects should include 'absorptive capacity'

work packages when working with government departments, and to have more secondments between industry/government and academia.

> *'The policy system needs to build absorptive capacity – allow the civil servants time to engage with researchers and better understand the implications of research findings.'*

> *'Secondments (e.g. three months full-time, or one day per week over a year) in both (researchers to government departments and civil servants to universities) directions are very useful from my experience.'*

Enhancing capacity in non-academic partners for knowledge co-production was a key focus question within the 'Better together' workshop (see Workshop Spotlight 3).

WORKSHOP SPOTLIGHT 2:

Strengthening the evidence base for the impact of co-production

A key barrier to perceptions around the value of knowledge co-production is a lack of clarity on the hallmarks of good-quality co-production and transdisciplinary research and how the knowledge produced will be used in decision-making. To consider how best to respond to this challenge, break-out groups in the 'Better together' workshop were asked the question, How do we strengthen our evidence base on the impact of co-production? The main responses are outlined below.

More case studies: A very strong response from the workshop participants was the need to gather, publish and promote more 'Irish-specific research case studies' on research co-production. The case studies should highlight demonstrable impact. Compiling 'warts-and-all lessons learnt' and 'information on what has not worked as well as what worked' would be of benefit. It was suggested that the case studies might be retained in a 'central virtual repository' to provide an evidence base for the benefits of knowledge co-production.

Improved metrics: The development of a 'broader set of bespoke metrics' that 'capture diverse understandings of impact and engagement' would support a stronger evidence base on the impact and benefits of co-produced research. It was recognised in a number of the break-out groups that what 'counts as evidence of impact and success' can be unclear, and that when working with different groups this can be highly contested. Greater value could be placed on impacts that are difficult to quantify, e.g. building societal capacities. Evidence of impact within non-academic partner organisations should be included as an indicator of project success; as well as quantitative metrics, this should encompass qualitative measures such as testimonials, narratives and performance stories. Metrics for success and impact, and how these might be measured, should be discussed and agreed as part of the development of the research proposal. The metrics should highlight the specific outcomes 'that could not have been achieved with "Ivory Tower" research'.

Post-project evaluation: More emphasis needs to be placed on ex-post evaluation within co-produced research projects. This could be done by sending out 'a short questionnaire to gather the key insights to assess the impact' and asking communities 'has the project helped them in a meaningful way?'. Ex-post analysis may be particularly valuable within projects relating to policy, although a longitudinal approach may need to be taken as 'ongoing monitoring post project is often difficult'.

Co-authored publications: The publication of 'co-authored papers with non-academic partners' helps to demonstrate transdisciplinary research

WORKSHOP SPOTLIGHT 2 contd.:

Increasing capacity within non-academic partners for co-production

in practice. In particular, published papers and briefs may give 'greater visibility on key issues in the policy-making system'. The papers should be published in publicly available journals and magazines, and be readily available to interested non-academic practitioners. Project teams should 'use the media to publicise positive results/impacts from co-production projects'.

Celebrating outcomes:
Highlighting and celebrating the outcomes of a project (sometimes occurring long after the co-produced research is complete) is important. The 'Better together' conference was highlighted as an example of an event that can 'provide demonstrations of co-production in practice across a variety of areas and provide frameworks to replicate'.

WORKSHOP SPOTLIGHT 3:

Increasing capacity within non-academic partners for co-production

A lack of capacity within non-academic stakeholder groups for sustained engagement with research projects was identified as a key barrier to co-production within the case study surveys. To consider how best to respond to this challenge, break-out groups in the 'Better together' workshop were asked the question, 'How can we increase capacity within non-academic partners for co-production?' The main responses are outlined below:

Funding non-academic partners: Specific funding should be set aside for non-academic partners to allow them to become more involved in research projects, recognising that co-production requires significant additional resources (time and personnel). The funding should cover 'real costs' and not be tokenistic. Many non-academic stakeholders are small organisations with limited administration personnel; flexibility in relation to funding by making it 'easier for the partner to claim funding' and 'simplify how they report can help'; community coordinators may need to be paid up front, as they potentially do not have a financial base to draw on.

Focusing on non-academic partner needs and interests: The research should address issues that non-academic stakeholders 'have a real belief in and is relevant to them'. Non-academic stakeholders are frequently approached with a fully developed research proposal but are not asked what is important to them. Ample opportunity should be given to non-academic stakeholders 'to voice their needs and wants'. Academics should commit to building real partnerships and 'meet people where they are, not just in language but also to broadening the scope of the work plan beyond a single issue or topic'. Outputs (reports, toolkits, etc.) should be usable for the stakeholders in their contexts. In public sector organisations, clarity around 'the concept and benefits of co-production projects' and 'getting buy-in at senior corporate level for concept of co-production, so that projects have backing' is key to success.

Providing proposal writing support and training: Non-academic stakeholders often do not have the time or skills to write competitive proposals. Workshop participants identified that there is a need for 'proposal-writing support', particularly within community groups, including 'feedback on funding applications and sight of past successful applications'. Consideration should be given to training/best practice for engagement in research projects to non-academic stakeholders to enable them to successfully participate in projects.

Effective communication and sharing of information: The project team should ensure that research learnings are shared with the wider relevant non-academic community to 'showcase the quality, value and added benefits of high-quality research to partners'. Engagements should be in the appropriate format, with 'simple messages which promote real engagement'.

WORKSHOP SPOTLIGHT 3 contd.:

Increasing capacity within non-academic partners for co-production

Consideration for the time limitations of non-academic stakeholders: In engagement with non-academic stakeholders, academics must be cognisant that 'not everyone has the luxury of time'. Researchers and research agencies need to be aware that 'organisations need to build these projects into their plans' and 'can't be expected to start within a month or so of an announcement of a successful proposal'.

Build absorptive capacity within stakeholder groups: To address critical bandwidth issues within stakeholder groups, some projects explicitly included work packages focused on 'increasing absorptive capacity' within the group. The projects 'devote resources to spending time one-on-one and in groups' with stakeholders to talk through questions they have, what insights the research can provide and what aspects it does not answer.

Create new networking platforms: Consideration should be given to creating networking platforms, databases and communities of practice for to enable non-academics to meet with academics and brainstorm the framing of problems and ideas for research e.g. such as Environmental Justice Network Ireland.

SECTION 5

Conclusion

The case studies in this white paper, along with the high attendance at the RIA 'Better together' symposium and workshop, demonstrates that there is a diverse community of academics and researchers in Ireland who are deeply committed to co-producing knowledge with non-academic stakeholders. There is a significant appetite and interest to deepen and enhance co-production across the Irish research ecosystem.

However, much of this excellent work has been done in the face of significant barriers, and has only been achieved through the commitment, passion and resilience of academic and non-academic participants.

There is a need to move beyond these individual exemplars of good practice to accelerate, scale up and build capacity for knowledge co-production. The challenge remains to create a research ecosystem that encourages, rewards and recognises knowledge co-production leading to the development of usable and actionable knowledge. This white paper maps out a way forward.

Ireland's relatively small size and population, our traditionally close connections between academia-policy-industry, and our strong civic base within towns and villages gives us a unique advantage in creating knowledge co-production communities. The need for a strong commitment to co-production approaches for sustainability research across the science and innovation system has never been greater; an investment now will help us to produce more impactful and usable knowledge to enable the necessary transition to a zero-carbon and resource-efficient society in the coming decades.

APPENDIX 1

Sustainability and environmental knowledge co-production case study summaries

Case studies listed alphabetically by project title

Case Study 1	
Project title	A vegetation management strategy for the Wicklow uplands
Co-production partnership	Research Consultancy and State Agency/Farmers
Academic	Dr Mary Tubridy Private research consultancy, National Parks & Wildlife Service (NPWS), Teagasc
Non-academic	Wicklow Uplands Council
Funding	Leader Company Wicklow

Overview of co-production: This research aims to develop a strategy to bring about improved management of habitats in land designated for biodiversity. The research carried out was on upland ecology. There were regular meetings held indoors and outdoors on farmers' lands to discuss priorities for management and a management programme was elaborated. The project was networked with similar initiatives in Ireland and the UK. The research process brought together state agencies and farmers to discuss Wicklow upland biodiversity and management for the first time. The resultant report provided a detailed account of the process and led soon after to the development of a European Innovation Partnership (EIP) project in the Wicklow Uplands (SUAS).

A co-production approach was adopted as there was a history of difficult relations between [Anon] and local farmers, which was limiting potential for sustainable farming practices. The project succeeded in creating a safe place for both and provided a common aim. NPWS needed to know more about land management and farmers needed to know more about biodiversity.

There was strong non-academic involvement in the project. A local community organisation developed the original brief and selected local farmers to work on the project and provided a chairperson. The researchers provided regular updates on progress for discussion. There was frequent engagement between academic and non-academic actors through meetings, reporting and informal contacts with the chairperson of the project working group who was a farmer.

The co-production process was successful in (i) being responsible for improving relations between NPWS and farmers, (ii) leading to an EIP in the Wicklow Uplands and (iii) allowing membership by stakeholders of a national network of EIP's all focused on sustainable farming in uplands.

Case Study 2	
Project title	Assessing knowledge and attitudes towards food sustainability amongst people who visit Overends Kitchen, Airfield Estate, Dublin
Co-production partnership	Academia (UCD) and NGO (Airfield Estate)
Academic	Assoc. Professor Clare Corish and Myriam Alhilou (UCD)
Non-academic	Dr Kirstie McAdoo (Airfield Estate)
Funding	UCD Master of Science in Clinical Nutrition and Dietetics

Overview of co-production: This study aimed to explore the knowledge and attitudes towards food sustainability amongst visitors to an Irish restaurant which prepares foods in a sustainable manner. The research provides an understanding of Irish consumers' knowledge and attitudes towards food sustainability. A cross-sectional study was conducted on 426 visitors with information on demographics, food choice motives, food preferences, nutritional knowledge, food literacy and attitudes towards food sustainability being obtained. A co-production approach with Airfield Estate was adopted.

Airfield Estate is an urban farm and educational charity located in Dublin; its aim is to inspire and enable people to make better food choices. Airfield's focus on food sustainability and its consumer community aligned with UCD's MSc in Clinical Nutrition and Dietetics programme and facilitated the conduct of this research as well as its dissemination and exploitation to enhance public health.

Airfield Estate was a full partner from initiation of this project, including development of the study hypothesis and protocol, ethical approval application, data collection, analysis, synthesis and dissemination, providing student guidance on the project throughout. Airfield and UCD staff and students collaborated meaningfully to ensure effective study implementation and timely and impactful dissemination of the study findings.

The benefit of the co-production approach in this project is that Airfield Estate offers the unique opportunity for academic researchers to access and work with consumers as well as the Irish food production system so that a whole system approach to food sustainability can be explored. The Estate also encourages research that directly explores and enhances our understanding of consumer behaviour so that this can facilitate the instigation of practical and consumer-centred interventions. The Estate offers a testing ground for ideas and hypotheses on which food sustainability interventions can be developed for national and/or international implementation.

Case Study 3	
Project title	Cereal renaissance in rural Europe (CERERE)
Co-production partnership	Academic and Industry/Policymakers/NGOs
Academic	Dr Áine Macken Walsh (Teagasc), Dr John Hyland (Teagasc)
Non-academic	Agronomists, farmers, social scientists, policymakers, heritage NGO representatives, historians, chefs, food processors and artists (Deirdre O'Mahony, Sadhbh Gaston)
Funding	EU Horizon H2020

Overview of co-production: The CERERE project aims to share practical knowledge across Europe of how to revive and commercialise low input heritage cereals. Teagasc was tasked with brokering innovation between diverse actors in how the renaissance of Ireland's heritage cereals was imagined and practised. In this context, artistic praxis was envisioned as a powerful tool in opening up conversations about CERERE to society. Public art was used to draw the gaze of those uninvolved in cereals and stimulate reactions and actions for a renaissance of heritage grains. A co-production approach was adopted using public art as a venue and mediation tool, creating installations and discourses that elicited, embodied, gave expression to and represented the cultural, social, environmental and economic values of the myriad actors involved.

CERERE involved a diverse set of actors who addressed specific issues pertaining to heritage cereals. Artists were tasked with developing engaging art pieces to entice stakeholders into dialogue as well as foster wider engagement with the general public. The project artist devised 'Mind Meitheal' events to engage both academics and non-academics using the cultural resonance of the Irish word 'Meitheal' as a generative catalyst for locally based think-tanks to animate active participation within diverse groups concerning heritage grains. Images, public events and videos were examples of the variety of artistic media used throughout the project; the artwork commissioned was exhibited, and catalysed participation in in four different venues.

Artists and art curators across Europe are implementing projects that engage and empower participants using socially engaged, participatory and group-based methods. The art forms commissioned for CERERE were powerful in fostering engagement, creating new relationships and igniting creativity around the topic of low input heritage cereals.

Case Study 4	
Project title	Citizen science investigations – river environmental stewardship (CSI-Rivers)
Co-production partnership	Academic and Local Authorities Water Programme/Communities
Academic	Donna Weiner, Dr Catherine Dalton and Dr Julian Bloomer (Mary Immaculate College/University of Limerick (UL))
Non-academic	Local Authority Waters Programme (LAWPRO), the Maigue Rivers Trust (MRT), Public
Funding	Environmental Protection Agency (EPA) and Mary Immaculate College

Overview of co-production: The CSI-Rivers project aims to explore and understand the different attitudes, values and perspectives that members of the public associate with and feel towards nature and their local river catchments. The study also aims to measure the potential appetite for participation in citizen science (CS) initiatives to monitor the water quality and biodiversity in their local river and riparian zone. The main focus for this study is on the catchment of the Maigue River in County Limerick. The data collected by the citizen scientist volunteers will inform water management decision-making and policy, and the CS initiative design will be tailored and co-designed to attract the largest number of volunteer participants. Co-production is integral to the project. The CS initiative is being co-produced to maximise participation of the local residents and communities within the Maigue River catchment in collecting scientific data related to local river water quality. Co-production is necessary to maximise participant involvement by seeking the opinion and perspectives of multiple community stakeholders as to what initiative would attract the largest number of people.

There is frequent and regular engagement between academic and non-academic actors. There is attendance at formal monthly directors' meetings of the Maigue Rivers Trust and attendance at events organised by the Maigue Rivers Trust. All events are planned to include elements related to the study, for example, face to face surveys of attendees or CS training.

The contacts in the Maigue River catchment facilitated by the Maigue Rivers Trust and their partners have been very useful to project development and delivery, and it is extremely beneficial to have the support of LAWPRO for feedback and sharing of knowledge.

Case Study 5	
Project title	Climate heritage and environment of reefs, islands and headlands (CHERISH)
Co-production partnership	Academia and State Agencies
Academic	Aberystwyth University, Department of Geography and Earth Science (Wales)
Non-academic	Geological Survey Ireland; Royal Commission on the Ancient and Historical Monuments of Wales (RCAHMW); Discovery Programme (Ireland): Centre for Archaeology and Innovation
Funding	Interreg Ireland Wales 2014–2020 European Territorial Cooperation programme

Overview of co-production: The CHERISH project supports specialist organisations in Ireland and Wales to employ cutting-edge technologies to analyse coastal and island archaeology and heritage sites most affected by climate change, coastal erosion, storminess and rising sea levels. The four main aims of CHERISH are to (i) target data and knowledge gaps to raise awareness of heritage in remote coastal locations, (ii) discover, assess, map and monitor heritage on land and beneath the sea and establish new baseline data and recording standards, (iii) link land and sea and (iv) reconstruct past environments and weather history. A co-production approach was adopted as the different organisations have different expertise that strengthens the project.

Non-academic partners are critically involved in project-design, setting goals and conducting the research. Three of the four organisations are non-academic. The RCAHMW is the lead partner and involved Aberystwyth University as an academic partner. RCAHMW had links with the Discovery Programme to investigate the archaeology of Ireland. The Geological Survey Ireland was involved for its expertise in marine surveying. All organisations were involved in setting and compiling their goals prior to funding being allocated. There is targeted and joint fieldwork arranged between academic and non-academic partners.

The co-production approach has been beneficial as the non-academic partners have experience in long-term data gathering (e.g. INFOMAR marine mapping programme). The large skill set acquired over these long-term projects assists with the targeted aims of the project, combined with the research expertise of academic partners.

Case Study 6	
Project title	Climate Ireland learning: raising awareness of climate change and action amongst Ireland's local authorities through online learning
Co-production partnership	Academic and Local Authority
Academic	Barry O'Dwyer, James Fitton, Dan Casey and Jeremy Gault (MaREI, ERI, University College Cork (UCC))
Non-academic	Climate Action Regional Offices and Local Authorities
Funding	EPA, Department of Environment, Climate and Communications

Overview of co-production: This project aims to raise awareness of climate change and action amongst Ireland's local authorities through the development of a bespoke online training course. The course was developed and delivered on the Climate Ireland Learning Platform. Climate action at the local scale is of increasing relevance to local authorities as local government is increasingly delegated responsibility to plan and implement climate action measures. This responsibility is often difficult to implement, however, given that climate change information and science is not easily translatable into everyday practical decision-making. Adopting a co-creation approach (co-design, co-production and co-evaluation) and to ensure the course met the specific needs of Ireland's local authorities, the course was developed in close collaboration with Ireland's Climate Action Regional Offices (CAROs). To date, 3089 learners have completed the course.

The CAROs co-ordinate and support climate action across the local government sector and enable engagement across local and national government. The development team worked in collaboration with the CAROs to understand existing awareness of and capacity for climate action amongst local authority staff and the parameters of climate action relevant to their decision-making. The CAROs were involved in all stages of project design (co-design), setting goals and carrying out the research (co-production) and evaluation of outcomes (co-evaluation). Development involved an iterative approach whereby initial prototypes were developed and tested in consultation with the CAROs and local authority representatives.

The co-production approach has been extremely beneficial in terms of achieving the project goals and outputs. Through this process, the research has successfully incorporated the most up-to-date scientific knowledge and understanding of climate change and action for Ireland with considerations of local scale climate action policy, decision-making contexts and capacity.

Case Study 7	
Project title	Coastal communities adapting together (CCAT) – Participatory mapping and geodesign workshops
Co-production partnership	Academia and Local Authorities/Community Groups/Communities
Academic	Dr Karen Foley[1], Dr Philip Crowe[1], Dr Brenda McNally[1], Dr Chiara Cocco[1], Saul Crowley[1], Dr Fernanda Terra Stori[2], Dr Emma McKinley[3], Dr Rhoda Ballinger[3] ([1]University College Dublin, [2]University College Cork, [3]Cardiff University)
Non-academic	Fingal County Council (FCC), Pembroke Coastal Forum (PCF), Port of Milford Haven (PMH)
Funding	European Regional Development Fund, Ireland–Wales Programme

Overview of co-production: The CCAT project aims to increase knowledge of climate change adaptation amongst businesses and communities in the Irish Sea region. CCAT is developing and exploring the use of digital tools and interactive resources to facilitate citizen participation in observation and learning about coastal change and the need to adapt, as well as the co-creation of solutions to address climate impacts. Examples include participatory mapping and geodesign workshops.

A co-production approach was adopted as adaptations to climate change are highly technical and morally complex problems. There is a need to involve communities in shaping future developments in response to climate change. Giving citizens a greater say in future planning about their local environment can lead to better decision-making about adaptations to climate impacts.

Non-academic partners were involved in setting the goals and carrying out the research in participatory mapping and geodesign workshops. Communities were selected by the non-academic partners. Online participatory mapping exercises in Pembrokeshire (Wales) enabled citizens to upload local information about observed changes, impacts or opportunities for action, and to identify the most appropriate spaces for planting trees as local action on climate change. A geodesign workshop with FCC involved community groups in Fingal (Ireland) and is part of the public consultation for the new County Development Plan. FCC worked closely with UCD researchers to identify the territorial systems (e.g. open spaces, active transport) to be used in the workshop and to link those systems to objectives identified in the Development Plan.

The benefits of the co-production approach were numerous. In addition to increasing knowledge of adaptations to climate change, the approach builds adaptive capacity in response to ongoing climate impacts such as coastal erosion. The participatory mapping tool invites citizens to engage with local climate impacts through volunteered geographic information, and the geodesign workshops provide communities with an opportunity to collaborate in future planning.

Case Study 8	
Project title	CoDesRes: Co-designing for rural resilience through P2P networks and STEAM place-based learning interventions
Co-production partnership	Academic, Post-Primary and Communities
Academic	Dr Anita McKeown, UCD
Non-academic	23 community partners
Funding	EPA

Overview of co-production: CoDesRes brings together an interdisciplinary team; artists, scholars, engineers and marine biologists, combining their expertise with local insights to explore the evolution and transfer of a unique culture-led co-design methodology, the permaCultural (pCr) resilience praxis. CoDesRes explores the potential of pCr for building a multi-stakeholder approach for a 'beyond-compliance' engagement with the Sustainable Development Goals. The permaCultural resilience framework embeds social and environmental justice in its processes. As a bio-psycho-social intervention it is a systemic approach to creative placemaking. A co-production approach was adopted as local knowledge was critical to developing the resources that were the outcome of the project, along with developing resilience and making an existing process more accessible, i.e. it was important to understand potential user experience.

The project had multiple projects within it and the engagement differed depending on the project/skills required; in some instances, an idea was presented to community groups and forums and the partners helped shape its delivery, and in other instances the partners invited the team to be part of the process. The process also included students (15–16 years) and teachers to develop place-based STEAM education resources that embed sustainable co-design. Although UCD was the host institution the project base was in south Kerry with the research assistants and the Lead PI permanently based in Kerry – total contact time was 183 events and activities over 22 months.

The co-production approach adopted by the project has been beneficial as traditional methods would not have achieved the same outcomes and being embedded meant an ability to be opportunistic and capitalise on activities that would have been missed or over-looked by traditional research.

Case Study 9	
Project title	Collaborative research for co-production of climate mitigation policy
Co-production partnership	Academia and Government Department
Academic	Professor Brian Ó Gallachóir, Dr Hannah Daly, Dr Paul Deane, Dr Fionn Rogan and Dr James Glynn (MaREI Centre Energy Policy and Modelling Team, Environmental Research Institute, University College Cork)
Non-academic	Department of Environment, Climate and Communications, Department of Public Expenditure and Reform and Department of Transport
Funding	Science Foundation Ireland (SFI) MaREI Centre for Energy, Climate and Marine and Department of Environment, Climate and Communications

Overview of co-production: The research team developed energy systems modelling tools and then worked with government departments to design and undertake scenario analysis and translate the research results into policy insights. Some examples include: (i) supporting government negotiations with the European Commission on 2030 climate mitigation targets, (ii) working with the Department of Environment, Climate and Communications to provide evidence and insights to inform decisions to increase Ireland's climate policy ambition and (iii) working with the Department of Public Enterprise to inform decisions on valuing greenhouse gas emissions in the public spending code. Co-production has been essential in this project. The researchers have the capacity to do energy systems modelling but need key inputs from policymakers (including on research questions, appropriate data scenario design and communication of results) in order to develop analysis that is useful for policy formation. The policy-makers are charged with designing, developing and implementing policy measures in a fast-moving political landscape, and ready access to analytical research capacity is very beneficial. Co-production ensures the researchers have access to policy priorities and policymakers have access to the best available science to inform their decisions.

The policy system (civil servants and politicians) has been a key target audience for the energy systems modelling research team for over twenty years. This involved many train journeys from Cork to Dublin and knocking on many doors. The persistence paid off and mutual understanding and trust through co-production have deepened since then. The integration of perspectives is formally done via meetings with department officials; however, the informal processes were also very important (meetings over coffee, impromptu meetings at conferences and events) for building mutual trust and respect.

The co-production approach has been hugely beneficial. A world class research capacity in energy systems modelling in Ireland has been established in a way that is highly policy relevant and impactful. By engaging with the policy system and co-producing with policy-makers, it has been possible to leverage this research to improve policy decisions. The feedback received from researchers internationally has been envy at the access to the decision-makers.

Case Study 10	
Project title	Community mapping Galway City
Co-production partnership	Academia and Local Authority/Schools/Community Groups
Academic	Frances Fahy, National University of Ireland Galway (NUIG)
Non-academic	Galway City Council, Westside Ladies Group, Renmore Retirement Group, Galway Mother and Toddler group and local schools
Funding	EPA

Overview of co-production: This research project involved a NUIG researcher working with the city's municipal authority to employ community mapping not just to record and promote the city's social, environmental, economic and cultural assets, but also as a practical tool to work with communities to explore what they value in their city. A co-production approach was used, as working with people is a central tenant of sustainability and the project was seeking to find ways to practically implement the concept of sustainable development on the ground in Galway City. From Galway City Council's perspective, it was hoped that the project would bolster public participation in policymaking and help shape sustainability practices through enhanced governance.

Galway City Council were involved in all stages of the research process, design and implementation; the goals needed to be aligned with their interests. Community groups and schools were involved once the initial design was approved and funded. Twelve mapping workshops were convened including school groups, retired people's groups, mother and toddler groups, ladies' groups and groups of professional workers.

While the physical map is a key project output, it was the processes that created them that had the most impact. Local community groups reflected on aspects of their urban environment and identified those elements of the cityscape that are of particular significance to them. The publicly accessible map promoted a new level of awareness amongst citizens and stimulated civic engagement. The ownership of the project and results was shared by many parties and the project and community maps outlive the original project time frame. A process that was instigated through an action-research project funded by a national-level agency and mediated by a local university has assumed a life of its own, contributing significantly to sustainable development objectives.

Case Study 11	
Project title	Controlled synthesis and production of biodegradable Poly (DL-lactic acid) for high value-added microfluidics lab consumables
Co-production partnership	Academic and Industry
Academic	Dr Nan Zhang, Professor Wenxin Wang, Dr Michael Gilchrist UCD
Non-academic	Industry users
Funding	SFI

Overview of co-production: The project proposes to establish a circular economy model for single-use lab consumables by developing biodegradable lab consumables for industrial composting. Currently there is no solution for sustainable single use lab consumables. To realise the proposed new value chain, a close collaboration between the stakeholders/beneficiaries is necessary and contributes to achieving a win-win result**.** This circular economy model involves material suppliers, manufacturing companies, lab users, waste treatment companies and the regulatory sector.

In the concept phase non-academic partners were contacted to confirm the feasibility of the proposed solution. In later phases, lab-scale experiments along with pilot-scale and/or mass production will be carried out with partners. During the implementation of this project both technical and non-technical questions will be addressed; close engagement with partners is necessary to ensure the practicability of the solution by the end of the project.

The benefits of a co-production approach will be to identify the synthesis of novel biodegradable material (collaboration with experts in synthesis) and the process ability of biodegradable lab consumables (collaboration with a company in advanced manufacturing), which is different from the traditional research approaches.

Case Study 12	
Project title	Co-production for sustainability, enabled by an open, extended, policy–academia secondment arrangement
Co-production partnership	Academia and Government Departments
Academic	Dr Ian Hughes, Dr Clodagh Harris, Professor Brian Ó Gallachóir (UCC); William Hynes (OECD).
Non-academic	Department of Further and Higher Education, Research, Innovation and Science (DFHERIS); Department of Enterprise, Trade and Employment (DETE); Evaluation and Audit Unit, Department of Foreign Affairs; New Approaches to Economic Challenges (NAEC) unit, OECD; International Humanistic Management Network, St Gallen, Switzerland.
Funding	NTR Foundation, SFI MaREI Centre for Energy, Climate and the Marine

Overview of co-production: The project entails a secondee arrangement in which Dr Ian Hughes was seconded, initially from the Department of Enterprise, Trade and Employment (DETE), and now from the Department of Further and Higher Education, Research, Innovation and Science (DFHERIS) to work with the SFI MaREI Centre, Environmental Research Institute at University College Cork. The secondment arrangement was agreed between DETE and MaREI to further the aims of the Civil Service Renewal Plan, to enable the civil service to strengthen capacity and build active networks of key stakeholders in the area of sustainability transitions. A co-production approach was adopted as the increasing complexity of societal challenges, such as climate change, is demanding greater use of innovation in policy-making, greater experimentation and learning during policy implementation, and the formation of deeper networks of actors to co-create sustainability transition pathways.

The project and secondment arrangement was initiated by the secondee Dr Ian Hughes on the basis of his experience of innovation policy. The secondment arrangement enabled the secondee and MaREI to develop an open-ended research agenda. The secondment allowed the secondee to work two days per week with UCC; this involved a combination of physical presence at the Environmental Research Institute at UCC and working virtually from the secondee's home in Dublin. Physical and online meetings, intensive group discussions and debates, iterative co-planning, and open engagement have been central features of the project methodology.

The co-production approach has been very successful. One very concrete example of how system innovation thinking promoted by the secondee and MaREI is having an impact is the fact that the government's National Statement on the Bioeconomy, and the Bioeconomy Implementation Group are explicitly adopting a system innovation approach. This example demonstrates the unique potential of the secondment arrangement between a government department and an academic partner, enabling the secondee to bring together academic and policy networks to broker key policy impacts.

Case Study 13	
Project title	Cross-border co-production of environmental knowledge: a collaboration with civil society
Co-production partnership	Academic and NGO
Academic	Alison Hough BL and Dr Mary Dobbs (Athlone Institute of Technology (AIT), NUI Maynooth)
Non-academic	The Environmental Pillar/NIEL Environmental Pillar (NIEL)
Funding	The Environmental Pillar/NIEL

Overview of co-production: This cross-border collaborative research project focused on how Ireland's shared island environment could be protected post-Brexit via the Good Friday/Belfast Agreement (GF/BA). Building on earlier research by both the NGOs and academics involved in the project that identified environmental governance as endangered by Brexit, this project focused on identifying and evaluating potential mechanisms to address both existing and future environmental governance challenges. A co-production approach was adopted as the NGOs and academics had complementary knowledge, skills and resources. The NGOs involved had hands-on knowledge of the practical problems inherent in cross-border environmental protection and the academics had the ability to frame the practical problems within the existing legal and policy frameworks for them in a way that enabled them to identify how Brexit might impact environmental governance.

Non-academic partners selected the academics involved and participated in the conception, design, framing and carrying out of all stages of the research and report preparation, and co-organising launch events. There was extensive discussion with the NGOs at each stage – from identification of issues and project design, throughout the report production process, to subsequent discussions. Multiple members of the NGOs extensively reviewed draft documents with review comments returned for consideration to academics.

The collaborative co-production approach was essential to this project's success. Without the involvement of the NGO partners this project would not have come about, been designed, funded or executed. The NGOs were best placed to identify the practical threats posed by Brexit to cross-border environmental protection. NGO involvement provided significant, alternative perspectives and enhanced the project's impact through post-project advocacy. Academic involvement assisted them in framing these practical problems in the law and policy context and in identifying legal and policy solutions to these problems, which they could then advocate for.

Case Study 14	
Project title	Cross-sectoral impact assessment of droughts in complex European basins (CROSSDRO)
Co-production partnership	Academia and Local Authorities/Government Departments
Academic	Conor Murphy, Sam Grainger (ICARUS Climate Research Centre, NUI Maynooth) and other EU universities
Non-academic	Local Authorities, Government Departments
Funding	EU/EPA – JPI Climate ERA-NET

Overview of co-production: Focused on the Boyne River catchment, CROSSDRO assesses the potential impacts of prolonged dry weather and water shortages on different aspects of Irish society (e.g. water supply, agriculture, industry, leisure and the environment).

Managing drought risks requires long-term collaboration between diverse groups with different values, interests and forms of knowledge. Science-driven projects can struggle to retain stakeholder engagement and produce actionable knowledge necessary to better manage drought risk. CROSSDRO is therefore committed to collaborative models of knowledge production (co-production) in which all participants recognise the multiple ways of understanding drought risk and strive to co-create knowledge for decision-making and resilience building. Such approaches create more equitable and meaningful interactions and have been shown to increase knowledge use.

The project team is interdisciplinary, bringing together expertise in historical weather series, modelling, remote sensing and qualitative social science methods to better understand drought risk in Ireland.
They are working closely with government actors and water-sensitive sectors in the Boyne catchment to learn about past drought experiences and challenges, identify current information needs and if appropriate, co-produce a scientifically grounded and tailored knowledge base for long-term planning.

The first year of the project focused on mapping and connecting with non-academic partners who might have an interest in multi-level drought planning in Ireland. So far, participation has involved email exchanges, online meetings and interviews with project team members to establish whether there is sufficient capacity and demand for co-production with partner organisations. Deep engagement and potentially co-production activities are due to start in Summer 2021.

Case Study 15	
Project title	Delivering environmental and sustainability agenda in agriculture and food (Food Futures)
Co-production partnership	Academia and Food Processors/Farming Organisations
Academic	Professor Nigel Scollan, Dr Ryan Mcguire, Dr Steven Morrison, Dr Aurelie Aubry (Queen's University Belfast and NI Agri-Food & Biosciences Institute)
Non-academic	Academia and Food Processors, Farming Organisations
Funding	European Innovation Technology, Horizon 2020 Invest Northern Ireland

Overview of co-production: The Food Futures project aims to develop a reporting tool to capture, credit and drive behavioural change in livestock systems in order to enhance the sustainability of agri-food production. Food Futures integrates multiple digital platforms to measure soil health, water quality interventions, carbon sequestration, precision nutrient applications and identification of key habitat areas across farms; it has developed numerous social, environmental and economic (SEE) metrics to develop a narrative of sustainability for project farms. A co-production approach was adopted for the project as environmental and sustainability challenges require a partnership approach to be addressed effectively. Food Futures aims to drive positive behavioural change right across the supply chain; industry-wide co-operation is key to ensure high quality data layers, whilst co-creation of the digital tool is vital to ensure all supply chain stakeholders are confident with its operation.

Non-academic partners were very involved in the co-design and the delivery of the project providing primary data access, commercial insights and inputs. Representative ambassador farmers were selected by the project's commercial partners. Farmers and their commercial partners have helped co-create performance graphics and report assessments tailored to their interests and needs. Quarterly workshops between project researchers and farmers have ensured project outputs are applicable and manageable at the farm level. From the policy side, DAERA have been instrumental in ensuring that the agendas of commercial partners are compatible with future agri-environmental policy at the national and European level.

The co-production approach has been decisive in terms of its commercialisation power, market pull and overall industry implementation. The feasibility of the performance reports and the dashboard were made possible through the continuous feedback from supply chain stakeholders, particularly farmers, food processors, policymakers and quality assurance organisations.

Case Study 16	
Project title	Dingle peninsula 2030
Co-production partnership	Academia and Community Groups/Industry
Academic	Professor Brian Ó Gallachóir, Professor Edmond Byrne, Dr Gerard Mullally, Aoife Deane, Dr Clare Watson, Connor McGookin and Evan Boyle (University College Cork)
Non-academic	Deirdre de Bhailís and Brendan Tuohy (Mol Teic – Dingle Creativity and Innovation Hub), Claire McElligott (ESB Networks), Séamus O'Hara (NEWKD – North East West Kerry Development)
Funding	SFI, ESB Networks, US–Ireland Partnership Programme

Overview of co-production: Dingle Peninsula 2030 is an innovative multi-partner initiative established to support a sustainable future for Corca Dhuibhne (Dingle Peninsula). For the past three years, researchers from sociology, community development and energy engineering have worked in partnership with Ireland's electricity distribution system operator (ESB Networks), local non-profit organisations supporting enterprise (Mol Teic) and community development (NEWKD). The key objectives are to work with the local community, schools, businesses and farmers to explore, support and enable the broader societal changes emanating from the low carbon transition. A co-production approach was adopted as research of this nature cannot be conducted in isolation; it requires a collaborative approach with stakeholders to make decisions on the research design and planning, as well as usefully tapping into existing networks and local knowledge.

A project committee holds regular meetings to discuss progress and to decide how to work together on upcoming engagement activities. Having agreed to form a partnership, a workshop with the Dingle Peninsula 2030 committee outlined shared goals, activity plans and research questions. The researchers work with the committee members to co-produce written material, including reflective learning briefs. The researchers have also served on several steering committees for various Dingle Peninsula 2030 projects such as the development of an energy masterplan for the area, anaerobic digestion feasibility study and energy mentor course.

The co-production approach has not only been beneficial but essential. It ensures that the researchers actively support the partners in their efforts to reach out to the community and also that research outputs contribute to the projects emerging from the initiative, while the partners contribute to the research by providing a grounding and focus, as well as directly feeding into some outputs. This means the project has a far more significant impact than would have been achieved by the organisations working in isolation.

Case Study 17	
Project title	Developing a route to zero waste in the marine sector
Co-production partnership	Academic and Industry
Academic	Dr Graham O'Neill, Professor Paula Bourke (Technological University (TU) Dublin and UCD)
Non-academic	Nadine Bonner, Irish Fish Canners
Funding	SFI Challenge Funding

Overview of co-production: The overarching ambition of the project is to reduce waste in the marine sector; specifically, to transform waste fish blood into a bioplastic. The stakeholder engagement had the aim of understanding the desirability, feasibility and viability of the project concept and the proposed solution. The project had a particular focus on stakeholders from (i) the marine sector and (ii) the users/manufacturers of packaging materials. A co-production approach was adopted as the academic team possessed knowledge of food technology but limited knowledge of the marine sector, particularly its day-to-day operation. Co-production allowed the team to transition from 'outside looking in' to seeing the existing challenges/limitations from a primary processor's perspective. Importantly, the team understood the existence of food waste is not due to the absence of a desire to prevent it, but rather the tools/know-how to prevent it.

The project identified stakeholders along the life cycle of the waste stream (fish blood), who could provide knowledge or perspectives on the proposed approach. A seven-week stakeholder engagement process was carried out. There were weekly meetings to review the outputs from interviews with the wider stakeholder groups; the input of the societal champion was particularly useful in helping to distil specific messages from the interviews and in understanding if the project should pivot in response to findings. The research in the project itself will be co-produced on a primary processing facility thereby directly involving the stakeholders and potential beneficiaries.

Co-production resulted in modifications to the overarching study goal and the approach to be taken. The modification means the study is more likely to develop processes/technology that can assist in reducing waste in the marine sector, as it is now integrated and co-located with a primary processor. The modification would never have been identified using traditional approaches.

Case Study 18	
Project title	Electrofuels in a circular economy (EFACE)
Co-production partnership	Academia and Industry
Academic	Dr David Wall and Professor Jerry Murphy (MaREI Centre, UCC)
Non-academic	Gas Networks Ireland (Donal Kissane) and DePuy Synthes
Funding	SFI Future Innovator Prize

Overview of co-production: The EFACE project explores the use of electrofuels produced using circular economy approaches (such as hydrogen) to be used in areas where electrification is not ideal, e.g. transport and agriculture. In this project the gas (Gas Networks Ireland), electricity (DePuy Synthes) and water (Ervia) sectors have come together with the MaREI Centre to investigate solutions that would offer symbiosis and integration of their services and furthermore allow for the decarbonisation of hard to abate sectors such as heavy transport, industry, agriculture and waste treatment.

The non-academic partners were involved consistently throughout the project. Donal Kissane from GNI was the societal champion for the project who advised from a commercial perspective including for regulatory framework, value chains and suitability of existing gas grid infrastructure. Quarterly meetings with DePuy Synthes to acquire real time granular data from two wind turbines was essential in formulating how an electrofuel system could be developed. Ervia engaged in wider stakeholder discussion held throughout 2020. A number of workshops and mini-symposiums offered a platform to discuss and debate the project and provide some key learnings for the team, e.g. two hydrogen workshops held in 2020 brought together all the key stakeholders (*c.* 130 attendees) to discuss the future of hydrogen in Ireland.

The co-production approach has been beneficial as academic institutes need to work with industry stakeholders so that a tangible development can be made in the project. Stakeholder engagement, feedback and instruction are essential in developing the EFACE concept. This continuous cycle of engagement with critique and feedback from essential stakeholders ensures the progression of the project in a realistic, commercially sound manner.

Case Study 19	
Project title	Environmental justice network Ireland (EJNI)
Co-production partnership	Academia and NGO/Lawyers/Community Activists
Academic	Dr Ciara Brennan, Newcastle University (Director), Dr Peter Doran (Queen's University Belfast QUB)), Alison Hough (AIT), Dr Andrew Jackson (UCD), Dr Michael Brennan (Ulster University (UU)) along with others
Non-academic	Key partners include Friends of the Earth NI, the Gathering, Friends of the Irish Environment, Climate Case Ireland, European Climate Foundation, Community Law Mediation's new Centre for Environmental Justice, SAFEWATER
Funding	Multiple Sources

Overview of co-production: The Environmental Justice Network Ireland (EJNI) is a partnership between academics, lawyers, representatives of community activism and environmental NGOs with the aim of creating a 'community of practice' to identify environmental justice challenges, opportunities and directions for reform across the island of Ireland (www.ejni.net). By creating transdisciplinary, solution-orientated collaborations between researchers and diverse non-academic stakeholders, EJNI is building capacity in research communities to undertake agile, evidence-based research in rapid response to urgent environmental, political and social needs.

EJNI uses an innovative, transdisciplinary model of collaboration which draws together diverse stakeholders and decision-makers who usually operate in almost completely separate spheres to enhance knowledge exchange and facilitate more effective and strategic research, advocacy and action. By adopting a co-production approach where research users directly influence the project design, research methods, output design and dissemination strategy from the outset, EJNI can respond directly and rapidly to knowledge deficits and thus help drive forward reform in practice. Every aspect of the EJNI project is the product of collaboration between academic and non-academic stakeholders including organisational design, website, every output (whether film, briefing paper, academic article or webinar) and funding applications. This requires frequent engagement with actors both within and beyond the network.

The co-production approach has been beneficial as traditional approaches to problematising and making recommendations for reform in the context of environmental justice on the island of Ireland have not been successful in achieving meaningful change. EJNI's goals and activities are novel in that they can only be achieved via meaningful cross-sectoral collaboration. The network is new but successes to date indicate that this new co-operative approach to deal with persistent problems may be an impetus for radical change in how environmental justice problems are viewed and responded to across the island.

Case Study 20	
Project title	Eye-Q – An Intelligent optical freshness profiler
Co-production partnership	Academic and Industry
Academic	Dr Ultan Mc Carthy (Waterford Institute of Technology) Dr Anastasia Ktenioudaki (UCD)
Non-academic	Professor Jean Pierre Emond (The Illuminate Group, LLC) along with international technology companies, farmers, wholesalers and retailers
Funding	SFI Food Challenge (SFI Future Innovator Prize)

Overview of co-production: Eye-Q is a cutting-edge solution in food supply chain management designed to minimise food loss and waste. It is unconventional and disruptive in its approach through fusing both optical and chemometric explicit and tacit supply chain stakeholder knowledge to calculate the Remaining Shelf Life (RSL) of food groups. It will be fully human/user accessible through affordable handheld devices. Eye-Q aims to develop a globally relevant solution-based approach towards addressing food loss and waste. A co-production approach was adopted as stakeholder engagement was a critical component in the bottom-up stakeholder driven design of Eye-Q. This approach facilitated the assessment and validation of the proposed design approaches and assisted in identifying technological and non-technological barriers. Co-production also facilitated the identification of 'value & impact' as opposed to 'value add'.

Non-academic partners were selected to answer the following key questions: (i) what is happening outside academia? (ii) what do industry need? (iii) are the needs the same across all trading partners? (iv) do all stakeholders share the same value? (v) are the risks of adoption the same across all trading partners? Non-academic partners were involved in the design of the concept and list of requirements as well as providing access to their existing networks in the private sector.

The co-production approach has been very successful. It facilitated the developers to filter out what stakeholders would like to 'see the technology do' and what was actually valuable to the stakeholder, i.e. what they truly value. This has allowed the development team to focus their efforts on a system that will add value to all stakeholders and have major societal impact. This will also facilitate the development of a globally scalable technology designed to minimise food loss and waste.

Case Study 21	
Project title	Finding common ground: towards all-island implementation of the Aarhus Convention (a preparatory study)
Co-production partnership	Academic and NGO
Academic	Alison Hough BL, Dr Ciara Brennan, Dr Peter Doran (AIT, QUB, Newcastle University)
Non-academic	Friends of the Irish Environment (FIE)
Funding	Irish Research Council (IRC)

Overview of co-production: The aim of this project is to engage in knowledge co-creation between academics and eNGO FIE (Friends of the Irish Environment), focusing on Aarhus Convention implementation issues on the island of Ireland. The Aarhus Convention is an international convention establishing a range of environmental procedural rights including access to information, access to participation and access to justice. This project also collaborates with the Environmental Justice Network Ireland (EJNI), and Friends of the Earth Northern Ireland (FOE NI). A co-production approach was adopted as the NGO partners required the assistance of the academic partners in framing research into how best to construct an Aarhus Centre on the island of Ireland.

The co-production approach taken involved the problem being identified by the NGO partners and framed in a policy context by the academics who developed the research questions from the practical issues identified by the NGO partners. The NGO partners engaged in discussions around an initial briefing paper and what stakeholders should be included in the survey. It is envisioned that the academic and non-academic partners will have equal involvement in the stakeholder consultation workshops which are core to this project.

The co-production of the initial research and the briefing paper allowed the academic partners to identify a novel problem in Environmental Governance: All-island Aarhus implementation and the role of NGOs in furthering it on an all-island basis. The academics involved could not initiate and carry out the type of research required without strong engagement from the NGO sector. The close collaboration with the project partners and their networks allows access to primary source information regarding Aarhus implementation not available from other sources. Co-production is anticipated to result in greater NGO engagement with the research, enhancing the validity of the final conclusions and dissemination/impact of the findings.

Case Study 22	
Project title	Geothermal in Ireland: barriers and incentives to geothermal energy adoption
Co-production partnership	Academia and Government Department
Academic	Nicholas Vafeas, UCD
Non-academic	Oireachtas Library and Research Service
Funding	SFI

Overview of co-production: Geothermal energy is a proven technology that has the potential to play a substantial part in Ireland's transition away from fossil fuels but is significantly impeded by the lack of policy at local and governmental level. This project provides an in-depth analysis of the advantages and barriers to geothermal energy development in Ireland. The project is an SFI Public Service Fellowship hosted by the Oireachtas Library and Research Service (L&RS). The Public Service Fellowship enables a co-operative, co-production approach in which gaps in policy can be better explored and presented to legislators in a way that can inform them of the real potential of geothermal energy in an accessible way.

Staff of the Oireachtas L&RS have participated at every stage of the project providing active guidance and direction throughout. Meetings were held with Oireachtas L&RS on a weekly basis. Members of the Oireachtas L&RS assisted in tailoring the approach in a manner that is accessible, evidence-led, objective and relevant to the research topic. They have also actively helped to effectively communicate the research in a non-academic manner. The Oireachtas L&RS scheduled meetings with key personnel, including a TD, members of the Irish parliamentary committee and library and research staff, as well as members from Northern Ireland government departments and stakeholders in the project.

The co-production approach adopted has resulted in the collaboration between two worlds (i.e. academic and non-academic) and has provided the best possible outcome for the project. The project's primary target audience is policymakers and members of the Irish Parliament. As a lone academic researcher, it would have been significantly more difficult to reach this audience to engage on meaningful policy development.

Case Study 23	
Project title	Grain-4-Lab: Reducing reliance on single-use plastics in laboratories
Co-production partnership	Academic and Industry
Academic	Dr Jennifer Gaughran, Dr Brian Freeland, Ms Samantha Fahy, Dr Susan Kelleher, Dr Keith Rochfort, Dublin City University (DCU)
Non-academic	Members of brewing & distilling industry
Funding	SFI

Overview of co-production: The Grain-4-Lab team are developing compostable, laboratory-grade bioplastics, using currently untapped waste-streams from the Irish distilling & brewing industries. While providing viable alternatives to single-use plastics the project will develop a pathway to inspire the adoption of sustainable solutions in laboratories. The project has ambitious goals around the implementation of greener practices in labs. A co-production approach was adopted as Grain-4-Lab determined early on in this project that it needed to ensure a clear understanding of the stakeholder pains and possible gains.

Stakeholders were contacted during the formation of the project funding application. Every week of the project to date has involved interactions of the academic team with non-academic partners and stakeholders. Whilst at an early stage there has been one-to-one meetings with 54 stakeholders with a further 42 to contact. A societal impact champion has been involved in all stages of the project. Conversations with public body representatives and audits conducted by Grain-4-Lab indicated that a drastic mindset and policy change towards sustainability is required. Interviewing laboratory users showed that they feel personally responsible for plastic waste.

Early engagement with stakeholders will be crucial to the success of this project. Already the project team members have learned that (i) lab users want a change towards sustainability and are willing to adopt bioplastics at a premium, (ii) institutional policy has not caught up with the labs user's and industry's 'green thinking' and (iii) Grain-4-lab should focus on certain waste, such as the most problematic waste-stream for the beverage industry.

Case Study 24	
Project title	Groundwater flood alleviation in karst lowland
Co-production partnership	Academia and Industry/State Agency
Academic	Laurence Gill (PI), Patrick Morrissey and Paul Nolan (Trinity College Dublin (TCD) and Irish Centre for High-End Computing – ICHEC)
Non-academic	Ryan Hanley (Engineering company), Office of Public Works (OPW), Galway County Council
Funding	Geological Survey Ireland (GSI) and Galway County Council (GCC)

Overview of co-production: This research investigates different groundwater flood alleviation options in a lowland karst catchment by using a pipe-network model of the karst aquifer populated with output from the high spatial resolution regional climate model simulations. The project provided an evidence base for flood alleviation works for the Gort lowlands region of south Galway, incorporating potential impacts of climate change on the design flood water levels. A co-production approach was needed between the academic and non-academic partners, Galway County Council and the OPW, who came up with the need for the flood alleviation project due to a number of severe groundwater flooding episodes over the past twenty years.

At an early-stage Galway County Council and the OPW contacted TCD who had been carrying out research for many years on the south Galway lowland karst area and had been developing a hydraulic model. Both academic and non-academic partners (including Ryan Hanley Consulting Engineers and Geological Survey Ireland) had regular Steering Committee meetings approximately once every six weeks, where the research results were presented and discussed, and new goals and deadlines were set. These discussions led to the scope of the research changing somewhat during the process. In addition, information was shared with other stakeholders when required, such as a local flood action group, the National Parks and Wildlife Service and the Marine Institute.

The co-production approach has been extremely beneficial in terms of achieving project goals and outputs. The research has led to a new way of characterising groundwater flood return periods as well as quantifying the impacts of future climate change on such groundwater flooding. This has then led to data that has been used for the design of a large-scale flood alleviation scheme. This level of detail would not have been possible without the research approach by the academic partner.

Case Study 25	
Project title	GWFlood
Co-production partnership	Academia and Local Authorities, State Agencies
Academic	Laurence Gill, Patrick Morrissey, Owen Naughton (TCD and Institute of Technology Carlow)
Non-academic	Geological Survey Ireland (GSI)
Funding	Geological Survey Ireland (GSI)

Overview of co-production: The Groundwater Flood project aims to investigate flooding specifically related to groundwater and turloughs. Groundwater flooding can pose a significant and long-lived flood hazard for many rural communities and its increased frequency in recent years highlights the clear need for further research into the issue of groundwater flood prediction and risk assessment in karst regions. GSI, in collaboration with I.T. Carlow (ITC) and TCD, developed a systematic monitoring, mapping and modelling programme to address the knowledge gap regarding these complex karst systems. The primary objectives of the project were to establish a permanent groundwater flood monitoring network, produce historic and predictive groundwater flood maps for Ireland, enhance understanding of groundwater flooding and provide expert advice to stakeholders affected by groundwater flooding. A co-production approach was adopted to remedy the knowledge gap on mapping of groundwater flooding by combining the latest academic research with the existing experience within GSI.

The non-academic partners, GSI, were the project leads. The goals were set by GSI in consultation with stakeholders and GSI took responsibility for delivering on them. ITC's research was primarily related to developing models which were critical to producing the GWFlood deliverables. TCD's research was related to the enhancement of a pre-existing TCD hydrological model for investigating flood solutions. Engagement between partners was approximately one to two times per week. Team members took part in steering committee meetings every two months for the South Galway Flood Relief Scheme.

The co-production approach enabled the project to develop necessary novel approaches to mapping and modelling groundwater flooding which may not have been achievable otherwise. Each team member was able to focus on their strengths: GSI managed data collection and field operations while the two academic partners focused on innovative hydrological modelling and analysis techniques.

Case Study 26	
Project title	Imagining2050
Co-production partnership	Academic and Communities
Academic	Gerard Mullally, Alexandra Revez, Niall Dunphy, Clodagh Harris, Fionn Rogan, Edmond Byrne, Connor McGookin, Paul Bolger, Brian Ó Gallachóir, John Barry, Geraint Ellis, Barry O'Dwyer, Evan Boyle, Stephen Flood, James Glynn (University College Cork and Queen's University Belfast)
Non-academic	Local community participants, local non-governmental organisations, state agencies
Funding	EPA and Sustainable Energy Authority of Ireland (SEAI)

Overview of co-production: The Imagining2050 project has engaged with civil society using innovative, future oriented, deliberative engagements to explore and co-develop future visions of and pathways to a low carbon and climate-resilient future. The compelling drive behind the project was to inform the ongoing work of the National Dialogue on Climate Action as to approaches and structures for engagement with society at different levels to promote public support and co-creation of short-term and long-term climate action plans. A co-production approach was adopted as transdisciplinarity is particularly relevant in advancing climate action strategies by establishing the grounds for a form of science that is interconnected, holistic, adaptive and anticipatory. This approach draws from participatory action research, co-production and deliberative democracy and pays close attention to dynamics of inclusion and exclusion.

The multi-staged research approach started with preliminary local engagements, followed by deeper community involvement to co-develop low carbon visions and pathways of change, and finally extended to wider engagements with civil society, policymakers and experts (see link to our animation and infographic here). The research involved a series of formal and informal engagement and knowledge co-development processes which included two preliminary online surveys, 'knocking on doors', four weekend-long 'deliberative futures' workshops, eight multi-stakeholder workshops, three thought leader workshops and a Delphi-panel survey. The project co-developed visions and pathways of change with two communities in Athlone and Ballincollig. An added innovative component of the project was the use of creative communication methods such as empathy mapping, storyboarding and audience polls (link to toolkit here).

The co-production approach ensured a continuous evaluation and improvement of tools and visions of change. Traditional approaches would have provided a more limited and static vision of change which would give little insight on how to turn these visions into more actionable objectives, in a manner that considers multiple actors at different scales and from different sectors.

Case Study 27	
Project title	Irish natural capital accounting for sustainable environments (INCASE)
Co-production partnership	Academic and Industry/NGO
Academic	Professor Jane Stout, Dr Catherine Farrell, Professor Stephen Kinsella, Professor Cathal O'Donoghue, Dr Daniel Norton, Lisa Coleman (TCD, UCD, NUIG, UL)
Non-academic	IDEEA Group, Natural Capital Ireland
Funding	EPA

Overview of co-production: Irish Natural Capital Accounting for Sustainable Environments (INCASE) is the first Irish project to develop natural capital accounts for different sites in Ireland. The project team will prepare accounts for four catchments across Ireland to map the stocks and flows of ecosystem and geosystem services, highlight challenges, knowledge and data gaps and recommend a framework to operationalise Natural Capital Accounting in Ireland. A co-production approach was adopted as natural capital accounting involves the collection of information from a range of data holders and the results have implications for policy and communities. The co-production approach was considered vital for this project to identify data sources, and to ensure good working relationships with data holders and buy-in from policymakers and communities that will benefit from the accounts.

The non-academic partners were selected because they are the leading international and national experts on natural capital. These partners were closely involved in project design, setting goals and carrying out the research. The academic and non-academic partners meet regularly (bimonthly) to discuss project progress. Both academic and non-academic actors participate in stakeholder events and the development of project resources like reports, videos and infographics. The INCASE project team engaged non-academic perspectives through discussion papers shared with specialist stakeholders such as NPWS, the Forest Service and other research groups working on natural capital.

The co-production approach has been very beneficial for the project as it has helped to identify additional data sources that can be used in the natural capital accounts, and also to identify gaps in research and knowledge. For example, it was found that data on ecosystem condition are limited and must be supported by ancillary data on ecosystem use, pressures and threats.

Case Study 28	
Project title	Irish nutrient sustainability platform
Co-production partnership	Academic and Government/Industry
Academic	Professor John McGrath (QUB), Professor Vincent O'Flaherty (NUIG)
Non-academic	Government agencies, regulators, industry
Funding	EPA

Overview of co-production: The Irish Nutrient Sustainability Platform (INSP) was founded in September 2019 as a cross-border, stakeholder-led, cluster initiative to promote nutrient (carbon, nitrogen and phosphorus) sustainability across the Island. The Platform's mission is to catalyse the development of circular bioeconomy-based business models amongst its stakeholder members through provision of a 'safe-space' to openly discuss challenges and synergies, and to test novel eco-technologies, co-design new business models and engage with policy-makers and regulators. A co-production approach was adopted as the issue of nutrient sustainability affects everyone from the farmer to the consumer.

The INSP is a member-led initiative with an organisational structure designed to ensure stakeholders are driving the activities and outputs of the platform. Non-academic stakeholders were involved in the project from the early stages. In June 2017, 76 stakeholders participated in an 'All-Island Phosphorus Sustainability' workshop. A transformative change process was used to capture participant perspectives on phosphorus sustainability in the context of agriculture, industry, wastewater and food security.

The co-production approach has been crucial as the challenge of addressing nutrient sustainability impacts a lot of stakeholders in a lot of different ways. By bringing stakeholders into the planning from an early stage, there has been a holistic approach to finding solutions and including stakeholders in conversations that they might ordinarily be left out of. This has helped us find synergies between members that would not have been identified otherwise and led to collaborations between members.

Case Study 29	
Project title	KelpRes: the diversity and resilience of kelp ecosystems in Ireland
Co-production partnership	Academia and NGO/State Agency
Academic	Kathryn Schoenrock-Rossiter, Stacy Krueger-Hadfield, Anne Marie Power, Kenan Chan, Aaron Golden (NUIG, University of Alabama at Birmingham)
Non-academic	Seasearch Ireland, National Biodiversity Data Centre
Funding	EPA

Overview of co-production: This project aims to better understand the historical distribution of kelp forests in Ireland and to monitor changes in the distribution of these habitats along the coastline. It also investigates the genetic diversity within and amongst *L. hyperborea* populations from Wexford round to Northern Ireland. A key part of the project is to gather data on kelp forest distribution by encouraging recreational swimmers, kayakers and divers to contribute to this effort through an online survey form. A co-production approach with Seasearch Ireland was adopted for the project. Seasearch Ireland trains and educates key stakeholders in the study of kelp ecosystems in Ireland and has fostered research in kelp forests for more than four years, directly contributing to data collection, and facilitating project dissemination through their programme infrastructure.

Seasearch Ireland was selected because they have extensive knowledge of nearshore habitats in Ireland, good SCUBA diving infrastructure, and vested interest in success of the research project to foster their non-profit citizen research group and other research in this discipline. Seasearch Ireland participated in writing project grants in areas of project outputs and experimental design (selection of field sites for research). There is weekly engagement between academic and non-academic partners on KelpRes. The members of this organisation regularly aid with field work/dive days and facilitate workshops on Zoom or in person quarterly in areas such as marine botany or kelp forest ecology.

KelpRes would not be possible without co-production. The collaboration with recreational divers and Seasearch Ireland enabled discoveries such as the presence of *L. ochroleuca* (the warm water, European kelp) in Belmullet, Co. Mayo, which was the first record of this species in Ireland. Project outputs include TV interviews, radio interviews, newspaper articles, academic publications (peer reviewed and not peer reviewed) and workshops.

Case Study 30	
Project title	Life cycle assessment of technologies for circular bioeconomy
Co-production partnership	Academic and Industry
Academic	Professor Nicholas M. Holden, Nishtha Talwar (UCD)
Non-academic	Commercial Mushroom Producers (CMP), Nutramara
Funding	BiOrbic Bioeconomy, SFI Research Centre

Overview of co-production: In this project the technical challenge is processing feedstocks (mushroom and seaweed) to produce chemicals for pharma-related industries. The sustainability challenge is how to estimate the likely impacts of commercial implementation while still at an early stage of technical development. The project will evaluate how the methodological choices for life cycle assessment (LCA) will influence the conclusions; the aim is to produce recommendations for better use of LCA in the bioeconomy and avoid greenwashing. A co-production approach was adopted as no one discipline or perspective can solve the challenge of finding sustainable solutions. The companies define the market demands, route to scale-up and provide data, the biomolecular and technology experts develop process solutions, scale-up and data, and the LCA experts use the data and information from the others, along with context knowledge to calculate the impacts of the system.

The non-academic partners co-designed the technical experimentation to meet their needs and worked with the LCA team to define the goal of the LCA and to provide inventory data for the LCA modelling. There is weekly engagement between the companies and the scientific teams; to ensure the engagement does not place too much demand on company employees a dedicated point of contact was agreed. To ensure buy-in, the decision to engage with the project was taken at board level by both companies and a working document was developed detailing expectations and requirements.

The co-production approach has been beneficial as a traditional approach would have defined one or more scenarios and relied on average or estimated data. The co-production approach has enabled a more robust analysis and actionable business-intelligence to be created for both companies, as well as interesting scientific outputs.

Case Study 31	
Project title	LIVE (Llŷn Iveragh ecomuseums)
Co-production partnership	Academia and State Agencies/Local Authorities/Communities
Academic	Dr Patrick A. Meere, Dr Fidelma Butler, Dr Einir Young (UCC and Bangor University Wales)
Non-academic	Kerry County Council, South Kerry Development Partnership CLG, Gwynedd Council, National Trust
Funding	European Regional Development Fund through Ireland Wales

Overview of co-production: LIVE aims to enable coastal communities to promote their natural and cultural assets, creating opportunities for sustainable tourism. LIVE will use the Ecomuseum model of co-operative marketing to create a powerful suite of digital and non-digital resources for eco and educational tourism. These resources will be underpinned by knowledge of the local environments of the Ll□n Peninsula in Gwynedd, Wales and the Iveragh Peninsula in Kerry, Ireland. A co-production approach is bringing academic research and knowledge out of the university and into the communities who live in the areas where that knowledge is gathered. The project also aims to gather local knowledge and identify knowledge gaps and areas of interest to local businesses, educators and communities.

The consortium includes four non-academic partners who developed the project from the outset and have full roles in implementation. The project is engaging with community stakeholders in the areas of education, environmental tourism, cultural promotion and those who are interested in the project from a personal perspective. The academic staff are open to following any direction that is relevant to the aims of the project and that will facilitate socio-economic benefits to the regions. The project managers and local co-ordinators, who form the bridge between the universities and the communities, are based in Kerry and Gwynedd.

The project is at an early stage. So far, the project has received a positive response from community members glad to have their voices heard. Co-creation will occur within the consortium, across borders and between the project and community stakeholders. It is expected that there will be a higher level of knowledge transfer and translation to local communities compared to traditional research. It is envisaged that this approach will increase local awareness and knowledge while adding to the academic pool of knowledge and will establish long-term sustainable programmes and relationships between institutions and communities.

Case Study 32	
Project title	Mapping green Dublin (www.mappinggreendublin.com)
Co-production partnership	Academic/Community/Artist/Social Enterprise
Academic	Gerald Mills, Niamh Moore-Cherry and Alma Clavin, UCD
Non-academic	Common Ground (arts organisation), Seoidin O'Sullivan, (independent artist), Connect the Dots (social enterprise)
Funding	EPA

Overview of co-production: Mapping Green Dublin is a collaborative action research project that aims to recognise the value of lived experiences in developing community greening. Our project responds to recent research that has highlighted the importance of green space and greening on urban health and wellbeing. We propose a place-based approach to green strategy-making that draws on and responds to community concerns and aspirations and engages with policymakers to explore how community visions can inform and be supported by more formal policies and plans.

The Mapping Green Dublin team worked with non-academic partners, local residents and other stakeholders to identify greening needs and co-create a community greening strategy. A co-production approach was needed as the project was based on iterative engagement combining academic, local and technical expertise.

Non-academic partners were selected based on previous collaboration on other projects and on their embeddedness in networks within the study area. The partners participated from the research proposal stage through to dissemination. They were most active during Phase 2 co-creation when their networks and expertise were central to successful community engagement. Events were designed and facilitated collaboratively. The post-doctoral researcher was embedded with the non-academic partners two to three days per week getting to know the community, building up knowledge and trust of the local context and acting as a key conduit between all partners.

The project could not have delivered the community greening strategy nor built such trust with the community without a co-production approach. The funders have remarked on how community engagement delivered beyond expectation. Because of the sustained and inclusive interactions, the project delivered a number of additional sub-projects and successively adapted to the Covid-19 situation. The community have been supported to articulate their greening needs and linked with practitioners and other stakeholders who can support their objectives.

Case Study 33	
Project title	Measuring sustainable actions at community level – The community SDG dashboard
Co-production partnership	Academia and NGO
Academic	Associate Professor Ainhoa González, Professor Enda Murphy, Dr Shane Mc Guinness, Dr Tobi Morakinyo, Cynthia O'Mahony, and Connor Podkul (UCD)
Non-academic	Tom Halton and Lyn Hagin Meade (Dundrum2030); Gráinne Kelliher (Airfield Estate)
Funding	UCD Earth Institute Strategic Priority Support Mechanism

Overview of co-production: The Community SDG Dashboard Project aims to quantify and track progress towards achieving selected Sustainable Development Goals (SDG) by 2030 by enabling communities to gather, manage and interpret data. It aims to develop the capacity of the Dundrum2030 community group to monitor progress towards sustainability in their area through the co-definition of an UN-aligned indicator set and co-creation of an indicator-led monitoring toolkit. A co-production approach was adopted as involvement of community representatives was important for the design of context-specific solutions, and to achieve tangible SDG progress. Community input was required to design a suite of effective data collection methods, as well as to encourage acceptability and voluntary data gathering efforts by prospective citizen scientists. Finally, co-production was important to ensure the maintenance of local community capacity for SDG actions and progress beyond the life of the project.

Dundrum2030 and the extended community have been project collaborators from the outset, with Dundrum presenting a testbed for the monitoring of local SDG progress through an online dashboard based on Geographic Information Systems (GIS). Early project design meetings were carefully facilitated to ensure the voices of community representatives were heard and their input shaped the development of the GIS-based dashboard. Community groups also staged a parallel public engagement process to identify priority SDG targets and indicators to be used. Further, members of the community are to be drafted into data collection stages that will feed into the SDG dashboard by, for example, installing domestic air quality and traffic sensors at their homes, and recording sustainable initiatives and actions.

Without the engagement of the community in this research, access to a broad range of citizens' insights and data collection would have been slower to set. It is envisaged that the trust and ownership built between the community and UCD will outlive this project and allow its application as a model in other community settings nationally.

Case Study 34	
Project title	Mitigation measures for renewable energy curtailment in 2030
Co-production partnership	Academia and Industry/Semi-State
Academic	Rory Mullan, Paul Blount, Conor Forde & Dr James Carton (DCU)
Non-academic	AboWind, Coillte, Mullan Grid
Funding	SEAI

Overview of co-production: The project aimed to understand what measures were needed on the electricity grid to ensure large amounts of renewable could get onto the system without vast amounts of renewable energy being wasted (called energy curtailment). The aim was to investigate 2030 system based on known plans and also to see what else was needed in 2040. A co-production approach was adopted as the commercial insights and various routes to problem solving are invaluable to develop the scenarios for the models/process to provide accurate results.

The project was co-created from the beginning with university and industry partners having a relationship and recognising the benefits of working together on previous projects. Non-academic partners were fully involved in all aspects of the project weekly group meetings.

The co-production approach adopted by the project been beneficial with the commercial insights proving invaluable to develop the scenarios for the model to provide accurate results. As commercial companies tend not to publish their outputs their knowledge is not usually visible to academics via normal journal searches which underlines the importance of strong engagement with stakeholders.

Case Study 35	
Project title	nZEB101
Co-production partnership	Academic and Industry
Academic	Dr Shane Colclough, Dr Oliver Kinnane, Dr Richard O'Hegarty (UCD)
Non-academic	3CEA Energy Agency, Nilan Ireland, MosArt, Michael Bennett
Funding	SEAI

Overview of co-production: Building on an established monitoring project of low-energy dwellings which has been running for over two years, the vision for nZEB101 is to uncover the key net zero energy building (nZEB) design and operations lessons in Ireland. nZEB101 monitors over 101 geographically dispersed properties which will yield operational performance of A-rated buildings and 'in use factors' for a span of energy-efficiency technologies. The data gathered will be key to ensuring design and operations lessons learned are captured to inform future design for industry at large. A co-production approach was adopted as there is a need for evidence-based decision-making in respect to informing industry of how best to build to low-energy standards. The detailed post-occupancy evaluation in this study will help industry gain insights into what worked well and what did not.

The non-academic partners were selected due to already established contacts by the project lead. They were engaged at the project proposal development stage and again once the funding was made available. They were then actively engaged when the post-occupancy evaluation results were available, as they were then involved in reviewing the results presented by the academic team and identifying what they would do differently for subsequent projects.

The traditional research approach would not have worked in this instance. Given that the property developer had well established contacts with the occupants, the involvement of the occupants was more readily obtained, resulting in approximately 80% occupant engagement. However, while hard data could be obtained on the performance of the building, the objective of the research was to inform industry practice. A key success factor was that the industry partners would openly share their perspectives, learnings and plans.

Case Study 36	
Project title	Planning for sustainability through Environmental Sensitivity Mapping
Co-production partnership	Academia and Local Authorities/Government Agencies/Industry
Academic	Dr Ainhoa González, Dr David Jordan (UCD); Justin Gleeson, Eoghan McCarthy (All-Island Research Observatory)
Non-academic	Local Authorities, Government Agencies, Industry
Funding	EPA

Overview of co-production: The Environmental Sensitivity Mapping (ESM) project has developed an online decision-support tool enabling the examination of environmental, societal and economic criteria at regional and local levels, and the creation of environmental sensitivity maps that incorporate public concerns and opinion. By highlighting the location of natural assets, their value and vulnerability, the webtool provides immediate and objective information to guide development to suitable areas. A co-production approach was adopted, as effective planning for sustainability requires shared knowledge and understanding of environmental sensitivities which are influenced by the importance or value that experts and stakeholders may place on environmental resources. Moreover, the co-production approach was necessary to ensure that the online interface satisfied user needs and requirements.

Steering committee members closely working with the project team were selected on the basis of their environmental and/or planning expertise. The project was co-designed with the committee members, who were subsequently instrumental in refining the scope and guiding the research. Steering committee members and other consulted representatives from both public and private organisations facilitated relevant datasets for incorporation into the ESM tool, as well as critical insights that shaped the tool's inputs and outputs. Several stakeholders also volunteered to apply the tool to the assessment of their plans, thus contributing to the research by providing real-life case studies and validating ESM results.

Without the engagement of stakeholders, the development of a webtool that pragmatically supports plan- and decision-making would have not been possible. The input of planners with regards to information needs, of environmental experts on the relative importance of natural assets and of users on interface requirements was crucial in ensuring a fit-for-purpose and user-friendly tool. Moreover, close engagement with high-level stakeholders enabled making it publicly available in Geohive, the national web data portal, and securing its long-term viability. It is unlikely traditional academic research would have succeeded in making the research output a fully supported, embraced and applied public good.

Case Study 37	
Project title	Plastic raiders
Co-production partnership	Academic and NGO/Local Authority/Schools/Government
Academic	Francesco Pilla, Jennifer Symonds (UCD)
Non-academic	ECO-UNESCO, Dublin City Council, Repak, schools, European Space Agency
Funding	SFI

Overview of co-production: The Plastic Raiders project addresses the challenge of removing polluting plastics from the coastal marine environment by developing and deploying an innovative STEM technological framework of plastic detection using airborne data. The project will amplify the utility for plastic removal by using bottom-up citizen science and create sustainable, intergenerational change in environmental activism behaviours. There are different levels of co-production in the project: (i) co-production of data through citizen science: this was necessary to gather data on plastic pollution in a pervasive way and to engage citizens in being part of the solution, (ii) co-design of goals: this was adopted to fine tune our mission according to the feedback from relevant stakeholders and (iii) co-design of app: the app which will be used for the citizen science activities will be co-designed with a wide range of users to increase its usability and ensure its engagement potential.

To minimise risks and overcome the barriers identified for the project there was significant engagement with non-academic partners including local authorities, environmental activism associations and schools. Non-academic partners were involved at different stages depending on the specific activity of the project, e.g. partners relevant to the plastic detection side of our project were engaged from the very beginning. There was continuous engagement with the environmental activism associations and schools as it was critical for us to guarantee a high number of youth and adults engaged in our collection activities.

The co-production approach adopted by the project enabled the fine tuning of the research and identification of new challenges to be addressed to maximise the impact, e.g. the decision to develop algorithms to identify plastics in rivers using cameras under bridges as an outcome of the co-development activities.

Case Study 38	
Project title	Protecting the built environment from the effects of wind
Co-production partnership	Academic and Industry
Academic	Professor Jennifer Keenahan, Dr Andrew Quinn, Dr Daniel McCrum, Dr Philip Cardiff, Licheng Zhu, Yuxiang Zhang (UCD)
Non-academic	Arup, Transport Infrastructure Ireland, Transport Scotland
Funding	Chinese Scholarship Council

Overview of co-production: This research investigates how wind can affect structures, pedestrians and cyclists. Computational Fluid Dynamics (CFD) is used to model wind in the built environment. Validation of these models is essential to ensure they accurately represent wind in the real world. This is done by comparing CFD results to wind tunnel test reports and field data. The research started with modelling a single vehicle, an overturning crane and a moving helicopter followed by buildings, bridges and even entire cities. It is extremely important that this research is relevant, applicable and useable in the real world. A co-production approach was necessary to truly understand the challenges associated with the impacts of wind in the built environment; it was essential to engage with infrastructure operators (e.g. Transport Scotland) to understand their challenges.

Non-academic partners were involved from the very beginning. Some partners were chosen based on their involvement in the engineering design of construction projects. Others were chosen based on collecting data in relation to wind speeds in the built environment. Non-academic partners were heavily involved in the research design and in setting its goals and they were pivotal to determining the real-world needs in the area of wind effects in the built environment. In particular, they identified the need for a 'wind management plan' for vulnerable parts of the built environment.

The co-production approach adopted by the project has been pivotal to its success. The research would definitely not be as high quality or have as high an impact without the co-production approach. To have attempted to undertake this work without engaging with the operators and end users of infrastructure would have resulted in miss-directing our efforts entirely. We would have solved problems that were purely academic, and not the problems that need to be solved.

Case Study 39	
Project title	Public STEAM: Inventing transdisciplinary tools and practices for 'education for sustainability' in adult and community education contexts
Co-production partnership	Academic and Citizens
Academic	Giselle Harvey, Limerick School of Art and Design, Limerick Institute of Technology
Non-academic	Non-academic, citizen co-researchers.
Funding	IRC GOIPG 2020

Overview of co-production: This project focuses on the development of a community education framework which responds to public calls for community-based education and empowered climate action along with emancipatory transdisciplinary practices. Through art-based participatory action research, non-academic actors are invited to become co-researchers of practice and use the framework to collaboratively research, identify and execute community-based climate actions. A co-production approach was adopted as public calls for education and empowered community climate action require pedagogy co-designed 'with' the public not simply 'for' the public.

Consistent engagement between academic and non-academic actors is embedded throughout the project's lifecycle. The public intervention workshops function as an outreach programme and praxis starting point. The interventions seek to gather together a 'community of curiosity' through which to identify non-academic co-research partners who are then selected based on their interest in community climate actions. While co-researchers are asked to experiment with specific processes to shape future practice, they have within that research context full creative freedom to collaboratively frame and set their own research agenda, decide what aspects of the problem they deem most important and what their project goals are.

This bottom-up co-production of knowledge lies at the heart of emancipatory adult education as a mechanism to give voice and tools for empowered informed social action to those excluded from decision-making power, such as decisions around national climate action. The approach hopes to demonstrate the benefits of co-produced knowledge between non-academic and academic actors in formal research contexts as a bridge between people and institutions in planning sustainable futures together, bringing public voices into decision-making and scholarship as key goals and outcomes.

Case Study 40	
Project title	Radon monitoring and hazard prediction in Ireland
Co-production partnership	Academia and Industry
Academic	Quentin Crowley (Mentor and Primary Investigator), Javier Elio (Post-Doctoral Researcher), TCD
Non-academic	Jim Hodgson (GSI)
Funding	IRC Enterprise Partnership Scheme

Overview of co-production: The central aim of this research was to gain a better understanding of geogenic (i.e. geological/natural) factors and processes affecting the generation, transport and distribution of radon as a pollutant in the natural/built environment. The project developed new high-resolution radon hazard maps of Ireland using Geological Survey Ireland (GSI) data on bedrock, groundwater, soils and Tellus geochemistry/geophysics. Environmental Protection Agency (EPA) data on indoor radon were also included in the data analysis and some of the resultant maps. A co-production approach was adopted as GSI did not have expertise to undertake the work.

GSI were involved in project design and guidance. There was frequent engagement between academic and non-academic actors with the postdoctoral researcher in the project being based in in GSI offices for 40% of the time. A schedule of regular meetings and presentations was put in place to integrate academic and non-academic perspectives.

The co-production approach adopted by the project was beneficial and processes worked well. The main project outputs are the development of new all-Ireland radon risk maps, which following evaluation will be adopted by the EPA as part of the revised Building Regulations.

Case Study 41	
Project title	Restoration of the River Camac, Dublin
Co-production partnership	Academic and Local Authorities/Community Groups
Academic	Mary-Liz Walshe, Laurence Gill, Trinity College Dublin and others in TU Dublin and UCD
Non-academic	Dublin City Council Departments, OPW, Kilmainham Inchicore Network, South Dublin County Council, EPA, CARO Dublin, LAWPRO
Funding	Dublin City Council

Overview of co-production: From the beginning, it was evident that in order to restore the River Camac back to good hydro-morphological condition, a multi-faceted, multi-disciplinary approach with multiple project partners and stakeholders would be needed. Interactions with local residents were invaluable to the framing of the challenges and understanding the sequence of events that brought the river to its current, unhealthy state. The river environs would need to be reimagined through river restoration, urban regeneration and using nature-based solutions. A co-production approach was needed to untangle and attempt to understand the many influences acting on the river; an appreciation of the river's story seemed a necessary step first step. The identification of potential co-benefits, e.g. tourism, promotion of wildlife and improvements to quality of life has been a critical part of this work.

Non-academic partners were selected initially and for their strong links to Camac catchment community groups and their influence in the study area. These partners helped to frame the wider questions surrounding river restoration, climate adaptation, local interest and potential to enhance the public realm. As the project has evolved, other public bodies have also partnered with us in recognition of the multiple benefits that can accrue from river restoration work, improved flood risk management and climate adaptation to biodiversity and public realm enhancements.

The benefits of the co-production approach are that it has enabled a mandate from the people in the form of the vision for the Camac River. Being able to build support for this project from the ground up and seeking early input has meant that this work has gathered its own momentum and people who might have initially been sceptical are quicker to recognise, and themselves identify, the many co-benefits that a multi-disciplinary approach to catchment management can offer.

Case Study 42	
Project title	SAFEWATER (Low-cost technologies for safe drinking water in developing regions)
Co-production partnership	Academic and NGOs
Academic	Dr Pilar Fernandez (UU), Dr Michael Brennan (UU), Professor Tony Byrne (UU), Dr Fermin Reygadas (Cantaro Azul (CA)), Dr Margarita Hincapie (University of Medellin (UdM)), MSc Catalina Barrientos (Centro de Ciencia y Technologia de Antioquia (CTA)), Dr Lyda P. Sabogal Paz (University of Sao Paulo (USP)); UU; UdM;
Non-academic	Cantaro Azul (CA), Mexico; Centro de Ciencia y Technologia de Antioquia (CTA), Colombia
Funding	Global Challenges Research Fund (GCRF) UK Research and Innovation

Overview of co-production: Low-cost technologies for safe drinking water have significant potential to improve the health of communities who rely on unsafe water. The objective of SAFEWATER is to develop low-cost technologies to supply and monitor drinking water in rural areas of Mexico and Colombia, as well as to assess its impact in the regions where the interventions take place. A co-production approach was needed due to the contested nature of water knowledge and to recognise the different discourses and understanding of impact between the different stakeholders. Water challenges and proposed solutions must integrate the views of a range of stakeholders to ensure the co-production of knowledge and meaningful impact.

The two NGO partners were selected on the basis of their reputation, knowledge, community engagement and established networks. Specific capabilities include the scoping and completion of field trials in communities as well as local culture, context and relationship with water. The non-academic partners provided the specific information about the local context of the target communities where the solutions would be implemented. This was done through technical and behavioural surveys by the NGOs about water issues in the communities. The NGOs also provided feedback from the communities during the co-design creation of the technologies. Frequent meetings, timely exchange of information and open dialogue amongst all researchers made the process of integration continuous and gradual from the early stages of the project.

An important outcome of the co-production approach within the project is capacity building for both societal and scientific stakeholders. The great level of learning of researchers involved in transdisciplinary research and co-creation is a success, producing better and more robust results, creative thinking, resilient solutions and overall positive end-user engagement, as observed in the communities.

Case Study 43	
Project title	SHARECITY
Co-production partnership	Academia and Social Enterprise/Co-ops/NGOs/Food sharing companies
Academic	Professor Anna Davies (TCD)
Non-academic	Social Enterprise, Co-ops, NGOs, Food sharing companies
Funding	European Research Council (ERC)

Overview of co-production: SHARECITY uses innovative social and environmental science alongside collaborative research methods to explore the international practice and sustainability potential of ICT-mediated urban food sharing. Initially, a novel online mapping exercise used a process of crowdsourcing in order to create the first international interactive search engine for urban food sharing (SHARECITY100 database). Relations were further cemented during ethnographic research in nine cities internationally. Co-production has continued through to the final phases of the project where initiatives helped develop the SHARE IT sustainability impact assessment toolkit. This was essential to ensure that the tool met the needs of users (e.g. food sharing initiatives, local government, food retailers), whilst also being scientifically robust.

Non-academic partners were invited to contribute through open calls posted on social media and to online networks. Co-production partners for SHARE IT were invited from the food sharing initiatives collated in the database and those who participated in the in-depth research in cities. It was vital that these partners were involved from the outset of the toolkit design process in order to identify and clarify their needs and capacities; the underlying research and toolkit development were carried out by the research team. However, interaction was regular, with face-to-face meetings, workshops and ongoing email interactions with partners throughout the process.

Co-production was an essential component of the research across all its phases and ensured relevance and resonance of research outputs which would have been impossible without such interaction with partners. This project was awarded an inaugural ERC Public Engagement Award in 2020 for its co-produced online and social media interventions: the SHARECITY100 interactive database and SHARE IT tool.

Case Study 44	
Project title	SolarCool
Co-production partnership	Academia and NGO/Industry
Academic	Professor David McCloskey, Erik Soderholm, Eoin Cotter (TCD)
Non-academic	Phelan Energy Group, Concern Worldwide
Funding	SFI Future Innovator Prize

Overview of co-production: The SolarCool project aims to address potential future global electronic waste problems arising from end-of-life solar panels. The project is engaging with stakeholders to understand the problem and design a cost-effective solution including improving efficiency, decreasing carbon footprint and extending the operational lifespan of solar PV technologies. A co-production approach was adopted as insights provided by Phelan Energy Group help identify the real problems and develop a cost-effective solution which will be taken up by the market.

Phelan Energy Group and Concern worldwide have been involved from the very beginning of the project and have been instrumental in the design and evolution of the project goals. Phelan Energy were extremely useful in explaining how solar farms are commissioned and developed and the tendering process and competitive nature of the industry. They gave us insight into the values of companies in the area and the terminology and metrics that they use. Concern provided insight into issues of resilience facing rural villages in Africa and their own power issues in serving remote sites. In the next phase we plan to deploy prototypes in operational solar farms in South Africa with direct help from our impact partners.

This project benefited greatly from interactions with our impact partners Phelan Energy and Concern worldwide. Early stakeholder engagement has been instrumental in setting realistic and impactful goals for the project. This has been a very successful model and is particularly useful for identifying and solving real industry problems with large potential impact.

Case Study 45	
Project title	Sustainable – [sector] – curriculum co-create
Co-production partnership	Industry/State Agencies/Local Authorities/NGOs
Academic	Julie Dunne, Cormac McMahon, Catherine Barry-Ryan, Graham O'Neill, Fintan Moran, Lucia Walsh, Adrienne Fleming, Gemma Kinsella, Catherine Gorman, Sandra, Thompson, Aileen Kennedy (TU Dublin)
Non-academic	Food & drinks-tourism-biopharma sectors, State agencies, Local authorities, NGOs
Funding	National Forum for Enhancement of Teaching and Learning in Higher Education – Strategic Alignment of Teaching and Learning SATLE 2020

Overview of co-production: The project goal is to build capacity for integrating enterprise-relevant sustainability learning outcomes across all programmes in TU Dublin through educator professional development. This will be achieved through the development and piloting of sector-focused sustainability modules with co-learning for academic staff, enterprise learners and campus-based students. The curriculum design involves all stakeholders in Education for Sustainable Development (ESD), and the curriculum will involve design thinking pedagogy. A co-production approach was adopted as sustainable development is complex, requiring transdisciplinary approaches, allowing knowledge to emerge between established fields, providing space for alternative perspectives, innovative ideas and solutions to be created. It must be influenced by viewpoints of all stakeholders, including enterprise, regulatory and state bodies, communities, social partners.

Enterprise partners were selected to contribute to sector-specific sustainability issues. Surveys, focus groups and interviews, as well as industry publications and policy frameworks contributed to decision-making for curriculum design. Non-academic partners will be commissioned for resource development for modules and as enterprise experts to deliver elements of the modules. Their input into setting goals is essential as they understand sustainability issues from the industry perspective and therefore compliment the academic knowledge. Non-academic participants will be involved weekly as guest speakers, and as participants in co-create design thinking activities. The University–Enterprise co-operation model 'Convene' at TU Dublin supports the collaboration.

The traditional model of curriculum design includes non-academic partners, generally through indicating support for new programmes, and through validation and QA processes. This project includes non-academic partners in all aspects, from curriculum design, delivery and co-creation through design thinking. Additionally, students will have an increased role in the design, through the curriculum co-create process. Additionally, non-academic partners will be included in Education Research and Scholarship activities and will contribute to the body of knowledge relating to best practice in ESD.

Case Study 46	
Project title	The new blue book
Co-production partnership	Academic and Government Department
Academic	Irish Centre for Research in Applied Geosciences (iCRAG)
Non-academic	GSI
Funding	GSI, iCRAG SFI Centre

Overview of co-production: The past half-century of mineral exploration and research activity in Ireland has generated a considerable amount of lithostratigraphic data. This project will produce a revised dynamic stratigraphy of the Tournaisian and Viséan with a comprehensive account of the lithostratigraphy linked to the considerable quantity of unpublished data collected in the last three decades. The final product, with a working title of 'The New Blue Book', will be made publicly available via a series of online chapters. This project was envisaged as a joint GSI and iCRAG project to integrate the diverse datasets and repository of knowledge that has been created over the past 30 years. A co-production approach allows for the full involvement of all stakeholders, including government, academia and industry and will drive accessibility of the outputs and leverage the maximum impact from the work undertaken.

GSI were involved in the conceptualisation of the project from the beginning and have been an ongoing partner across all aspects of the project contributing as authors, editors and reviewers. GSI is also the data host for the final products. GSI and iCRAG researchers were in constant contact during this project. In practice formal meetings were largely superseded by much more frequent informal contact to ensure that all perspectives were taken into account in the development of the research. Additional external perspectives were sought from industry contributors who had a breadth of knowledge in specific areas.

The partnership process has been extremely beneficial and has allowed for the efficient integration and harmonisation of data and knowledge from across diverse sources. While individual research efforts may have been able to replicate some of the outcomes, the positioning of this project as the framework for all future research into the Irish Carboniferous was only possible with an integrated approach across multiple stakeholders.

Case Study 47	
Project title	Valorisation alternatives to landfill for organic residues
Co-production partnership	Academia and Industry
Academic	Brian Kelleher, Jessica Graca, Brian Murphy, Tim Duggan (DCU)
Non-academic	Enrich Environmental Ltd
Funding	EPA

Overview of co-production: This project investigates and assesses higher value options for the organic fraction of municipal solid waste (OFMSW) and formulates strategies to minimise its disposal to landfill. The non-academic partner, Enrich Environmental Ltd, is an ambitious and award-winning compost and soil manufacturer. Collaboration between the non-academic partner with academia is vital to gain access to analytical equipment and expertise. Field trials and incubator studies are carried out in Enrich Environmental Ltd while analysis and interpretation are performed in DCU.

Engagement has generally been at least once a week; more formal meetings are held about four times per year. It is the informal meetings where much of the research is done and ideas flow. Enrich employees are free to use the laboratories in DCU and similarly, Enrich facilities are open to staff and students of DCU.

The project would not have occurred without the questions posed by the non-academic partners. Throughout the process, input from all parties is required and facilities at Enrich and DCU are open to the researchers involved. It is very much a shared collaboration that brings benefits to all parties. The strength of the co-production approach has been that all partners benefit from a multi-disciplinary, multi-sectorial environment working together for solutions that are both commercially viable and good for our environment.

Case Study 48	
Project title	Water management for sustainable use and protection of peatlands
Co-production partnership	Academia and State Agency
Academic	Professor Mark Healy (NUIG)
Non-academic	Bord na Móna
Funding	EPA (Water JPI)

Overview of co-production: This project aims to quantify the impact of management of peatlands on water quality. The project is stakeholder-led. Bord na Móna were a key stakeholder, and were responsible for identifying the main issue to be investigated in this project, i.e. the creation of ammonium through the re-wetting of organic soils.

A number of stakeholders were needed at the proposal stage. Once funding had been won, the project team then met with the stakeholders who advised on the research question and who provided access to their field sites. Bord na Móna were hugely important in designing the project and in facilitating the research. Without their involvement, the project could not have been completed. There has been very frequent collaboration with the project team and the stakeholders throughout the project (which is ongoing until June 2021. Stakeholder meetings are held each year in each partner country.

Co-production has been essential to framing the research question and implementing the project .The project is still ongoing (completion date in June 2022). The site work and laboratory work continue.

Case Study 49	
Project title	WaterMARKE
Co-production partnership	Academic and State Agencies/Community Groups
Academic	Professor Mary Ryan, Professor Cathal O'Donoghue, Dr Denis O'Hora, Dr Jenny McSharry, Dr Karen Daly, Professor Owen Fenton, Dr Yuting Meng, Rossella Di Domenica (Teagasc-NUIG)
Non-academic	Dr Jenny Deakin (EPA), Pat Murphy (Head Environment Knowledge Transfer, Teagasc), Catherine Seale (LAWPRO), National Rural Network, DAFM;
Funding	EPA-DAFM

Overview of co-production: WaterMARKE is an ambitious multi-actor research project which connects the areas of biophysical science, socio-economics, behavioural psychology and implementation science in a unique and novel framework that advances knowledge, and crosses over between research and knowledge transfer.
The project co-designs risk assessment and mitigation measures in conjunction with farmers on the basis of biophysical, economic cost, transaction cost and farmer behaviour perspectives, before trialling these measures on a wider cohort of farms. A co-production approach was adopted as the purpose of the project is to find innovative system wide solutions to water quality issues in agriculture; it was therefore essential to engage with a wide variety of stakeholders to consider their individual responses.

The non-academic partners came from Policy and Regulation (EPA & DAFM), Knowledge Transfer (Teagasc Environment KT), Farmers, Regulation (local authorities) and Community Engagement (National Rural Network). These partners have been involved with the project from the beginning; this was necessary both to design the systemic review of the behavioural drivers, to ensure that the research was usable, to aid the collection of data, to improve understanding of their roles and to co-design solutions to improve water quality. Frequent engagement has been essential given the breadth of the project, both in the complexity of the subject and in the range of different academic disciplines involved.

The co-production approach has been beneficial as given the multi-dimensional nature of the problem and the project, it would simply not have been possible to integrate the different perspectives required to inform system-wide change to achieve improved water quality, without taking a non-traditional multi-actor and multi-disciplinary approach. This has been necessary in relation to knowledge and understanding, human capacity and skills, research infrastructure and data and direct contact with stakeholders in an action research setting.

APPENDIX 2

Questionnaire for call for case studies in knowledge co-production for sustainability

Project Details

Q1 Title of project:

Q2 Funding source:

Q3 Main research institutions involved:

Q4 Principal investigators and researchers:

Q5 Academic disciplines involved:

Q6 Non-academic stakeholders and partners:

Q7 Summary of project (200 words):

Q8 Why was a co-production approach adopted or needed for the project (50–100 words)?

Q9 Were stakeholders in the project involved in framing and designing the research agenda and goals? Please select Yes/No

Process

Q10i Outline the nature of the co-production process in the project (How were non-academic partners selected and at what stage did they participate in the project? (50–70 words)

Q10ii How involved were non-academic partners in project design, setting goals and carrying out the research? (50–100 words)

Q10iii Was there frequent engagement between academic and non-academic actors? (50–100 words)

Q10iv What processes, formal and informal, were in place to integrate academic and non-academic perspectives and participants? (50–100 words)

Impact/Evaluation

Q11 What were/are the main project outputs and impacts to date? (50–100 words)

Q12 Has the co-production approach adopted by the project been beneficial and successful in terms of achieving project goals and outputs, as compared with traditional research approaches? (50–100 words)

Challenges/Lessons Learned

Q13 Did you or your partners encounter any challenges during the co-production process? If so, how did you address them? (50–100 words)

Q14 What were the main lessons learned? (50–100 words)

Q15 Do you have any recommendations for other researchers seeking to pursue co-production approaches? (50–100 words)

Q16 How do you think the use of co-production in research could be better supported? (50–100 words)

Q17 Any other comments? (50–100 words)

APPENDIX 3

Programme for Better together: knowledge co-production for a sustainable society symposium and workshop

Better together: knowledge co-production for a sustainable society

Online symposium • 3 June 2021 • **Book here**

Programme

M.C.: Jennifer McElwain, Climate Change and Environmental Sciences committee

9.00 Welcome

9.10 **Reflection on discussion paper and case studies**
Paul Bolger, University College Cork

9.30 SESSION 1
Chair: Peter Brown, Irish Research Council
Keynote: Christian Pohl, ETH Zurich
Global perspective on research co-production for improved sustainability outcomes

APPENDIX 3 CONTD.

10.00 CASE STUDIES – POLICY AND NGOs

Collaborative research for co-production of climate mitigation policy
Brian Ó Gallachoir, University College Cork

Restoration of the River Camac, Dublin
Mary-Liz Walshe, Dublin City Council

Cross-border co-production of environmental knowledge: a collaboration with civil society
Alison Hough, Athlone Institute of Technology and Mary Dobbs, Maynooth University

SAFEWATER: Low-cost technologies for safe drinking water in developing regions
Pilar Fernandez-Ibanez, Ulster University and Catalina Herrera, Centro de Ciencia y Tecnología de Antioquia, Colombia

10.40 Discussion and Q&A

11.00 Break

11.15 SESSION 2
Chair: Kerrie Sheehan, Sustainable Energy Authority of Ireland
Keynote: Carthage Smith, OECD

Addressing societal challenges using transdisciplinary research: policy implication

11.45 CASE STUDIES – INDUSTRY AND COMMUNITY

Food Futures: delivering environmental and sustainability agenda in agriculture and food
Nigel Scollan, Queen's University Belfast

Eye-Q: an Intelligent optical freshness profiler
Ultan McCarthy, Waterford Institute of Technology

Mapping green Dublin
Niamh Moore-Cherry, University College Dublin

Measuring sustainable actions at community level: The Community SDG Dashboard
Ainhoa Gonzalez, University College Dublin

12.25 Discussion and Q&A

12.45 Summing up

13.00 End

Organised by the Climate Change and Environmental Science Committee in collaboration with Future Earth Ireland and the Environmental Research Institute, UCC.

Supported by the Sustainable Energy Authority of Ireland

futurearth IRELAND seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND eri Environmental Research Institute RIA Acadamh Ríoga na hÉireann Royal Irish Academy

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