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Prepare Scientists to Engage in Science-Policy

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Abstract There is a dire need for deeper science-policy engagement to face recent developments such as entering into the Anthropocene and our dependence as a species on technological and scientific advancements. However, there is a lack of preparedness and training of scientists about what science-policy engagement is and how to get involved, with substantial discrepancies globally. We present four gaps and possible solutions to those gaps to better train and prepare scientists to engage in science-policy. (1) Frame science-policy as a system. The framing of a science-policy interface is misleading. A better framing is the science-policy system, in which two processes, science and policy, are under the influence of each other. (2) Teach the science-policy system. Scientists should have a basic understanding of what the science-policy system is, and the implications that has for their research. (3) Engage in the science-policy system. Make the research on science-policy more readily accessible to the users and share experiences and lessons learned from those that have engaged in science-policy to foster greater engagement. (4) Value engagement in the science-policy system. Scientific institutions need to place greater value on science-policy engagement by setting up structures, award systems, and incentives for scientists to engage science-policy.

Plain Language Summary There is a dire need for deeper science-policy engagement to face recent developments such as entering into the Anthropocene and our dependence as a species on technological and scientific advancements. However, there is a lack of preparedness and training of scientists about what science-policy engagement is and how to get involved. We present possible solutions to better train and prepare scientists to engage in science-policy. (1) Frame science-policy as a system. The framing of a science-policy interface is misleading – the systems are already linked in myriad ways. A better framing is the science-policy system, in which two processes, science and policy, are under the influence of each other. (2) Teach the science-policy system. Scientists should have a basic understanding of what the science-policy system is, and the implications that has for their research. (3) Engage in the science-policy system. Make the research on science-policy more readily accessible to the users and share experiences and lessons learned from those that have engaged in science-policy to foster greater engagement. (4) Value engagement in the science-policy system. Scientific institutions need to place greater value on science-policy engagement by setting up structures, award systems, and incentives for scientists to engage science-policy.

1. Introduction

In recent years the calls for greater science-policy engagement have gotten louder, and the complex challenges that require greater discourse - among scientists and policy makers - and action have become even more urgent. To address the planetary and societal challenge of climate change, and tackle the necessarily ambitious targets set forth by the Sustainable Development Goals, we need science in policy (Dilling & Lemos, 2011; Rosen, 2018; Safford & Brown, 2019). Similarly, we need policy to be an integral part of science, whether it is to regulate scientific research around controversial issues like climate intervention (Jinnah et al., 2019; Low & Schäfer, 2019; Parker, 2014) or human gene-editing (Cyranoski, 2019), or to prioritize research efforts in emerging areas of societal importance, such as the health impacts due to the smoke from the recent Australian bushfires (Vardoulakis et al., 2020). We need tighter coupling between science and policy in order to manage grand challenges – global and societal challenges that require commitment from science, technology, the public, policy and politics due to their complexity and far reaching impact (Omenn, 2006). Coupling science and policy leads to closer connections between decisions and evidence,

faster uptake of new findings by policy, understanding of both problems and solutions, and clearer mechanisms for prioritizing knowledge generation for a transformation to a sustainable future (Watson, 2005; von Winterfeldt, 2013). And yet, we recognize that policy making integrates a variety of voices and inputs reflecting different goals, and that engagement by the scientific community is just one voice among many (van der Hel, 2018).

The challenge and complexity in these problems will not be solved by greater science-policy engagement alone. However, the voice of science should be stronger and more effective with better preparation (Selin et al., 2017). As called for by Jane Lubchenco, the former administrator of NOAA, "it's time for us collectively to make a quantum leap in our [scientists'] engagement with society. It's time to change the culture of academia and to mobilize enabling conditions for science to serve society more effectively" (Showstack, 2019).

Scientists are increasingly being asked to provide information to support decision-making and inform policy (EC, 2016; Nowotny et al., 2001; Sarewitz & Pielke, 2007; van der Hel, 2018). Both the European Commission and the US National Science Foundation, for example, require proposals to address the broader impacts of research, such as how the proposal addresses the Sustainable Development Goals and benefits society (https://www.nsf.gov/pubs/2007/nsf07046/nsf07046.jsp). The growth of the American Association for the Advancement of Science (AAAS) Science and Technology Policy Fellowship program and global initiatives such as Future Earth that call for "a new type of science that links disciplines, knowledge systems and societal partners" (FutureEarth, 2014) are testament to an increased interest in science-policy engagement from both scientists and policymakers. Despite the requirements for scientists to indicate the societal impacts of their research, the increased interest from scientists, particularly early career scientists, in science-policy engagement, and the recognition that we live in a time when science and policy are constantly impacting each other, there is little to no training for scientists, particularly outside of the US, on why it is important to understand the policy context in which they conduct their science, what it actually means to engage in science-policy, and what the different options for engagement are.

A parallel to Earth systems science can be drawn. Although we as scientists often specialize in a discipline, such as atmospheric science, we recognize the importance of understanding the Earth system as a whole, as the processes in one area have implications and impacts on the other areas. Similarly so, scientific research is not conducted in a vacuum, but rather in the science-policy system. Scientists need to understand the policy decisions that determine why their scientific research is being funded from governments (policy for science) and the potential implications and impacts that their research results will have on policy and society (science for policy) (Neal et al., 2008).

While we recognize that science-policy engagement needs work from both communities, here we identify gaps and provide some foundational information and suggestions for action to encourage such knowledge on the science side. In isolation, these changes will not be the silver bullet to the world's most pressing problems, but hopefully, they will be part of a move to foster more informed action and solutions.

2. First Step: Frame Science-Policy as a System

Science and policy aren't two separate enterprises on either side of an 'interface'. Much of the literature, however, refers to a 'science-policy interface' (e.g., Hinkel, 2011; Kowarsch, 2015; López-Rodríguez et al., 2015; Lyytimäki et al., 2015; Watson, 2005). There is also literature that looks at 'boundary organizations' which are conceptualized as external, autonomous organization are aimed at increasing the use of science in decision-making by facilitating collaboration between the science and policy communities (Smith et al., 2016), as well as supply and demand for science (Sarewitz & Pielke, 2007), or the production of 'useable science' (Dilling & Lemos, 2011). While the nuances and depth of science-policy and even the inappropriateness of framing it as an 'interface' or portraying science and policy on different sides of a boundary are discussed in such literature, for those who do not dive into the literature, the term 'interface' evokes an image that scientists do science, findings get packaged to be sent across an interface, and then policy uses it. However, this is a very simplified idea that does not reflect the reality of how the two processes, scientific research and policy-making interact.

With the science process and the policy process both being in constant motion, there are points when the two processes come together and provide an opportunity for engagement from scientists and policy

makers, a co-evolution. A better conceptualization of these two processes that influence each other would be a 'science-policy system'. This would encompass and more clearly communicate the dimensionality of the engagement opportunities, as well as other aspects, such as the necessity of relationship building, the longer-term rather than one-off exchanges that are needed, the influence of politics on policy, and crucially that both science and policy are complex processes on different timelines that are constantly evolving, reacting, and changing in response to context, external drivers, and each other. Furthermore, it is critical that scientists have at least a basic foundation for understanding the science-policy system, be it for the acquisition of funding or to create societal benefit from their research, similar to how discipline-specific scientists need to be aware of the entire Earth system to fully understand their science and conduct the best research.

3. Second Step: Teach the Science-Policy System

All scientists work within the context of a science-policy system and at minimum should understand the context in which they are working. Graduate programs should have coursework dedicated to teaching the science-policy system, and indeed some do, although this is currently most common in the US. Whether as part of an introductory course or more in depth, from this starting point, scientists would have the opportunity to determine at what level they wish to engage in the science-policy system. Think of it this way: In the education system all of us, as students, receive some level of science education. Those who are interested in the topic may go on to get different levels of qualification and education in science, such as a bachelor's, master's, or doctorate degrees. Similarly, all students of science should gain some basic level of education on the science-policy system during their pursuit of higher education (Selin et al., 2017). This would allow for an exploration of desires and abilities and for those who are particularly interested, there should be options for more in depth training.

Currently there is little information being passed on to the next generation of scientists on the science-policy system as part of their training, despite the requirement to understand, and engage in, science-policy by funding agencies. Indeed, as one study found "most researchers are not trained to create policy impact from their work, engagement with policy makers is not encouraged or rewarded in most settings, and the communication of scientific findings occurs within the academic community but rarely outside it" (Brownell & Roberto, 2015). While there has been a ground swell in training for science communication that has been hugely beneficial, and we now see far more science communicated outside of the academic community on social media platforms, blogs, and in the news, this training is not sufficient to increase and sufficiently address science-policy engagement. There are a number of skills and aspects beyond science communication that need to be considered when engaging in science-policy. Three key aspects are the role of scientists (Beall et al., 2017; Gluckman, 2014; Kotcher et al., 2017; Meyer et al., 2010; van der Hel, 2018), awareness of policy processes for identifying windows of opportunity (Benson & Jordan, 2015; Safford & Brown, 2019; Selin et al., 2017), and the importance of relationships built on trust (Jarvis, 2016; Safford & Brown, 2019). This type of knowledge is simply not being taught to scientists despite the demand for them to engage more in the science-policy system.

This does not however, need to be the case and we do not need to start from scratch to provide this training. In addition to the practically oriented commentaries, career columns, and policy forum pieces (e.g., Gluckman, 2014; Rosen, 2018; Safford & Brown, 2019; Stokstad, 2017), there is also an established community and body of literature on the theory and concept of science-policy (e.g., Bilotta et al., 2015; Brownell & Roberto, 2015; Dilling & Lemos, 2011; Hadorn et al., 2008; Hoppe, 2005). Unfortunately, this field of science-policy research is generally not reaching the stakeholders of this research, the scientific and policy communities (Evans & Cvitanovic, 2018). This wealth of knowledge can provide the overarching context for the science-policy system and it would be beneficial to discuss it in, e.g. the context of classes that address science-policy in the educational system. This can be a useful complement to individual experience(s). In addition, there is also a wealth of information built on the experiences of those who already engage in the science-policy system: whether from scientists who have chosen this path without formal training or those that have participated in science-policy training opportunities provided by e.g., the AAAS Science and Technology Policy Fellowship, the American Meteorological Society (AMS) Summer Policy Colloquium, American Geophysical Union (AGU) Science Policy, European Geophysical Union (EGU) Policy, or

boundary organizations like ProClim. Greater information exchange, training, and documentation about science-policy engagement based on experiences, including best practices, successes, and failures is needed (Cockerill et al., 2019). Training could take a variety of forms, building on initiatives that already exist, as well as integrating methods and experience from other disciplines.

The existing efforts and programs are just the tip of the iceberg and there is still a much larger need for scientists to receive training on the science-policy system. This need is particularly pronounced in areas outside of North America and Europe, where there are little to no training opportunities and resources available that support science-policy engagement. Including course work at the graduate school level that addresses the science-policy system and engagement in it, not only in isolated cases, but for all scientists in all parts of the world, would be a massive step to preparing the next generation for the reality and needs of the world as well as possible future career paths (Anderson, 2019; L. K. Lautz et al., 2018; National Academies of Sciences & Medicine, 2018).

4. Third Step: Engage in the Science-Policy System

There is a spectrum of opportunities for engaging in the science-policy system, which range from those that are within the bounds of 'typical' scientific work to those where scientists take their expertise and work more directly in the policy arena (Figure 1). An action as simple as a scientist calling a program officer to discuss areas of research that are up and coming or need a boost in funding, is science-policy engagement. Scientists that participate in assessment reports such as the Intergovernmental Panel on Climate Change (IPCC) or the Arctic Monitoring and Assessment Programme (AMAP), which aim to synthesize the state of the science for policy makers to support decision-making, are engaging in the science-policy system. Organizing science-policy dialogues in cooperation with (environment) ministries such as the Arctic Science Ministerials, or together with NGOs, or collaborating on transdisciplinary research projects where partners from policy, civil society, or industry are involved throughout, are engaging in the science-policy system. More recently, global change and sustainability research has had a more clear objective to support societal transformations toward a sustainable future by engaging in transdisciplinary research (van der Hel, 2018), defined here as scientific and societal partners such as industry and policy makers co-developing research and knowledge to address a societal issue (Jahn et al., 2012). Participating in transdisciplinary research, is also engaging in the science-policy system. Choosing a career in a government agency or running for public office as a scientist can also be a way to engage in the science-policy system depending on the role and topics that are focused on. A variety of engagement opportunities are highlighted in Figure 1. While this figure is by no means comprehensive, it aims to show the breadth of options for engaging in the science-policy system. Such engagement can happen at multiple levels, in different contexts, and at varying times.

When thinking about the science-policy system, communication between science and policy communities in the initial stages of policy formation, e.g., determination of air quality limit values, is important but there are many other steps within the policy process for scientists to engage in. For example, the implementation and evaluation of a policy benefit when scientists are involved in these steps to provide the data and knowledge necessary to know if a policy is achieving its goal. In practice, the policy process and the opportunities for scientists to engage in it are not necessarily straightforward, in sequence or occurring at a clear boundary or interface (Lyytimäki et al., 2015; Pohl, 2008; van den Hove, 2007). This means engagement in the science-policy system relies on building relationships that last, span thematic spaces, and are responsive when opportunities arise. Science-policy engagement opportunities are myriad and highly diverse, with multiple entry points from both communities.

5. Fourth Step: Value Engagement in the Science-Policy System

Scientific institutions have hardly evolved to provide incentives and award systems for scientists with an interest to engage in science-policy. This needs to be remedied. Greater engagement in science-policy needs to be supported by institutional structures and reward systems that recognize the value of such engagement (Singh et al., 2019). One study that tracked researchers who engaged in science-policy activities found that the "formal and informal institutional reward mechanisms impose powerful constraints on the flow of knowledge sharing between researchers and decision-makers" and that "making time for boundary
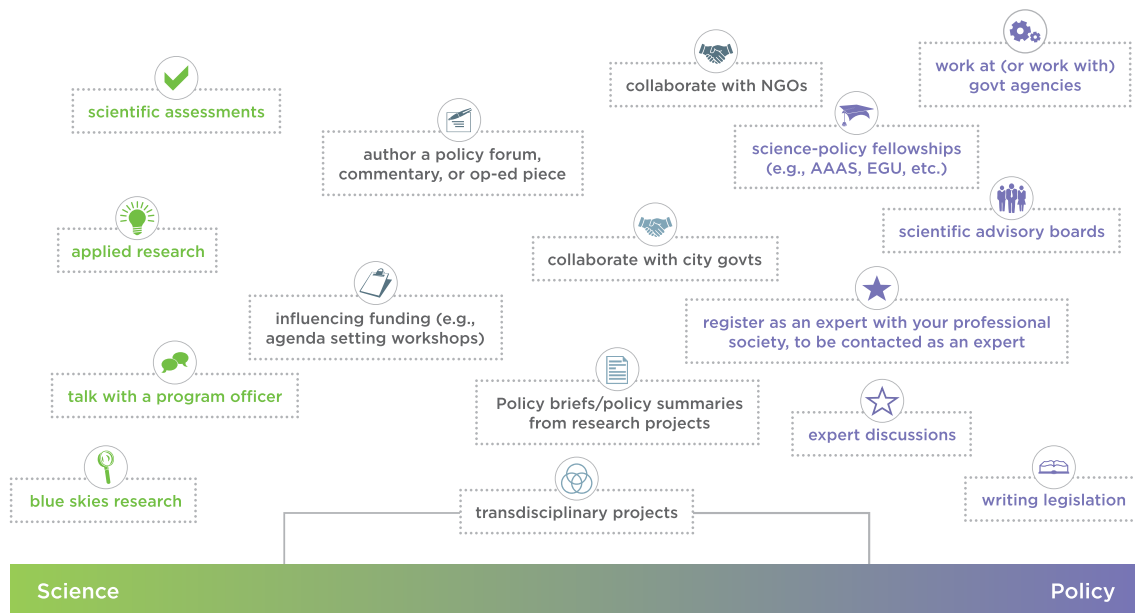
Figure 1. Science-policy engagement opportunities for scientists on a spectrum.

activities [science-policy engagement] on top of the regular requirements of [the scientists'] jobs proves to be an ongoing challenge" (Smith et al., 2016). Unless incentives and institutional structures progress to place greater value on science-policy interactions – valuing science-policy engagement at a similar level to papers and grant proposals (rather than as an additional requirement) – such engagement will likely continue to be hampered by the lack of recognition and support. This includes the challenge of identifying or developing appropriate metrics to capture the outcome of science-policy engagement in order to measure these activities to the appropriate extent (Singh et al., 2019).

In addition, scientific institutions need to recognize the fact that many graduate students do not end up with a career in an academic or scientific institution. Teaching university students about the science-policy system can enhance their employability in policy while at the same time creating a strong link to science because of their educational background. There has been some advancements to prepare graduate students for non-academic careers (National Academies of Sciences & Medicine, 2018). It is imperative these advancements include teaching graduate students about the science-policy system and opportunities both within and outside academic position to engage in the system. In addition, these efforts must expand beyond the U.S. and Europe into the developing world (Koch, 2018).

6. The Way Forward

The first step is to frame science-policy as a system, which is a clearer conceptualization of how science and policy interact. Second, educate scientists about the science-policy system in order to bring awareness to how policy influences scientific research and how scientific research influence policy and the time frames on which they occur. Third, train scientists about the nuances and myriad opportunities for science-policy engagement in a systems framework, which will provide a clearer conceptualization of how science and policy interact, each influencing the other. Fourth, reform the reward mechanisms in scientific institutions to value the necessary and critical work of engaging in science-policy for those scientists who choose to engage and train scientists to excel in careers outside academia and scientific institutions. While the aforementioned four steps are not a silver bullet to solving the world's grand challenges, with a stronger focus on science-policy engagement training and opportunities, scientists can learn from the research on the science-policy system, augment it with their own experiences, recognize the multiple benefits from such engagement, motivate institutions to provide award systems and training

for science-policy engagement, and usher in an era of more effective science-policy engagement accessible to all scientists.

> **Science-Policy Definitions**
>
> There are a few crucial concepts that are important to define here. For one, science-policy in this context is meant in the bi-directional sense, which can be considered as both 'science for policy', as well as 'policy for science'. As summarized by Neal et al. (2008), science for policy "concerns the use of knowledge to assist or improve decision making", while policy for science is "decision making about how to fund or structure the systematic pursuit of knowledge". Furthermore, Sarewitz and Pielke (2007) acknowledge that "decisions about science determine the composition and size of research portfolios that 'supply' scientific results," and in this way, the creation of scientific knowledge and the application of that knowledge in society are quite interdependent.
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> The distinction between policy, which can be defined as the commitment to a particular path of action involving decision-making, and politics, which refers to the process of negotiation and compromise over a specific matter, should also be highlighted. There are different perspectives as to whether or not scientists should engage in politics or restrict themselves to providing information or perspectives on policy, however, it is important to be clear that policy decisions will not be made without politics.

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