Climate Change—Does the IPCC Model Provide the Foundation for a Potential Global Technology Assessment Framework?

Peta Ashworth and Elliot Clarke

1 Introduction

Climate change has been identified as the "perfect moral storm"—global in nature with long-lasting intergenerational impacts (Gardiner, 2011) with a lack of the political will necessary to address the issues. The anticipated damage that ecosystems and society will bear because of adverse climatic events will place a significant burden on people, societies, the environment and the global economy unless greenhouse gas (GHG) emissions are significantly reduced. While there is now, a dedicated move towards net-zero emissions through stated aspirations of various industries and the laws of some governments, there is still a need for a pressing upheaval of existing systems, if the world is to remain well below the 2°C target of the Paris Agreement (UNFCCC, 2015) or the 1.5°C target outlined in the Special Report of the Intergovernmental Panel on Climate Change (IPCC, 2018a).

Beyond the hard science, climate change has become much more than just an aggregation of scientific data from the natural sciences. As Hulme (2010a, 267) states, the adverse impacts of a changing climate include "political, social and psychological functions", requiring important consideration of cultural interplays, value systems and regional differences that exist between the global north and south, and developed and developing countries.

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P. Ashworth (✉)
School of Chemical Engineering, The University of Queensland, Brisbane, Australia
e-mail: p.ashworth@uq.edu.au

E. Clarke
School of Political Science and International Studies, The University of Queensland, Brisbane, Australia
e-mail: elliot.clarke@uq.edu.au

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Integral to the global response to climate change are two international bodies. The first, the Intergovernmental Panel on Climate Change (IPCC), was established by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) in 1988. The IPCC serves as the core scientific advisory body delivering evidence-based climate policy recommendations from global scientific data into international climate negotiations convened by the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC comprises 197 countries and entered into force in March 1994 with the aim of preventing "dangerous human interference with the climate system" (UNFCCC, 2015). Understanding the potential societal impacts of mitigation technologies and supporting science that unpacks the use of resources and practises across sectors is a key function of the advice from the IPCC. Such a process of providing independent scientific advice is also at the heart of technology assessment (TA).

Here, we examine the structure, practises and methods of the IPCC as a legitimate scientific institution and its interplay with the global political decision-making forum of the UNFCCC and compare it with TA theory and practice. The principal aim is to investigate if such an institutionalised process of co-design, between governments and the researchers who gather scientific evidence for policymakers, could serve as a potential global TA model that can be applied to other global challenges. Through examining successes, shortfalls and some criticisms of the IPCC process, we identify how these challenges may be mitigated. We use TA analytical and impact frameworks (Belluci et al., 2002; Hennen et al., 2004) to investigate whether an image of legitimacy can be realised from a global governance perspective, and whether this can also help to build trust in science advice at the country and community level (Sanz-Menéndez, & Cruz-Castro, 2019). In short, this chapter applies a critical lens to the IPCC as one potential global TA model, arguing for the inclusion of grassroots participatory TA alongside traditional governance and reporting frameworks to deliver holistic solutions to climate change outcomes, and ideally other global challenges.

2 Technology Assessment

There is a long history that outlines how TA aims to support policymakers, and ultimately society, when making decisions surrounding the value of existing or emerging technologies and the potential risks and challenges they may present (Michalek et al., 2014). Historically, it originated as a science-led policy consultation device within economically developed institutions (Scherz et al., 2019). Framed as neutral decision-making advisories, immune from ideological or political interference, the use and prevalence of TA frameworks has varied across societal, geographical and temporal scales. This has resulted in a range of TA methods being developed over decades as a way of finding solutions to controversies and associated risks with the introduction of new scientific breakthroughs and technological innovations (Cruz-Castro & Sanz-Menedez, 2005).

At its core, TA provides the knowledge and processes to help society cope with innovation and mitigate potential social and environmental risks in future. The focus on societal outcomes has mutually implicated a strong reliance on political elements and influences (Ladikas & Hahn, 2019; Van Est & Brom, 2012). In so doing, TA as a source of advice, "must compete—and try to co-exist—with many other sources of information that politicians, governments, bureaucrats or parliaments use" (Cruz-Castro & Sanz-Menedez, 2004, 106). Competing sources of data for global problems like climate change are complex and require a global TA response at the corresponding scale. However, what often happens is that the experts that constitute TA advisories and policymakers as target audiences, often disagree about what path to take (Ladikas, 2019). This may result in a standoff, total inaction, or ineffective untested solutions being implemented-often decided in efforts to win votes and remain in power rather than being truly solutions oriented as recommended by the science. Evidenced in the climate change domain, this can have dire and often irreversible consequences.

The call for TA to be applied as a global model stems from the ever increasing need to address real-world problems through international cooperation and dialogue (Ladikas & Hahn, 2019). While some technological solutions have resulted in positive impacts, it is also evident that there can be unintended consequences across geographic regions of the world (Scherz et al., 2019). This is further influenced by the type of political system in which the technology is being deployed (i.e. liberal versus autocratic) and the country's level of economic development,[1] as this limits or enables capacity to respond. Van Est and Brom (2012) also refer to the importance of normative frames and an openness to consider and include alternative views as part of TA responses. Despite leading TA scholars acknowledging the need to bring together diverse cultural and societal nuances into a global framework (Ladikas & Hahn, 2019), there remains limited consensus on what a TA model at the global scale should look like, and how, or who by, it should be implemented.

While global TA has merit for dealing with complex challenges, there is also some discussion about its inability to accommodate different levels of scale. For example, some concerns remain surrounding how the deployment of TA solutions transpire locally. Currently, TA remains a high-income state-driven pursuit in more economically developed regions of the world (Ladikas, 2019). While there is a clear need for a global TA framework that transcends socio-economic and neo-liberal considerations, there is also recognition that local problems will require solutions that exist beyond a global TA framework to "consider contextual circumstances and aid decision-making in different settings" (Ladikas, 2019). The EUROPTA analytical framework (Bellucci et al., 2002), with a focus on participatory TA, provides a starting point for identifying necessary elements of what may constitute a global TA framework. It does this through recognising the interplay between society and institutional contexts and how participatory systems are organised. The solutions,

[1] The *World Economic Situation and Prospects* classifies all countries of the world into one of three broad categories: developed economies, economies in transition and developing economies.

outputs and corresponding advice generated from TA can be understood in terms of impact.

The connotations applied to "impact" within TA are often described as subjective. For decades, TA scholars have strived to balance the need to reflect normative endeavours without rigid expectations in the form of hard policy as its impact. Hennen et al. (2004) describe impact in the form of a three-dimensional typology aimed at policymakers that includes: (1) raising knowledge and/or awareness, (2) forming opinions and attitudes and (3) initialising action.

Raising knowledge can be viewed as an increase in the visibility of technical knowledge, or a broad overview of potential societal outcomes as a consequence of a new technological development (Hennen et al., 2004). This is because it is important to understand the social impacts of advances in technology, rather than solely an assessment of implications through scientific data. This can be further extended to an exploration of existing policies and objectives (Hennen et al., 2004). Second, forming attitudes and opinions helps in agenda-setting through influencing public discourse or stimulating public debate. This is invaluable when the public and other stakeholders are exposed to new technology and ideas with a relatively high level of uncertainty. These can be further explored through participatory TA activities such as scenario constructions or deliberative processes, which both present imagined futures of the technology as well as meeting expectations of procedural fairness through democratic deliberation (Hennen et al., 2004). The third dimension to the proposed impact typology references initialisation of action that may result in policy development, delivery and decision-making. There are also pathways towards introducing new models of governance, process implementation and other tangible initiatives (Hennen et al., 2004).

These understandings of impact aim to include varying outputs and lend themselves to a wider definition of impact: "Impact of TA is defined as any change with regard to the state of knowledge, opinions held, and actions taken by relevant actors in the process of societal debate on technological issues" (Hennen et al., 2004, 61). This is also true when considering climate change.

Across the world, the public are increasingly exposed to the potential social and ecological impacts of climate change, with those countries least able to respond to climate change being the ones most vulnerable to its impacts (UNFCCC, 2020). To overcome this, there are a range of mitigation and adaptation solutions being generated, particularly, as the urgent need to mitigate GHG emissions becomes even more apparent (IPCC, 2021a). Some of these are challenging the status quo, or traditional ways of working, as well as associated cultural rituals. Given the complex and global nature of the climate crisis, a global TA response has been positioned as a necessary framework to address the corresponding risks. The IPCC offers a substantive global TA model that not only provides scientific advice to policymakers but may also be applied to other grand challenges. Understanding the influence of the IPCC and climate change on real-world outcomes requires further investigation of the constructed and definitional nature of 'impact' as a consequence of distributed climate assessments. The impact of IPCC advice through Hennen et al.'s (2004) typology holds true for how advice is received and inserted into public debate,

particularly when attempting to measure its influence on policy. Reflecting on the current state of play for climate change mitigation suggests the IPCC framework, while not perfect, provides one potential model for an effective global TA framework, as detailed below.

3 The IPCC Model: Potential as a Global TA Framework

3.1 History of the IPCC

Established by the World Meteorological Organisation (WMO) and the UN Environment Program (UNEP), the IPCC was endorsed by the UN General Assembly on 6 December 1988. Its initial task, as outlined in UN General Assembly Resolution 43/53, was to review and prepare climate change science and outline the ecological, social and economic costs of environmental degradation (IPCC, 2021b). The IPCC brings together scientists from approximately 80 countries across the world. Critical to its relevance to governments is its recognition as a government institution, as demonstrated in its name; "Intergovernmental". The IPCC releases an update on the latest science every 5–7 years. The first assessment report (FAR) was released in 1990, which "underlined the importance of climate change as a challenge with global consequences and requiring international cooperation" (IPCC, 2021b). The second reporting cycle was released in 1996, and directly guided decision-makers prior to the finalisation of the Kyoto Protocol in 1997. These were subsequently followed by a third report (2001) aimed at addressing adaptation, and a fourth report (2007) that laid the foundations for a post-Kyoto world. The fifth report, issued in 2013, directly advised what would become the Paris Climate Agreement on December 12, 2015. Currently, in its sixth assessment period, the IPCC has recently produced "AR6 Climate Change 2021: The Physical Science Basis" from Working Group 1 (IPCC, 2021a), along with technical papers, methodology reports and special summary reports (IPCC, 2021b).

Throughout these periods of assessment, releases and reporting cycles, the IPCC asserts that their advice has accelerated peer-reviewed literature on climate science, increased public awareness, and fostered collaboration and participation between different actors to achieve the targets set by the global community. In its view, this consistently leads to international climate change decision-making and policy reforms (IPCC, 2021b). Notably, in 2007, IPCC authors, in conjunction with Al Gore, were awarded the Nobel Peace Prize "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change". There is possibly no higher recognition of their contribution and policy impact on the world.

3.2 IPCC Structure

The IPCC has a sophisticated structure which is integral to its success and operations. It comprises three core working groups: Physical science basis, impacts, adaptation and vulnerability and mitigation of climate change; and a Task Force Bureau that oversees the National Greenhouse Gas Inventories Programme (IPCC, 2021c). The nature of these working groups in many ways resembles what has been described as expert TA, where experts come together to gather scientific information in relation to an identified problem (Van Est & Brom, 2012). Using Hennen et al.'s (2004) typology, much of this early work would fit under the first stream of raising knowledge and awareness of the issues at hand. Each working group consists of lead authors, review editors, and chapter scientists who are tasked with collating and presenting relevant research. As experts in their own fields, IPCC authors have been approached by member governments to participate and, if accepted, volunteer their time to do so (IPCC, 2021c). There is also a large external cohort of government representatives and researchers who operate as expert reviewers, based on their fields of expertise. All of this is underpinned by a secretariat which coordinates the wider IPCC organisational, administrative, and planning matters.

The IPCC 195 member governments, along with representatives from observer organisations, convene at least once a year (more during assessment cycles), in the form of Plenary Sessions. This government mechanism is known as "the Panel" and is critical to the overall functioning and success of the IPCC. "The Panel works by consensus to decide on the organisation's budget and work programme; the scope and outline of its reports; issues related to principles and procedures of the IPCC; and the structure and mandate of IPCC Working Groups and Task Forces. The Panel also approves and adopts IPCC reports and elects the IPCC Chair, other members of the IPCC Bureau and the Task Force Bureau." (IPCC, 2021c, 1). Whether the structure and mandate of the Panel can be replicated will be an important consideration for a global TA model.

3.3 Processes

The IPCC processes, and any subsequent reviews, are advised by a set of 10 sub-principles (IPCC, 2018b). These include reaching consensus amongst working groups for decisions relating to procedures; deciding when IPCC findings are made official; matters relating to time-frames for participating actors; issues surrounding how reports are made available, by when, and in what languages; process scheduling; financial procedures; and how elections are conducted (IPCC, 2018b). The resulting processes can be understood in terms of (a) reporting, (b) writing and reviewing, (c) error protocol, (d) conflicts of interest, (e) funding, (f) communication, (g) gender and (h) observer organisations.

Firstly, IPCC publications consist of three sub-channels to deliver climate advice. IPCC Reports include "Assessments, Synthesis and Special Reports, their Summaries for Policymakers, and Methodology Reports" (IPCC, 2021d). These are supported by technical papers and other materials inclusive of workshop proceedings and databases to assist other generational processes. Second, writing and review processes are subject to Review Editors that include the "consideration of the range of scientific, technical and socio-economic views" (IPCC, 2021d). Third, error protocols were introduced whereby concerns surrounding reporting can be investigated. Fourth, a conflict-of-interest component of the procedural process is designed to protect the legitimacy and integrity of the IPCC's reporting and associated activities: "individuals must disclose circumstances that could lead a reasonable person to question an individual's objectivity, or whether an unfair advantage has been created, constitute a potential conflict of interest." (IPCC, 2021d). Fifth, IPCC funding is sourced from member organisations and parent bodies, the WMO and the UNEP. Further support is provided as in-kind contributions from governments providing experts to produce the advice generated by unpaid member-sponsored experts (IPCC, 2021d). Finally, communication constitutes who the audience is, that is, which policymakers are viewed as important in the global climate discussion and which are not. This can be problematic throughout the internalised decision-making process when selecting authors and editors (IPCC, 2021d).

3.4 Technologies

Relevant to any TA discussion about the IPCC are the technologies being assessed. Within the IPCC there is a focus on both mitigation and adaptation, which means there are a range of technologies being examined. With mitigation, the IPCC reports synthesise the latest peer-reviewed information on each of the technologies and the scenarios which model their potential deployment, to make an assessment on their potential for effective GHG mitigation. Most of the work to assess these technologies, i.e. the early TA component, is undertaken by other reputable external bodies, including the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA) and various other regional or country-specific researchers and research groups. This TA work tends to be funded by the different bodies who are subsequently referenced within the reports. However, at times the UNFCCC will issue calls for specific technological reviews to inform their work. The range of technologies for mitigation includes renewable energies such as solar, wind, biomass, biofuels, nuclear energy, energy storage, hydrogen and other more contentious technologies such as carbon dioxide capture, utilisation and storage.

Work is also undertaken specifically around technologies for developing countries, through the United Nations Sustainable Energy for All (SEforAll), for example. These programmes tend to focus on technologies for improving energy access and reducing harmful effects of more polluting and inefficient technologies (e.g. biomass cookstoves and kerosene lamps), prevalent in many developing countries. Coupled

with this work, is the identification of necessary government support and trialling the effectiveness of various financial mechanisms to achieve greater technology deployment. Most of the SEforAll work is funded from philanthropic organisations and large aid initiatives such as UK Aid and USAid Power Africa.

For adaptation, the technologies can include anything from new land management practises, livestock systems and management of their ruminants, agroforestry, irrigation efficiencies, waste management and more novel technologies such as molecular biology, genome modification, new marine and freshwater flora and fauna and so on (de Coninck et al., 2018). The specific types of TA activities vary, depending on the level of technological development, where the TA activity is being undertaken, and what the assessment need might be. All of this information feeds into specific country targets.

4 Climate Change State of Play

Following the Paris Agreement, all countries were obligated to set national targets known as Nationally Determined Contributions (NDCs), which outline the ways in which they will reduce their GHG emissions. NDCs have been "at the heart of the Paris Agreement" (UNFCCC, 2021), and represent the initialising action stage of the typology of impacts discussed earlier (Hennen et al., 2004). It is the responsibility of each member country to set targets to reduce emissions at the nation state level and report these through the UNFCCC every five years. Other critical elements relate to adaptation, finance, transparency and accountability mechanisms for emissions trading.

Despite all these processes, the world continues to do poorly in delivering the goals and targets required by the Paris Agreement. Today, the world is 1.1°C warmer when compared to pre-industrial levels, and on a decadal average in 2020, was 1.24°C above pre-industrial level (IPCC, 2021a). This clearly requires an immediate coordinated global response, as often highlighted by the UNFCCC and other concerned scientists (UNFCCC, 2020; Union of Concerned Scientists, 2020). More recent climate data also underscores the urgency for mitigating climate change and to stay within the Paris Agreement targets of limiting global warming to 1.5°C, or at most 2°C, and achieving carbon neutrality by 2050 (UNFCCC, 2021). The International Climate Energy Related Developments Review (UNEP, 2020) and others have determined that emissions have continued to rise since the Paris Agreement and are mostly attributed to the burning of fossil fuels (Le Quéré et al., 2021).

While there is some optimism that certain countries are projected to make positive inroads towards decreasing their emissions, there is consensus that no country is doing enough to keep temperatures well below the required 2°C increase (IPCC, 2018a). Even with the countries who committed to the Paris Agreement fully implementing their NDCs, the world is falling well short of meeting the required GHG emissions reduction (Roelfsema, et al., 2020). This of course is leading to substantial consequences for the environment and the global community (IPCC, 2021a). In

particular, the most vulnerable and marginalised people, who are least likely to be able to withstand the potential impacts of climate change, are unfortunately often the ones who are most exposed (UNFCCC, 2020; Rigoud et al., 2018). This places a burden on more developed countries to find solutions which, often, are technological in nature.

Accelerating the support, advice and access to information provided to vulnerable regions from wealthier states, which are tasked with fostering resilience across varying societal scales, is critical to mitigate climate change impacts. Such conclusions have real-world implications for ecosystems and livelihoods when determining vulnerability and accountability. For example, while China remains the world's leading emitter of carbon dioxide (CO_2) emissions, contributing 28% of global emissions, its contribution per capita remains relatively low, particularly when compared to the Organisation for Economic Cooperation and Development (OECD) nation states (Union of Concerned Scientists, 2020). This brings into question the responsibilities of more developed regions when measuring per capita carbon emissions, and how best to ensure the necessary climate change action, by whom and at what level (World Bank, 2016; World Bank et al., 2016).

In Europe, the European Parliamentary Technology Assessment (EPTA) network has undertaken a number of TA-focused activities in relation to climate change. Its 2015 report was designed to provide politicians with climate change information containing "…new and rigorous insight on these challenging and far-reaching questions, generally not presented by medias in proper ways for political decisions" (EPTA, 2015, p.8). More recent activities have included the Norwegian Board of Technology's focus on Norway's emerging capacity to produce green hydrogen through the availability of cheaper sources of renewables (NBT, 2021). Germany continues to focus on energy efficiency in building construction to discern adequate cost–benefit results (TAB, 2021). And, Greece has been working on tools for investigating the effects of natural disasters arising from climate change (GPCRT, 2019). Despite activities such as these, progress on mitigation remains low.

5 Reflections on the IPCC Model: Successful or Not?

Given the slow progress towards mitigating climate change impacts, there is an opportunity to unpack the interplay between the IPCC and the global political decision-making processes and the policy implementation of the UNFCCC and nation states. Acknowledging both the IPCC's successes and shortcomings provides an opportunity to understand whether the structure of the IPPC model could be more successfully developed into one possible global TA framework to be applied across multiple grand challenges. It evokes the question whether building such a model of trust and legitimacy through global science can better serve advisory outcomes for international policymakers, and ultimately broader society, around contentious issues.

Indeed, it has been a global success that an assessment of scientific data and technology to combat climate change was cooperatively established in the form of the

IPCC. Certainly, there have been more nuanced successes when measured against the impact typology outlined by Hennen et al. (2004). The first, raising knowledge, can be evidenced through the visibility of technical knowledge via the reports that are created and distributed to policymakers and made accessible to the public. Second, these reports are regularly inserted into public debates surrounding action on climate change by various actors, including NGOs, community groups, journalists, industry and policymakers. Third, states have initialised action by making commitments towards net-zero emissions as a consequence of IPCC reporting. These have manifested into policies that subsidise renewable energy projects at both a household and commercial scale, along with other mitigation and adaptation policies. However, are these successes enough? While these accomplishments can be understood and mapped to Hennen et al.'s (2004) impact typology, most countries which are signatories to the Paris Agreement will miss their reduction targets. There remains a serious discord between softer impacts and initialising collaborative real-world policies to mitigate climate change, although this does fall outside the mandate of the IPCC.

Although many are supportive of the IPCC/UNFCCC process, there remain some areas of contestation surrounding it. These include: lack of impact in achieving global emissions targets, mainly due to a lack of political will; the degree of autonomy the IPCC has when conducting a reporting cycle and communicating its findings; whether seeking consensus results in obscuring or making invisible the crucial differences between diverse global communities; the minor historical errors in reporting advice which diminished perceptions of the integrity of the advice at the time; and finally, whether the IPCC publications, at times, have been too technical, thus compromising their ability to be accessible to policymakers and other actors. These critiques aimed at the top-down model of the IPCC are expanded upon below.

5.1 A Requirement for Increasing Impact Through Initiating Action

The IPCC process was established to inform policy without being policy prescriptive, which is what allows it to gain support within government processes. However, a vacuum in mandatory oversight combined with the observed inability to initialise action at the global level, appears to be a major obstacle in generating and maintaining trust in the effectiveness of the IPCC process. Questionable and misleading claims of enforceability through the UNFCCC have also complicated the translation of the IPCC advice into real-world policy actions. Whereas in other issue areas such as the Montreal Protocol on Substances that Deplete the Ozone Layer (UNEP, 2020), marine dumping laws through the 1996 London Protocol which entered into force in 2006 (IMO, 2006), and the General Data Protection Regulation in the European Union (European Commission, 2016), international compliance remains high. It appears that the complex nature of climate change poses a significant barrier to

international cooperation in meeting targets to mitigate GHG emissions, particularly if governments choose not to respond to the IPCC's advice.

An example of this is the problematic nature of the Kyoto period climate targets. The targets were thought to impact economic competitiveness, be too complicated to ensure compliance, and ultimately difficult to monitor and enforce (Victor, 2011). Without binding commitments through the decision-making arm, the UNFCCC, or some other governance mechanism, this raises an important question of legitimacy, and whether public confidence in such processes can be maintained, and more importantly if they will ever be effective.

The complications come in two forms. The first, the flexible set of country-based actions determined by each individual state (NDCs), makes serious targets difficult to enforce; and second, a lack of binding penalties (Denchak, 2021) further complicates mechanisms to penalise or encourage non-conforming states which are party to the Paris Agreement. While there have been instances of the UNFCCC enforcement branch issuing notices of Paris Agreement compliance breaches for reporting failures (UNFCCC, 2020), the examples do not recommend any action other than submissions or reviewing internalised reporting protocols. It has been suggested that implementing such a mechanism would likely undo the ability of governments and scientists to reach agreement in the first place.

While enforceability, and lack thereof, at the global level through the UNFCCC is outside the remit of the advisory role of the IPCC, the failure to meet current global mitigation targets suggests the need for additional measures alongside the scientific advice and recommendations of the IPCC process. This corresponds with the initialising action stage of Hennen et al.'s impact framework, which implies there may be a role for regulators which are not involved in steering the science to play a role in mitigating poor outcomes (Van Est & Brom, 2012). Alternatively, another peak body could be established for this purpose, but either way, it is a question that will need consideration when trialling any global TA model in future.

5.2 Consensus and Situated Knowledge

The scientific community has conferred support for the overarching consensus on climate change knowledge claims, including the advice and modelling by the IPCC. Agreement can also be found outside the domain of science within government institutions. For example, US, UK and other European officials are charged with providing direct advice to politicians and committees. The IPCC has found allies in civic society, activists, and NGO groups aligned with environmental matters (Ray, 2011). However, the push for consensus through the UN process has been accused of simultaneously "making invisible" localised challenges and individual struggles at the community scale. How climate knowledge is created or discarded, respected or shunned, or determined to be of value within the scope of the IPCC reporting cycle may exclude some knowledge into the periphery. However, given the nature of

the synthesis, which combines the work of over 50,000 research outputs, this is not unexpected.

Researchers are not arguing against the need for a global model to approach TA and climate change, rather Kunelius et al. (2016) and Hulme (2010a, 2010b) are mindful of presenting knowledge as a universal truth determined by consensual processes that ignore key concepts such as identity, sense of place and time (Hulme, 2010a, 2010b). "Rather than seeking a consensual global knowledge which erases difference and allows the most powerful to determine what is "known", we need to pay greater attention to the different ways knowledge comes to be made in different places and how different kinds of knowledge gain hold in people's minds, traction in different cultures and assent in global fora. This is spectral knowledge which emerges from a cosmopolitan perspective." (Hulme, 2010a, 2010b, 563).

Potentially "washing over" situated knowledge of climate change in the quest for consensus may curb nuanced understandings. This is especially true for indigenous knowledge and other cultural representations that are often neglected in the IPCC reporting in favour of positivist Western ways of knowing and understanding a changing climate (Corbera et al., 2016; Ford et al., 2016). Ford et al., (2016, 351) argue the importance of prioritising indigenous knowledge in the next round of IPCC reporting. This highlights an important challenge confronting the IPCC that has not been solved. How does the IPCC maintain a global purview while acknowledging the diverse cultural and situated experiences and knowledge at the community scale? This is particularly so if not all indigenous knowledge has been published in the more traditional literature formats, which is also a requirement of the scientific approach to knowledge. Ladikas and Hahn (2019, 10) acknowledge this challenge as important to any global TA framework that may be developed.

5.3 Public Trust in Reporting: Integrity, Errors, and the Need for Transparency

Similar to the discussions on TA, the IPCC is not always considered a neutral knowledge base. Authors, editors, reviewers and the UNFCCC which responds to the advice of the IPCC are all compromised by their own norms and values that determine what knowledge is valuable and what is not (Corbera et al., 2016; Ford et al., 2016). While Ford et al., (2016, 349) acknowledge the importance of the IPCC in delivering climate advice, they also argue that applying a critical lens to IPCC reporting reveals inequalities hidden by a specific technocratic approach to knowledge and consensus: "… it has also been noted that the procedural rules governing how the IPCC operates and the positionality of the author teams (for example, disciplinary background) has resulted in the privileging of positivist science and technocratic perspectives, the marginalisation of other ways of knowing (for example, local, traditional and indigenous knowledge) and the prioritisation of scenarios and modelling approaches" Ford et al., (2016, 349).

Arpino and Obydenkova (2020) concede there has been a decline in trust in the United Nations and its associated bodies since the 2008 financial crisis. This coincides with ongoing miscommunication problems that destabilise or erode trust between the scientific community and the general public (Rabinovich et al., 2012). These concerns are exacerbated by the ever-increasing complexity of the inter-related nature of climate change and the evolving consequences that need to be absorbed by the public in order to take effective action (Rabinovich et al., 2012).

The IPCC as an international organisation is no different to others of equivalent standing, and has been subject to various criticisms. For example, it has been challenged about the lack of transparency in assessment models and questionable funding agendas within the research community (Robertson, 2020); the "Climategate" issues associated with the email hacking of the Climate Research Unit at the University of East Anglia in 2009 which impacted overall trust in the process (Nature, 2010); and issues challenging the ambiguity of its assertions in relation to Himalayan glaciers and Amazon rainforests which were later clarified (Ray, 2011). Clearly, issues of transparency need to be proactively addressed and considered for any global TA model.

5.4 Accessibility: Understanding and Scale

Harold et al. (2020) suggest that some of the IPCC information and data is, at times, considered too technical for policymakers, and therefore requires improved presentation to make the information more accessible. Criticisms have focused on the information being difficult to understand and inaccessible to non-specialist audiences, especially policymakers, primarily based on poor readability of the text (Barkemeyer et al., 2016; Budescu et al., 2014; Mach et al., 2016) and the structure of documents (Stocker & Plattner, 2016).

This challenge can be further extrapolated to the overall process of national country actors identifying their nationally determined contributions (NDCs). While the NDCs may be developed with the best intentions, they too can become inaccessible to those at the state and local government level, not to mention local communities. This has been attributed to both a lack of clarity surrounding the information, and also the required mechanisms for implementation. This suggests that while there is a need for a global TA model, attention must also be given to making the information accessible across different scales, rather than leave it solely to national governments.

Since the 1990s, there has been a long history of change in TA practises from more expert-centred advice to more participatory practises (Joss & Belluci, 2002), implementing methods such as consensus conferences, citizens summits, and future panels, for example. In climate change, citizens' panels provide a model that enables local communities to engage with the science and technological innovations in an evidence-based way. Implementing local deliberative panels could easily work in unison with the global and national level TA models outlined above to ensure translation at the local level. Key authors in the field have long argued for new and

innovative ways to include citizens in decision-making. They assert the need for new pathways and innovative TA models that create cooperatives of experts, citizens, and policymakers (Ladikas & Hahn, 2019). Similarly, Van Est and Brom (2012, 312) contend that TA can be "positioned as a more general and open process for involving the public in policy dialogues and building societal consensus on issues of technological change."

What is not clear is how this may be accomplished in developing countries with varying levels of capacity to participate. If the underlying assumption of participatory TA implies participation of the range of stakeholders impacted by the technology, then careful consideration must be given to involving developing countries in these processes. Fortunately, the IPCC funding model, which sponsors developing countries to attend the range of meetings that form the process of the assessment period, has allowed for the participation of some key representatives from the developing countries at these meetings. However, whether such sponsorship is all inclusive, allowing equal participation from the range of developing countries remains to be seen. There is also a need to consider how to engage at local sites to maximise stakeholder participation within countries. Fortunately, the experiences gained from the development literature is also of value here, presenting tried and tested processes for engaging with local communities across developing countries (Gaventa & Barrett, 2012; Najam, 2005).

One example of how collaboration has been facilitated between the developed and developing world through multilateral funds is seen in the Kigali Amendment to the Montreal Protocol (UNEP, 2021). In the amendment, where countries "agreed to phase down Hydrofluorocarbons (HFCs) over the next 30 years and replace them with more environmentally friendly alternatives" (UNEP, 2021), it was agreed that developed countries would take the lead from 2019 and then, through a phased approach, developing countries agreed to "freeze" their HFC levels in subsequent years beginning from 2024. All countries participated in reaching the decision, but the roll-out approach provided greater consideration to the needs of those in developing countries. This provides an example where the developed world took the lead to learn the process and then assist developing countries through capacity-building and shared knowledge. Such knowledge-sharing across all scales is a key part of the successes of the IPCC.

6 Discussion

The IPCC model of bringing together scientific experts from across the world to synthesise scientific evidence that relates to climate change, provides an encouraging framework for one possible global TA model. However, given the slow progress towards climate mitigation goals we recommend there is a need to address the identified deficiencies to ensure a truly effective model. There is also scope to better understand what the barriers to change have been and then assess whether information or political and economic processes are the best ways of addressing these. A

global TA model ideally needs to have some influence on both policy and real-world outcomes to be considered as having impact-providing leadership and direction for appropriate and long-lasting solutions to persistent problems. Further, there will always be other institutions or actors that produce competing information, including regulatory bodies, think tanks and lobby groups on contested issues which governments and individuals must grapple with (Oreskes & Conway, 2010). TA needs to compete with these other forms of information if it is to have a significant influence on decision-making at the highest levels, and of course be based on the best scientific evidence. The interplay between governments and researchers in the IPCC process provides hope for this.

The four central challenges of the IPCC identified were: (a) lack of impact through initiating action based on current government commitments; (b) the pursuit of consensus-based and situated knowledge; (c) reporting inaccuracies leading to mistrust; and (d) accessibility of information across different scales. While these deficiencies lead to matters of legitimacy, they are not dissimilar to the ongoing discussions of TA scholars. We suggest there is potential for each of these deficiencies to be addressed using lessons learned from TA scholarship and frameworks that may result in more authentic and accepted outcomes.

For example, establishing legitimacy through TA processes has been fostered through the inclusion of participatory TA and deliberative democracy as grassroots ways to address matters of scale, inclusivity and knowledge production. Admittedly, there are challenges with translating deliberation in social trust, and results can vary depending on how strong a country has been at conducting deliberation historically (Jørgensen et al., 2016). This is made even more challenging in poorly organised civil societies or in political environments closed from public participation (Jørgensen et al., 2016). Such considerations are reflected in the EUROPTA analytical framework (Bellucci et al., 2002), which recognises that within social and institutional contexts Participatory TA has three dimensions. These include: (i) set-up and process—ultimately focusing on the design and interaction arrangements; (ii) values assumptions and goals—that relate to the problem definition and justification for participation; and (iii) outcomes—directly referring to communication of the results and impact. Importantly, herein remains a normative challenge. Neither shared visions nor values result in tangible impact or political outcomes by default, and therefore cannot be guaranteed (Delvenne & Parotte, 2019). This could be due to a lack of reflexivity amongst actors, or an explicit or implicit preference towards a matter within TA communities for political reasons (Delvenne & Parotte, 2019). Whether shared visions or values are aligned or divergent is also a matter for consideration across scales.

Similarly, when considering participatory TA models across jurisdictions, there has been extensive debate around whether the processes developed for one country can be simply introduced into another country without modification (Joss & Torgersen, 2002). Whether this is possible or not, will be influenced by the role the participatory TA method is expected to play. What is the issue being investigated, and who should participate to ensure the process is truly inclusive and representative across scales? What assessment is being sought and for whom? When considering

a global TA participatory framework, it will be important to acknowledge where governance systems either converge or diverge, as this will impact the likely success of the process and its perceived legitimacy. Similarly, how marginalised groups are treated within such participatory processes will also significantly affect outcomes and whether the results are valued. Trying to extrapolate these considerations across scales is not without its challenges, and should not be underestimated.

In relation to climate change, Michalek et al. (2014, 17) suggest that: "A lack of consensus on the global level greatly affects the local, where, for example, the negative effects of climate change are often mostly visible. In this sense, sustainable behaviour can only be fostered by participation of the general public in local policies (e.g. the e2democracy project, 2012)." This global versus local impact is relevant to many global challenges beyond climate change, and is why considerations of other TA activities that work at different scales is important. This confirms the need for an expanded role for participatory TA at the grassroots level while continuing to deploy global TA based on either the IPCC or other models. Such a process would allow for broader political debate and directly manage the linkages between science, policymakers and society more generally (Van Est & Brom, 2012). Subsequently, it develops a deeper understanding of the social dimensions of technology (Van Est & Brom, 2012), and can foster more viable visions for the future use of technology or issues across the different scales and through discussion, helping to facilitate knowledge acquisition across broader society, beyond the experts (Ely et al., 2011, 2).

Rabinovich et al., (2012, 11) also highlight the value of the interactions and deliberation between actors when reconciling trust in science between those communicating the message and those receiving it. "…the success of communication often does not reside within the message itself (however masterfully it may be constructed and framed), but within the dynamic interaction between the communicating partners … Of paramount importance to such interactions is communication partners' ability to recognise each other's position and the fact that this position may be different from one's own." This applies for almost any contested topic. It reinforces how the communication of scientific information can benefit from public deliberation between actors and citizens. Ultimately, this allows for a broader TA model that is inclusive of public input, leading to less confusion on the topic. In addition, where scientific information is localised and contextualised this could also improve its accessibility across scales: geographical, societal and temporal.

Outside the IPCC and participatory TA models, there is a clear shift away from the linear historical understanding of how technology is incorporated and used in our lives. This is important, as technology and society are in a mutually fluid, dynamic relationship. Van Est and Brom (2012, 316) note: "During the mid-1980s, the central tenet of science and technology studies (STS) became that technology and society co-construct each other. This implies that technology not only effects society but is also shaped by society." This interplay is heavily reflected in more recent discussions surrounding the legitimacy of TA. It is therefore critical that social, economic and political dimensions are acknowledged across IPCC processes to further develop legitimacy through transparency. This advice is similarly suggested by other scholars

advocating for ongoing awareness of the political role of science across all forms of TA (Delvenne & Parotte, 2019; Van Est, 2019).

A word of caution is required in relation to translating the IPCC model into one potential global TA framework. One example that shows the difficulty in replicating the IPCC is the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). This began with the intention of being a science-led arrangement. However, as it failed to gain traction, it subsequently tried to integrate governments using the IPCC model, but failed (Larigauderie & Mooney, 2010). Criticisms of the IPBES suggest this is because governments saw it as the research community attempting to gain influence over policy rather than a legitimate approach to co-design. Other criticisms surrounding the IPBES include the difficulties of trying to gain consensus over the very localised and regional nature of specific biodiversity loss, compared to the global need to reduce GHG emissions. This need for consensus is exacerbated by the increased demand for diversity (i.e. youth, other stakeholders, knowledge systems) amongst those participating in the process, beyond just the expert view (Diaz-Reviriego et al., 2019). This lack of unity across the scientific community of biodiversity experts has exacerbated its ability to influence policymakers and has negatively impacted its overall credibility (Masood, 2018). However, those from within the IPBES are proactively working to overcome these challenges in an attempt to maintain the legitimacy of an important scientific area (Borie et al., 2020).

A final consideration, if the IPCC framework is to be applied more broadly as a potential global TA framework, is the issue of funding. In 2017, the IPCC formed an ad hoc task group to reflect on its financial stability because of a concern about the overall drop in long-term funding. The establishment of the IPCC Trust Fund early in the life of the IPCC has helped it to be sustainable over the longer-term (IPCC, 2017). However, this success is very much based on the generous contributions of member organisations, combined with the large in-kind contributions from governments who provide not only experts and their associated advice and attendance at meetings, but also host IPCC events at no charge (Takashima et al. 2010). Reliance on such generosity is perhaps one of the greatest weaknesses for the IPCC model if it is to have potential as one such global TA model. While this will need special consideration, the existence of the EPTA network suggests some governments are already supportive of TA, and therefore provides hope that this might be extrapolated to a more global approach to funding. As always, consideration for how developing countries are provided for within these frameworks must remain a priority.

7 Conclusions

The IPCC process as a TA model has achieved significant success in raising public awareness and informing attitudes towards climate change. Recent reporting corresponded with clearly discernible responses from the international community charged with policy construction and delivery. This continues to instal optimism in the ongoing quest to mitigate climate change impacts. However, despite wider public

awareness and engagement across different scales and between diverse actors, there are known barriers that have impaired the IPCC's progress. The problems identified in this chapter included measuring the effectiveness of impact through commitments, the problematic nature of consensus and accommodating situated knowledge, transparency and reporting accuracy and accessibility of information across scales.

Applying TA analytical and impact frameworks to these problems suggests these challenges are not insurmountable, especially when the global successes of the IPCC are taken into consideration. Improving transparency through participatory approaches across scales is at the heart of TA. There are examples of TA participatory practises in both democratic and non-democratic states which provide further insights for building a global TA framework that will help in overcoming the concerns surrounding trust, inclusivity and communication across scales.

All grand challenges, including climate change, need a sustained social and political commitment to overcome them. Integral to the IPCC process is the influence of the Panel and the unique co-design elements between government and researchers in setting parameters for ongoing assessment and reporting. Coupling these insights with the analytical TA framework underscores a process that accommodates the fluid nature of how humans and society interact with technology. Using participatory processes, which are mindful of situational and institutional contexts and allow stakeholders to co-create their own understandings provides hope for demonstrating a concrete way forward: One, that is inclusive of cooperation between the state, industry and citizens to inspire and strengthen innovation fairly. The reflexive nature of participatory TA, combined with the learnings from the IPCC process and its interactions with the UNFCCC, solidifies a point of departure for delivering one such practical global TA framework more broadly in future.

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