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Improving the Transfer of Knowledge from Scientists to Policy Makers: Best Practices and New Opportunities to Engage

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Improving the Transfer of Knowledge from Scientists to Policy Makers: Best Practices and New Opportunities to Engage

June 2022

A White Paper from the National Center for Sustainable Transportation

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National Center for Sustainable Transportation
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16. Abstract
Many scientific projects are intended to inform public policy, however there are often difficulties transferring or translating research from scientists to policy makers. This paper reviews the existing literature on the quality of communication between scientists or field experts and policy makers and the challenges they face in conveying their research. A majority of best practice recommendations related to effective communication are rooted in anecdotal evidence and have not yet been subjected to systematic scientific study. This is, in part, because the nature of public policy makes data collection, randomization, or correcting for confounding factors extremely challenging. Studies that do put these recommendations to the test are most commonly fielded as national surveys of field experts and policy makers in comparative contexts. Few studies examine this subject in the United States, however, and most find mixed results as to the efficacy of well-accepted scientific communication strategies. Further, existing work often fails to account for the impact of *reputation* on the willingness of scientists to engage in policymaking and the willingness of political actors to seek and accept expert input in the policymaking process, unless it confirms pre-existing biases. The authors explain how this gap in the literature has important consequences for the quality of policies produced and suggest future avenues of research in the pursuit of sincere evidence-based policymaking.

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Improving the Transfer of Knowledge from Scientists to Policy Makers: Best Practices and New Opportunities to Engage

A National Center for Sustainable Transportation White Paper

June 2022

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EXECUTIVE SUMMARY

Both scientists and policy makers typically desire that public policy decisions are grounded in the strongest possible science. Despite this shared motivation, communication between the two groups is often difficult and inefficient. This is often attributed to differences in priorities, background, incentives, and most commonly, the different "languages" spoken by researchers and policy makers. Many authors have written about these communication difficulties and a wide range of books, training methods, and resources have emerged to help support scientists as they seek to improve their ability to bring more science into the policy making process. Most of these materials, however, are based on the personal experience of practitioners, rather than formal scientific study.

This report reviews a significant cross-section of the academic literature on communication between scientists and policy makers, focusing primarily on studies relevant to the U.S. political and academic systems. This review supports two primary intended outcomes. First, to observe and collect the studies on this subject that are primarily based on rigorous scientific study, as opposed to personal experience or anecdotes. Second, to synthesize a set of guidelines for improved scientific communication based on principles that have been validated by science. While we recognize the value of personal experience, as well as qualitative research methods that include personal experience within the scope of a study, the goal was to focus on the areas where empirical evidence could provide guidance.

There were comparatively few studies that actually satisfied the criteria of being based on empirical evidence, however. This is likely due to the nature of the public policy system; controlled trials and repetition are infeasible in the context of real-world governance, and there are myriad confounding factors which make quantitative analysis even more difficult. Where evidence existed, it generally supported the guidelines typically offered by experts in the field. Based on the evidence uncovered in the review, and filling in gaps with guidelines derived from commonly-held principles in this space, we synthesize eight principles, in three main categories, for effective scientific communication between scientists and policy makers:

1. **Clear, effective communication**
    a. Pick an appropriate venue or medium
    b. Use simple language and minimize jargon
    c. Minimize, but do not avoid, uncertainty
2. **Audience-focused messaging**
    a. Know your intended audience's background and expectations
    b. Frame your message so your audience can relate

3. **Outcome-awareness**
    a. Identify and focus on desired goals
    b. Sustain engagement over time, with a diverse set of policy makers
    c. Make recommendations specific and actionable

Finally, we focus on one topic that is often cited as being important in science-policy interactions, but about which comparatively little has been written: the effect of reputation on communication. Scientific reputation is a concept that most stakeholders in the policy space recognize, however it is uncertain, vaguely defined, and subject to a number of possible risks. We discuss scientific reputation and explore some ways in which a more robust, and empirically-derived understanding of its effects might be developed.

Science clearly has an important role to play in the policy-making process, however scientists have often been unable to leverage the tools of their own field to improve their communication with policy makers. While it may be impossible to study, and particularly to quantify, characteristics of effective scientific communication with policy makers, there are lessons to be learned from the scholarship that has already been conducted, as well as numerous opportunities to improve upon current understanding.

Introduction

Evidence-based policymaking grounded in sound scientific principles is widely viewed as the gold standard for efficacy and objectivity by scientists and non-scientists alike. While the notion that policies should be informed by the best available science is not novel, in practice, achieving this outcome is often difficult because of challenges that arise at the interface of science and policy making. The subject matters, professional backgrounds, and communications norms that exist within the scientific sphere, especially in academia, are quite different than those in public policy. While there are many guides for how to improve science-policy communications, most of these guides offer advice that lacks evidence in support of the efficacy of these recommendations. Indeed, much of the evidence in support of such recommendations is anecdotal and driven by professional experience rather than evidence-based findings on effective communication strategies. There are myriad science communication guides, textbooks, and best practice manuals available for scientists and policy makers alike. However, many of these documents— perhaps even most—draw their material from the personal observations and experience of the authors, or from applications of communications theory, rather than objective, systematic evidence regarding the efficacy or impact of any particular communications strategy.

In this paper, we explore the state of science/policy communications in the United States. First, we analyze a selection of commonly cited 'best practices' for scientists looking to engage with policy makers. Second, we review existing literature to assess the degree to which these best practices are based upon or supported by rigorous evidence as opposed to theory or anecdotal accounts. Our goal is not to offer normative judgment about the value of any particular communications strategy or recommendation but rather to assess the degree to which the strategy is developed through a robust scientific process. Notably, we find that many 'common sense' recommendations found in popular science communications guides lack empirical support despite broad expert consensus.

Guided by this review, we synthesize some common best practices, with a focus on understanding the degree to which they are based on empirical evidence. Finally, we investigate *reputational risk,* an issue discussed in several sources, finding it under-researched and well suited for further scientific examination. In that vein, we present a theory of how reputation might limit the flow of information between interested political actors and concerned scientists or field experts. We conclude with a discussion of avenues for future research, highlighting (un)promising analytical methods, on the under researched and underdeveloped relationship between reputation and science-policy communications.

Best Practices in Science/Policy Communications

The communication of research between the scientific community and government, or individuals who influence policy, is part of a larger field of *science communication* [1]. Within this field, there is no shortage of advice for scientists on how to best communicate their research findings to policy makers. To assess the empirical support for common 'best practices' in science/policy communications, we first conduct a naive Google Scholar search engine search of the words (1) "science," "policy," and "communication" and (2) "best practices" and "scientific communication." We then identified the first 20 papers, blogs, and guidance documents resulting from these searches. While there are a great many more documents relevant to this subject, they did not offer any substantively different best practices or guidance beyond what is summarized below. We present the first 12 'best practices' guides here, but a full list of our references may be found in the References section.

Table 1. Selected Sample of the 'Best Practices' Sources Reviewed

Source	Document Type	Key Recommendations	Nature of Evidence
Safford, Hannah, and Austin Brown. 2019. "Communicating Science to policy makers: Six Strategies for Success." *Nature* 572 (7771): 681–82. https://doi.org/10.1038/d41586-019-02372-3.	Essay	Know your audience Make actionable recommendations Distribute your work in an accessible fashion (e.g., a two-page policy brief) Write clearly and concisely Time your publication Maintain on-going communications with policy makers	Professional experience
Rosen, Julia. 2018. "Help to Shape Policy with Your Science." *Nature* 560 (7720): 671–73. https://doi.org/10.1038/d41586-018-06038-4.	Essay	Observe what science policy makers are looking for Establish durable relationships with policy makers Use accessible language Construct a scientific narrative Expect policy incrementalism	Professional experience, interviews with experts and relevant academics
Evans, Megan C., and Christopher Cvitanovic. 2018. "An Introduction to Achieving Policy Impact for Early Career Researchers." *Palgrave Communications* 4 (1): 1–12. https://doi.org/10.1057/s41599-018-0144-2.	Journal article	Identify key stakeholders and policy makers Build and maintain a public profile Align your message with the goals/values of the target audience Use narratives to convey key points Maintain a professional reputation Communicate through accessible, informal channels (e.g., blogs) Convey 1 or 2 messages at a time Engage in public consultation processes Work in explicit policy spaces Be honest, humble, open and resilient	Professional experience, interviews with experts, empirical research

Source	Document Type	Key Recommendations	Nature of Evidence
Christian, Katherine. "Communicating Your Research: Get It Right, Do It Often. It Really Matters. : Naturejobs Blog." n.d. Accessed June 12, 2020. http://blogs.nature.com/naturejobs/2018/03/30/communicating-your-research-get-it-right-do-it-often-it-really-matters/.	Blog post	Promote work via social media Communicate research succinctly and in approachable language	Professional experience
Oliver, Kathryn, and Paul Cairney. 2019. "The Dos and Don'ts of Influencing Policy: A Systematic Review of Advice to Academics." *Palgrave Communications* 5 (1): 1–11. https://doi.org/10.1057/s41599-019-0232-y.	Article	Understand the policymaking process Communicate often Build durable relationships with policy makers Promote your work	Academic peer-review journals, "grey" literature
Scheufele, Dietram A. 2014. "Science Communication as Political Communication." *Proceedings of the National Academy of Sciences* 111 (Supplement 4): 13585–92. https://doi.org/10.1073/pnas.1317516111.	Article	Attend public meetings Frame your message to appeal to your audience	Professional experience, academic peer-review journals

Source	Document Type	Key Recommendations	Nature of Evidence
"Best Practices in Science Communication." n.d. *ASCB* (blog). Accessed June 12, 2020. **https://www.ascb.org/science-policy-public-outreach/science-outreach/communication-toolkits/best-practices-in-effective-science-communication/**.	Blog	Know your audience Focus on the bigger picture Avoid jargon Use relatable metaphors and analogies Emphasis your contribution to evidence-based policymaking	Professional experience
"Communication Fundamentals." n.d. American Association for the Advancement of Science. Accessed June 12, 2020. **https://www.aaas.org/resources/communication-toolkit/communication-fundamentals**.	Best practices guide	Know your audience Streamline your message Avoid jargon	Professional experience
"Communicating Science Online." n.d. American Association for the Advancement of Science. Accessed June 12, 2020. **https://www.aaas.org/programs/center-public-engagement-science-and-technology/communicating-science-online**.	Best practices guide	Select the proper platform for your audience Maintain a credible image Engage in public conversation Share your work Build relationships through social networks Maintain your reputation	Professional experience

Source	Document Type	Key Recommendations	Nature of Evidence
Docquier, David. "Communicating Your Research to Policy Makers and Journalists." 2017. Author Services. July 6, 2017. https://authorservices.taylorandfrancis.com/communicating-science-to-policy makers-and-journalists/.	Blog	Time your message appropriately Target your message Peer-review should come before press coverage Construct a narrative around your scientific contribution Be concise	Professional experience
Marshall, Nadine, Neil Adger, Simon Attwood, Katrina Brown, Charles Crissman, Christopher Cvitanovic, Cassandra De Young, et al. 2017. "Empirically Derived Guidance for Social Scientists to Influence Environmental Policy." *PLOS ONE* 12 (3): e0171950. https://doi.org/10.1371/journal.pone.0171950.	Journal article	Understand the policymaking process Align your goals with those of your target organization Maintain your reputation Engage with policy makers regularly Anticipate policy needs	Interviews of international policy makers and scientists
Cairney, Paul, Kathryn Oliver, and Adam Wellstead. 2016. "To Bridge the Divide between Evidence and Policy: Reduce Ambiguity as Much as Uncertainty." *Public Administration Review* 76 (3): 399–402. https://doi.org/10.1111/puar.12555.	Journal article	Rely on solid evidence and persuasion tactics	Journal articles, other best practices guides

After a formal review of prominent and heavily cited works in this strand of literature, we identified eight specific recommendations for science-policy engagement common to many of these articles, which we have grouped into three broad categories, inspired by the classification system presented in Bubela et al. (2009) [2]:

1. **Clear, effective communication**
    a. Pick an appropriate venue or medium
    b. Use simple language and minimize jargon
    c. Minimize, but do not avoid, uncertainty
2. **Audience-focused messaging**
    a. Know your intended audience's background and expectations
    b. Frame your message so your audience can relate
3. **Outcome-awareness**
    a. Identify and focus on desired goals
    b. Sustain engagement over time, with a diverse set of policy makers
    c. Make recommendations specific and actionable

In the following section, we review the evidence regarding effectiveness for each of these considerations and highlight where existing literature relies on anecdotal evidence or personal perspective in contrast to where it has been backed up with scientific rigor, empirical data, and peer-review. Despite the volume of 'best practices' guides for effective scientific communication, there are few systematic studies of the effectiveness of these recommendations due, in part, to the difficulty of studying the search-and-integrate behavior of policy makers and the inherent challenges in designing and executing rigorous scientific investigations in a complex field like public policy.

The recommendations made on the following pages are collected and presented in concise fashion in Appendix: Collected Recommendations.

Clear, Effective Communication

Pick an Appropriate Venue or Media

Targeting an appropriate audience for one's research is made more challenging by a communication space that often lacks established avenues for conveying scientific information to policy makers. Scientists may be uncertain how to deliver their information in a way that does not get lost in the density of competing messages and motivations.

Though a sizable portion of 'best practices' guides suggest that the method of transmission is key to effective communication between scientists/field experts and policy makers, many disagree as to the best avenues for such communication. For example, the Union of Concerned Scientists advocates using social media to convey one's research to non-academic audiences [3], and there is some evidence suggesting that social media is an effective means for communicating with general audiences and amplifying the impact of one's research [4]. Social

media can also serve as a complement to traditional avenues of scientific publication or in-person transmission of information [5].

However, others caution against social media as a main avenue for communication with the public and with policy makers, citing fears that scientific research conveyed through social media may fall prey to platform algorithms that silo their research or elevate articles based on exploitable characteristics (e.g., Search-Engine Optimization, keyword hacking). Social media users are also prone to consuming content in socially-segregated ways, sticking to politically-agreeable content—whether intentionally or as a byproduct of the communities they commonly interact with—and avoiding research that challenges their prior beliefs. The 'publicness' of social media that compromises efforts to retract or withdraw scientifically unsound research; even where credible scientific outlets retract and revise conclusions, these may not gain the mainstream distribution or attention that the initial, erroneous publication commanded [6]. Further, participatory communication channels, like science blogs, commonly offer readers the ability to provide feedback in the form of ratings or user comments, which may further skew how a scientific message is interpreted [7].

Beyond social media, scientists may also wish to disseminate their research to policy makers through short-form briefs, which provide easily digestible material which can convey key findings or implications in a short format, stripped of complexity and jargon. As an editorial in *Nature* expresses,

> "Policy Briefs offer short (no more than two pages) high-level takes on a research study and its findings from a policy perspective. [The] intention is to provide a non-expert and time-poor reader with an understanding of the policy context and findings of a piece of research, along with the key policy messages they should take away from it, so that they can hopefully make better use of the research featured in [a] journal." [8]

Research as to the efficacy of policy briefs as a means for scientists to disseminate critical information is mixed. Lalor and Hickey (2013) find that politicians express a preference for policy briefs authored by academics operating outside of the bureaucracy because of the stature and objectivity typically associated with academic experts, and their customary disconnection from vested interests in a policy or business space [9]. Furthermore, they also find that the general consensus among lawmakers in Canada and Australia is that they "generally felt the responsibility to engage in and lead public policy debates was largely that of senior academics (e.g., professors) as they were perceived to be amongst the most credible knowledge holders in society." Alternatively, Haynes et al. (2012) demonstrate that policy makers do prefer briefings from researchers who communicate skillfully but prefer oral communication over written memos [5]. A similar survey of forestry scientists and policy makers across Europe found that both parties actually felt that the worst ways to communicate research was through full publications, executive summaries of research, and 1-page policy briefs [10]. This is largely because policy makers identified the following as their biggest challenges in making use of scientific research: (a) information overload, (b) research complexity, and (c) limited access to relevant sources of information (e.g., gated journals, paywalled databases). Similarly, policy makers expressed dissatisfaction with research

conveyed in academic journals, suggesting that the slowness of the peer-review process hinders the usefulness of scientific research for policy purposes [5].

Ultimately, the available evidence generally supports policy briefs as part of the portfolio of effective communication strategies for science policy engagement, though briefs are clearly not effective in every circumstance. There is strong support among policy makers about the value of transmitting information in-person and through one's personal or professional network. As one study puts it, "people are more persuasive than papers" [5]. Another study suggests that policy makers and civil servants tend to rely on their department colleagues and other close policy makers in searching for new sources of information, but a third study found that a large barrier to science communication was the willingness of government agents to seek out relevant research in the first place [5, 11] This correlates to multiple anecdotal reports by policy staff that their primary method for searching for scientific information is to seek out a trusted person in their professional network who can connect them to resources, translate scientific language where necessary, and validate the source's conclusions.

A survey of UK public health policy makers found that these civil servants are most likely to search for new information and field research on government websites (e.g., National Institute for Health and Clinical Excellence), from the Directors of Public Health, and other *internal* sources. Notably, these policy makers repeatedly omitted academics and other research organizations (e.g., universities, think tanks) from their list of regular sources for scientific information [12]. In the U.S., a study of health policy makers also found that the sheer volume of information received was "overwhelming" for civil servants, forcing these decision-makers to prioritize concise and current scientific evidence [13]. Whereas younger policy makers were more likely to rely on electronic information, older policy makers strongly preferred printed materials; both groups preferred government-generated reports over external ones, suggesting a need for more research on how policy makers (and authors of government reports) acquire information [13].

A fourth, though less common, suggestion is for scientists and field experts to rely on institutionalized resources to communicate with policy makers. Such resources include "interface" organizations designed to assist researchers in bringing their findings to the public and to relevant policy personnel. These organizations are often university-operated, non-profit, or organized by field experts themselves. Successful interface organizations, like the Cooperative Extension and the Hubbard Brook *Science-Links* program, are meant to facilitate information exchange between scientists and policy makers by connecting these groups in one place and, in some cases, even rewarding participants with access to research monies that can fund collaborative projects [14]. Interface agents, like communications specialists, have also been shown to improve scientists' opinions of engaging in policymaking and improve scientists' sense that their message is communicated accurately and in the spirit of the original research question [15]. Likewise, these intermediate organizations may be able to point interested policy makers towards useful science. For example, a randomized control trial of health department policy makers found that policy makers were more likely to use scientific evidence in

policymaking when they had been explicitly provided access to systematic public health review articles [16].

Admittedly, in our search, we found mixed evidence on the best channel(s) through which science-policy communications should occur, suggesting a need for further study on this issue. One article urges, however, that concerns about reaching policy makers should not prevent scholars from publishing in peer-reviewed journals; instead, scholars should craft "complementary" articles for more popular media outlets to appeal to policy makers in a practice called "dual dissemination" [17]. Future work should also take into account the varying capacities of different agencies across the federal landscape. That is, what works for a well-staffed, professionalized federal department will not necessarily work in attempting to reach a local agency that is resource or staff-deprived [18].

A topic of particular interest to scientists over the last decade is how to respond and combat inaccurate information presented in the media or other venues. Modern channels of communication leave scientific content prone to subversion by political or financial interests. As creators and curators of knowledge, the scientific community has historically had a role in combating scientific misinformation (inaccurate or unsupported information) and disinformation (intentionally created or disseminated misinformation). Often, the scientific community held the opinion that providing accurate information is a sufficient response to the existence of misinformation or disinformation. In a study of the causes and consequences of scientific misinformation, Scheufele and Krause (2018) find that individuals are often misinformed because they lack the ability to recognize misinformation or are unmotivated to recognize misinformation when it is encountered [19].

Use Simple Language and Minimize Jargon

Perhaps the most common and straightforward recommendation in science communication guides is to use simple language and avoid jargon, or other types of opaque, discipline-specific language. Technical jargon typically refers to language that is accessible to specialists within a given field but not to audiences that lack technical expertise, e.g., terms of art, abbreviations, acronyms, or other specialized language specific to a given discipline [20]. Technical jargon inhibits comprehension of scientific information, decreases support for the adoption of new technologies, and does not necessarily improve the credibility of the messenger [21, 22, 23, 24]. Jargon can serve a useful purpose in scientific, and among other, communications, by providing a shorter and more usable term for a complex or unusual concept; yet, jargon can be exclusionary to audiences who are unfamiliar with the term being used and can lead to audiences disengaging from communication, or perceptions of scientists as disconnected, unapproachable or elitist. Further, civil servants readily suggest that jargon hinders the usefulness of scientific research [25].

But there are several tools several tools scientists can use to ensure their communications are accessible to general audiences and policy makers, like the De-Jargonizer, which identifies the frequency of technical jargon in a piece of text, or the Flesch-Kincaid Grade Level readability test, which determines the level of English education a reader would need to understand a

given document [26, 27]. These tools should be used cautiously, however, as they only evaluate language complexity and do not address subject matter complexity. Further, the success of readability tests for reader comprehension has only been demonstrated to work with the general public, and our search did not reveal any evaluations on the success of readability metrics when communicating with policy makers, who may have some understanding of technical detail [28]. As an alternative, there is some evidence that pictorial representations of complex topics are more effective at communicating information than written material [29].

Communicate Uncertainty, but Focus on Certainty

Uncertainty is inherent in science, and communicating uncertainty to audiences is a tall task for any subject-matter expert. In an attempt to stay faithful to their research, and to minimize the appearance of over-confidence, many scientists will couch their findings in a way that emphasizes the uncertainty of their results [30]. This often reflects the nature of scientific communication, where scientists are trained to avoid over-inferring meaning from data, and where uncertainty tends to be the focus of ongoing inquiry. Despite the scientific value of uncertainty, these disclaimers are often not useful for policy makers looking to consume research quickly or apply policy tools that do not always align with scientific ones. A survey of U.S. legislators finds that state politicians specializing in healthcare-related fields, prefer data and statistics when searching for new science, but whether those policy makers interpret the science correctly is less well-understood [31].

According to one guide, how a researcher communicates uncertainty should depend on whether their research argues for a timeline for action, compares the viability of different existing solutions, or merely identifies potential solutions to an existing problem [32]. Similarly, researchers should understand whether the policy context and timeline around a problem allows for the resolution, or at least reduction, of scientific uncertainty, or whether an immediate action is forthcoming. Recommendations from best practice guides are straight-forward, ranging from using the word “estimate” early and often when reporting numerical values and visualizing uncertainty in graph form (e.g., confidence intervals) to employing plain English and communicating absolute risk instead of relative risk [33, 34, 35].

Existing systematic or empirically-focused research says little on whether these communication strategies are effective for conveying research to policy makers. What literature does exist is concentrated on individuals’ ability to interpret numbers and probabilities. For example, Pedersen (2017) demonstrates that the way numbers are framed can impact policy preferences for taxes and education spending among the general public and political elites, producing a bias such that individuals tend to overemphasize numerators without adequate consideration of the denominators in ratios [36]. This ratio bias poses particular problems for the natural sciences, whose work is largely quantitatively driven. Other work in health literacy suggests that relying on round numbers to communicate numerical data can be useful to minimize the impression of precision [37]. A second study finds that numeric comprehension is best achieved by providing more perspective to target audiences (e.g., “to put this in perspective, this effect size is comparable to...”) [38].

Recommendations for Selecting the Proper Venue or Media Space

- **Social media has value as a scientific communications tool, but may not be highly effective for reaching policy makers.** Much research on social media's impact on science-policy communications focus on the impact social media usage has on changing public opinion, not the minds of crucial policy makers.
    - *Evidence: Professional anecdotes (e.g., Union of Concerned Scientists 2017* [3]*)*
- **Policy briefs or synopses are better than peer-reviewed journal articles for reaching policy makers but neither are as effective as in-person communication.**
    - *Evidence: Interviews with/surveys of policy makers and politicians (e.g., Lalor and Hickey 2013* [9]*, Haynes et al. 2012* [5]*)*
- **Meet policy makers where they are (e.g., internal reports)**. Policy makers often rely first on internal sources of information, then their immediate professional networks, and only after they have exhausted those outlets do they turn to academics and other research outfits for policy-relevant information.
    - *Evidence: Surveys of civil servants (e.g., Oliver et al. 2017* [12]*)*
- **Use "interface" organizations to get your research in front of the right people in a way that is faithful to your scientific findings.**
    - *Evidence: Professional experience (e.g., Dunwoody and Ryan 1983* [15]*) and policymaking trials (e.g., Osmond et al. 2010* [14]*, Perrier et al. 2011* [16]*)*

Recommendations to Improve Language Simplicity

- **Minimize use of jargon or terms of art as much as possible.** Some jargon can be useful for educating the audience, if it's defined clearly, used repeatedly, and serves a role that is both essential and obvious to the audience. Readability tests can be useful for making scientific writing more accessible but are not adequate for boiling down substantive complexity.
    - *Evidence: Interviews with policy makers (e.g., Haynes et al. 2011* [25]*)*
- **Pictorial representations of complex information are more digestible than written text.**
    - *Evidence: Experiments (e.g., Powell et al. 2015* [39]*).*

Recommendations for Communicating Uncertainty

- **Embrace the value of data and statistics in conveying information to policy makers.**
    - *Evidence: Interviews with legislators (e.g., Dodson et al. 2015* [31]*)*
- **Convey findings in terms that provide context about uncertainty.** This includes using terms like "estimate," visualizing uncertainty (e.g., confidence intervals), and communicating absolute risk instead of relative risk ratios.
    - *Evidence: Experiments with the public (e.g., Covey 2007* [35]*) but little on the civil service*

Audience-Focused Messaging

Know the Audience's Background and Expectations

A majority of the most-cited 'best practices' guides argue the need for scientists and field experts to *know their audience* when communicating with policy makers and other political practitioners. At a colloquium on science communication hosted by the National Academy of Sciences, Alan Leshner, CEO emeritus at the American Association for the Advancement of Science, stated that the failure of scientists to target their messages for the appropriate audience "is the biggest mistake that I see people make. They talk about what they want to talk about, not what people want to hear" [40]. This criticism does not imply scientists should seek audience approval or aim to confirm pre-existing beliefs, but rather, understand the interests, background, and communications preferences of their audience and align their messaging accordingly. People have myriad streams of incoming communication, across dozens of media channels competing for their attention. Policy professionals typically have massive backlogs of reports, articles, or other material that they intend to read but rarely have time for. Scientific messages have to not only provide value to their audience but also a reason for the audience to focus their attention on the message in the first place.

Though popular accounts of scientific literacy suggest most members of the American public are capable of some level of scientific reasoning [41], other researchers are less certain of the public's ability to draw appropriate conclusions from scientific communication. For example, despite finding that over half of all American adults express interest in new scientific discoveries or technological advancements, only 28 percent of adults surveyed were actually able to find, interpret, or employ information about science and technology [42, 43, 44]. Concerns about the public's ability to engage with scientific findings may limit the audiences that scientists and field experts are willing to target, putting added pressure on scientists to engage directly with policy makers rather than disseminating their research directly to the public. In our review, we were unable to determine if similar fears also prevent scientists from engaging with policy makers.

Still, there is some evidence that scientists should approach communications with civil servants differently from communication with legislators and their staff. Specifically, a survey of Wisconsin legislative staffers and high-ranking family-service agency officials finds that agency officials, in general, have higher levels of education and longer job tenures than legislators, endowing them with greater appreciation for scientific research and a better understanding of where to find it and how to employ it. Further, the institutional culture of the target organization matters greatly, as civil servants are more likely to feel supported in the pursuit of evidence-based policy than legislators and their staffers [45]. This implication, then, is that scientists should tailor their messages to the level of expertise they can expect their audience to have.

Understanding the audiences' motivation for communicating with scientists is also critical. When critical deadlines loom, policy makers may seek direct, actionable answers to scientific problems. At other times, they may be more amenable to exploratory or abstract discussions of underlying principles. Considerations relating to legal authority, budget or political acceptability

may limit the potential solutions to a given problem in ways that are not reflected in scientific studies of the same topic. A study may yield a clear and relevant conclusion relating to a given policy problem, but if the study's mechanism of action cannot be implemented by existing or plausible policy tools. Scientists may be able to effectively present the conceptual foundation of their work to policy makers, but if it is not framed and focused on the problems of greatest interest or the tools available to policy makers, the message may not have a lasting effect.

Frame Messages So the Audience Can Relate

One of the most commonly cited concerns among scientists and field experts looking to inform or influence policymaking is the fear that their message will be distorted or disregarded entirely. This fear is not without merit as an online survey of scientists affiliated with the American Association for the Advancement of Science found that over 70 percent of scientists felt that news media often misconstrued the certainty or conclusions of scientific findings [46]. Yet other (older) studies suggest that concerns about accuracy are more common than actual communication inaccuracies. In one such study, participants were asked to read science news articles and recall their content to interviewers. These audience summaries were then rated by the scientists quoted in the news articles based on their perceived accuracy, and, positively, almost two-thirds of all readers' news summaries were described as passably accurate or better [47].

Issue framing, defined as the process by which people develop a particular conceptualization of an issue or reorient their thinking about an issue, has significant consequences for how messages are received in public life [48]. Pertaining to the physical sciences, the study of message framing in science communications is most developed in the study of climate change [49]. For example, describing public efforts to curb climate change using a motivational frame (e.g., "The economy will be stronger if we act first to cut greenhouse gases") are more effective at increasing citizen interest in climate change and willingness to change their behavior to reduce emissions than a sacrifice frame (e.g., "To stop climate change, I have to make sacrifices") [50]. Message frames that emphasize the local impact of climate change as opposed to the global consequences also improve citizens' receptiveness to information on climate change mitigation, as do messages highlighting the economic value of climate action [51, 52, 53].

Alternatively, some recommend use of *narratives* to ground scientific evidence in the real-world, simultaneously demonstrating the generalizability of scientific evidence and the practical application of scientific findings [54]. For example, Spoel et al. (2008) find that the narratives used in media such as *An Inconvenient Truth* and *Climate Change Show* are effective in engaging citizens, specifically non-experts, and motivating both scientific fluency and spurring action [55, 56]. However, most of these studies on the efficacy of narratives for science communications focus on the value of narrative for communicating with the public and *not* with executive or legislative policy makers. Moreover, narrative-style communications involve important ethical considerations, like whether the purpose of science communication is audience comprehension or persuasion and how to provide narrative that does not compromise the accuracy of the science [57].

Recommendations for Identifying Audience Background and Expectations

- **Understand that civil servants are looking for different information than politicians and their staffers.** Politicians (e.g., legislators) are more interested in conclusions and impact than civil servants, who may prioritize methodology, outcome metrics, and citations. Focus presentations to policy makers on what the science says regarding the policy issue in question; those who care about methods can be connected to that material (e.g., sent a copy of the paper).
    - *Evidence: Professional experience (e.g., National Academies of Sciences 2017* [40]*)*
- *Understand the timing and context around a given subject. Public policy is often deadline-driven, and subject to limitations on legal authority, budget, or politics. Messages to policy makers should understand these constraints and provide messages that are framed and focused on the goals of their audience.*
    - *Evidence: Bielak et al. (2008)* [58]

Recommendations for Framing Messages so Audiences Relate

- **Make explicit the connection between your work and its direct impact on your audience.** policy makers generally care most about issues that are directly under their control or directly affect their constituents. Identifying the mission, duties, and constituency of different political actors can help build a rapid connection to them and maximize their interest in your work.
    - *Evidence: Professional anecdotes (e.g., Stecula and Merkley 2019* [51]*)*
- **Test your messaging on an audience similar to those you are trying to reach**. While it's good practice to test a policy-focused presentation or communication on your research colleagues, their experience and perspective may not reflect that of the policy makers that comprise your target audience. An audience that's unfamiliar with the topic will likely allow for more effective practice and feedback.
    - *Evidence: The value of practice, especially practice that is highly representative of actual performance, is well-established.*
- **Narrative science can broaden the appeal of your research by reinforcing the external validity of your work.** People often respond to stories, which provide context and relatable elements to what may otherwise be abstract. If a narrative can be crafted around your message, it may be helpful to do so.
    - *Evidence: Spoel et al. (2008)* [55]*, Dahlstrom (2010)* [59]*, Dahlstrom & Ho (2012)* [57]*, Dahlstrom (2014)* [54]*, Ghuman & Kumari (2013)* [60]

Outcome-Awareness

Identify and Focus on Desired Goals

Scientific communication can embrace a wide variety of communication styles, venues and tones. The most effective scientific communication intentionally adopts characteristics to maximize its desired impact. Understanding what impact is desired, is therefore one of the first

and more critical steps in effectively communicating science to policy makers. Common motivations for engagement include:

- Sharing their research findings with relevant policy makers,
- Drawing public attention to their research program,
- Influencing behavior, opinions, and preferences, or
- Encouraging/informing the creation of evidence-based public policy [40].

In a survey of UK scientists and engineers by the Royal Society, a majority of scientists felt that public engagement with non-specialists was best understood as a practice of explaining and promoting a public understanding of science and then as a method for "highlighting the implications, relevance and value of science" [61]. Note that neither of these priorities for public engagement involve directly influencing or informing the policymaking process, which may be an intentional effort to focus on the commonly perceived role of scientists as neutral and at arm's length from the political entanglements of policy, instead sticking to 'objective science'. This view holds that the scientific mission ends when information is provided to the intended audience. In practice, however, multiple studies have demonstrated that simply providing information does not necessarily lead to action by policy makers or the public, and that contextualizing the information, by highlighting implications or real-world impacts for example, may be necessary to achieve a desired result [62, 63].

Scientists must navigate a careful balance between being aware of, and focused on, the desired outcome of communication to policy makers, while still maintaining high standards of scientific integrity. While scientists can, and often do, have a particular point of view or desired outcome—just like any person involved in the policy process—they must also recognize that with the authority of expertise comes the responsibility to exercise it judiciously. A common modern perception of science among political and policy actors is that it is just another argumentative tool for reinforcing biases or supporting vested interests. It is critical that scientists who choose to engage with policy makers be careful that their communications are still grounded in science and that simplifying or re-framing a message to maximize impact for general audiences does not facilitate the dissemination of disingenuous or misleading information.

Sustain Engagement Over Time

An oft repeated recommendation for effective science communication is that field experts should be in constant communication with policy makers in order for their messages to be received and appropriately applied. The logic here is that repeated contact between scientists and policy makers reinforces scientists' intended message to increasingly busy politicians and civil servants [40, 64]. But Koch and Zerback (2013) show the limits to simple repetition; while repeated messages can improve a statement's credibility at first, when repeated too much, the less authentic and more manipulative the message is perceived by general audiences [65].

The key distinction is making engagement authentic and bidirectional, demonstrating an interest in and commitment to being audience-focused and outcome-aware. To effectively sustain engagement, scientists should proactively reach out to policy makers and communities

of interest, regularly checking in to see whether and how science is being considered as they make decisions and to help re-interpret or re-contextualize as circumstances change. Scientists should also attempt, as much as possible, to stay involved in policy processes to demonstrate that their interests are not narrowly constrained to finishing their research project, but instead, are relevant to solving broader problems.

Further, on-going relations between scientists and policy makers can improve information transmission between these two pools of actors. For instance, a meta-analysis of health sciences reveals that evidence-based policymaking in public health is more common and easier to achieve when research is timely, accessible, and provided by researchers who have an established working relationship with policy makers [66]. This finding hints at the tacit role reputation may play in science-policy communications, which we discuss in depth below. Additionally, scientists should not expect their research to reach policy makers through the peer-review process. Indeed, interviews with policy makers suggest that the slowness of the journal publication process often hinders the usefulness of scientific research [5].

Another key benefit of ongoing communication is that it positions scientists to be part of the policy making process at the times when policy makers are most receptive to outside expertise. Legislation, administrative rulemaking and other policy processes typically follow a rigid timeline. In most cases, there are opportunities for public engagement or comment, but they're not always well publicized and scientific voices can sometimes be drowned out by political or commercial ones when they do. Most policy makers engage in formal or informal consultation with stakeholders, to the extent allowed by law, prior to formal policy making and public comment opportunities. At this early point in the process, the policy in question is often more amenable to expert input than after interest groups have staked out positions. Maintaining regular and open communication with policy makers improves scientists' chances of being aware of, and contributing to, policy development at this highly receptive stage.

If Making Recommendations, Make Them Specific and Actionable

A common goal of science communication is to present specific policy recommendations that are actionable, to the best of the scientist's knowledge. One survey of Australian policy makers suggests a unified preference for researchers to be pragmatic and to produce research that is focused on real-world problem-solving [5]. Likewise, in-depth interviews with UK policy advisors in public health, education, social welfare, and health services found that public health officials were most frustrated by academic researchers' lack of understanding of the cost-effectiveness of policy interventions and a dearth of predictive research [67]. Yet scientists are not policy makers and may not know the precise feasibility of their policy recommendations (e.g., budgetary constraints or legal authority), nor may they be certain if their role is to inform policy or to influence it.

Scientists have traditionally relied on a *deficit model* of science communications. The deficit model posits that the reason the public has a negative impression of science is due a lack of scientific knowledge and that the public will grow to appreciate science as scientific knowledge becomes more accessible [1]. This relationship has been observed, albeit at modest strength,

across a number of studies [68, 69]. Thus, the relationship between scientists and policy makers is conceived as unidirectional where policy-relevant information flows from experts to decisionmakers, suggesting that policy would be more informed if scientists provided enough policy-relevant information. But the deficit model of science communication has come under fire in recent years for underestimating the public's penchant for knowledge and not recognizing the information constraints the public faces in interpreting scientific research [70, 71].

Modern models of science communications instead argue that it is scientists' responsibility to ensure their policy recommendations are feasible for the intended governing body to implement. This new role has given way to a new field, implementation science, which focuses on scaling up evidence-based practices to better suit real-world applications [72]. Implementation science first emerged to improve healthcare provision and has since expanded to cover other fields of interest for policy makers, like child welfare and education reform [73, 74, 75]. Implementation science has been the subject of significant scholarship, e.g., Meyers et al. (2012), identified four phases of quality implementation: (1) evaluating the target host setting, (2) establishing a structure for implementation, (3) maintaining the structure for on-going implementation, and (4) improving the structure for future implementation [76].

Recommendations for Identifying and Focusing on Goals

- **Identify a beneficial outcome, based on current science, and focus communication there.** Why was this line of scientific inquiry begun in the first place? Does a given finding indicate that policy makers need to pay attention to a niche or underappreciated problem? Is there information they need to consider when shaping policy? Is there a specific action or outcome that is strongly influenced by the evidence?
    - *Evidence: Professional experience (e.g., Dahlstrom and Ho 2012* [57]*)*

Recommendations for Maintaining Engagement

- **Find critical policy making venues, or policy makers and reach out to them before a formal process begins.** Legislative and regulatory processes typically have multiple opportunities for outside expertise to be considered, but these are often long before a policy change is reported in the media or enters public consciousness. The best time to have science make an impact on policy is early, while all parties are still open to new information and perspectives.
    - *Evidence: Interviews with policy makers and politicians (e.g., Koch and Zerback 2013* [65]*)*
- **Understand the timeline for policy processes and make suggestions at an appropriate time**. Realize that there are times in a policy process that are designed for, or highly amenable to outside input. By the time key votes occur, most stakeholders have solidified their position. Engaging early and understanding the timeline is critical to ensuring that scientific advice is positioned to be effective.
    - *Evidence: Kingdon (1984* [77]*)*

- **Build relationships with key policy makers.** Scientific advice can often be very useful outside of a formal policy process. By building relationships with key staff, elected officials, or community groups, scientists can become a resource for these communities and over policy-relevant advice at times when the audience is highly receptive.
    - *Evidence: Surveys of civil servants (e.g., Oliver et al. 2017* [12]*)*

Recommendations for Making Specific and Actionable Recommendations

- **Understand the political environment in which a policy maker or politicians operate.** Approach policy makers with an eye on the costs, legal or regulatory authority, and overall feasibility of a given programmatic prescription, and approach politicians with an understanding of the politics surrounding a given proposal.
    - *Evidence: Surveys of policy makers and politicians (e.g., Haynes et al. 2012* [5]*, Petticrew 2004* [67]*)*
- **If diagnosing a policy predicament, come prepared with feasible solutions to the identified problem(s).** It is preferable to present policy makers with solutions when identifying an existing problem. Rely on strategies, like those recommended by implementation scientists, to assess the viability of your proposed solution.
    - *Evidence: Professional experience (e.g., Damschroder et al. 2009* [73]*)*

The Role of Scientific Reputation in Science-Policy Communication

Even if scientists are confident in the strength of evidence underpinning their recommendations, or the feasibility of implementing evidence-based policy changes, they may still be wary of wading into policymaking spaces, especially in fields that have been highly politicized in recent years, like climate change and stem cell research [78, 79].

Some politicians and civil servants feel that academics have a moral responsibility to participate in policy debates, inform the public, and make the public more science-literate [9]. Further, interviews with civil servants reveal a preference for working with subject-matter experts who recognize that those in academia and government bear different types of organizational or professional responsibility and are subject to different institutional constraints [5]. That is, in the view of bureaucrats, field experts involved in policy cannot just be technical experts but must also be conscious of the politics that affect, and are affected by policymaking. However, some scientists feel that influencing policymaking threatens scientific objectivity and that the role of scientists is to provide analysis, not to advocate policy stances. Others criticize scientists for overthinking the appropriateness of advocacy and failing to engage policy makers as a result [80].

This tension is only exacerbated by increased public attention to the influence of scientists on public policy. Despite broad public agreement that science has had a positive impact on American society, public opposition to government investment in science, engineering and technology rose between 2009 and 2014 [81, 82]. Further, the public is split on the role scientists should play in policy debates with four-in-ten Americans believing that scientists should stick to fact-finding and leave policy to politicians and policy makers [80].

These conflicting views on scientists' engagement in policymaking suggest there may be unique consequences (e.g., reputation-based ramifications) for scientists who engage with policy makers and the political system. Scientists may fear their reputation in the scientific community will be harmed by getting involved in politics or politics-adjacent areas of public policy, especially if this may affect future funding or career prospects. Scientists may also worry their messages won't be received well by politicians due to perceived biases. Concerns about ineffectiveness and reputational harm can disincentivize scientific engagement with policy makers, ultimately depriving the public of important, evidence-based contributions to the public good. A casual scan of headlines in major news outlets over the last 5 years reveals increased public attention to the politicization of science, with stories promoting the separation of science and state (e.g., "How Marching for Science Risks Politicizing It" [83]) and those calling for a deeper link between science and policy (e.g., "The Case for the Politicization of Science" [84]). Administrations, Democratic and Republican alike, have been roundly criticized for biases toward specific scientific experts, who are perceived as supportive of their desired policy outcome [85, 86, 87]. Further, the general public, especially ideological conservatives, is increasingly distrustful of science since the 1970s, suggesting a decline in science's status as a cultural authority in the modern era [88].

Mainstream attention on scientific engagement with public policy has not been matched by academic study, however. Quantifying outcomes, isolating them from confounding factors and randomizing treatment groups is extremely challenging, often infeasible, when studying the interactions between scientists and policy makers. There are often not enough examples of quantifiable science-policy interaction to provide a sufficient sample size for statistical analysis of observed outcomes. Study through traditional social science means, like surveys and interviews, is difficult due to risks of satisficing, social desirability bias, and nonresponse bias; however, these methods may represent the only option to apply scientific rigor to the study of science-policy interactions. These challenges, which limits the ability of researchers to effectively study these systems in formal, systematic fashion.

The paucity of evidence about the effects of scientific reputation on policy engagement is acutely felt since there is clear evidence that reputation does at least influence the number, type and quality of opportunities a scientist may have to engage with the policy making system. When policy makers look for experts to weigh in on new policies, one study of Australian politicians and civil servants suggests that politicians are more reliant on researchers' media presence to identify new sources of expertise than civil servants. Politicians also preferred to work with researchers who had established organizational and network reputations (e.g., credentialed at prestigious universities), and there is some evidence that an institution's reputation can even confer additional privilege to its less-published researchers [5, 89]. Yet civil servants cared less about academic credentials and more about the policy-relevance of an expert's work and their previous experience collaborating with them, reinforcing the point that experts' on-going participation in policymaking is key to science-policy communication [5]. Some political advisors also expressed a negative opinion toward researchers who went directly to politicians with their work rather than going through official channels; by skipping gatekeeping advisors, researchers were viewed as less credible and as potentially forwarding a specific political agenda [5].

Positively, credibility of scientific evidence can be bolstered in the eyes of politicians and public servants alike by improving institutional transparency, like the disclosure of funding sources and the production of public, universally-accessible data and methodologies [9]. Independence really appears key to convincing policy makers of a researchers' credibility, too, though politicians seem to care more about *public perception* of an expert's independence than civil servants [5]. For example, in one survey, Australian and Canadian Environmental Ministers expressed a preference for policy briefs crafted by academics outside the bureaucracy in order to increase a sense of scientific legitimacy and decrease the impression that "an expert [is just] brought in to spin the government line" [9]. Similarly, civil servants at regulatory agencies have been shown to emphasize their reliance on scientifically rigorous research when the agency operates in a highly decentralized policy space that lacks dominant actors who are seen as preeminent authorities on the subject matter in question. That is, agencies competing with other political actors to be heard will emphasize their reliance on science-backed evidence to send a strong professional signal to relevant policy makers [90]. Politicians also seem to foreground scientific rigor in decision-making when working with an agency that is viewed by the general public as less independent and more politically motivated [91].

Policy makers also express a preference for researchers who communicate skillfully in briefings, committee hearings, public meetings, and through the media. But a researcher's media profile can also be detrimental if the researcher has previously expressed disdain for or outright opposition to the government or its policies. Yet these dissenting experts may also be used by policy makers to demonstrate their openness to a range of information, too [5].

Indeed, different venues call for the use of different experts. Examining floor speech citations and official requests for think tanks to testify before Congress, Lerner (2018) finds that think tank ideology impacts a think tank's political influence in policymaking. Specifically, a more ideologically extreme think tank was more likely to be cited in floor speeches than a more moderate think tank, but more moderate think tanks were more likely to be called to testify before Congress than more extreme ones [92]. The logic here is that the floor speech is a more performative act than a congressional hearing, encouraging politicians to engage in political posturing, whereas hearings with expert testimony are meant to inform and persuade colleagues, placing emphasis on ideological moderation [93]. A think tank with a high number of employees who previously worked in bureaucracy, on the hill, or as registered lobbyists also increases a think tank's citation rate in floor speeches but has a great impact on the frequency with which the think tank is asked to testify before Congress [92].

Given the varied ways in which experts' reputation impacts the willingness of policy makers to engage with them, it is reasonable to ask if these reputation considerations prevent scientists from entering the policy space in the first place. Yet we lack empirical evidence that reputation concerns prevent scientists from engaging in policymaking, despite good reason to believe that such considerations could hamper effective science-policy communication. Scientists may be worried that their work will be distorted by policy makers with political aims, that policy makers will be overconfident in their findings despite scientific uncertainty, that policy makers will dismiss certain findings because they do not comport with prior beliefs, or that they (scientists) will be sidelined altogether if they are perceived as advocates rather than objective experts [94].

Subject-matter experts may also be unwilling to participate in policymaking for fear of damaging their standing in their research community. Scientific reputation among peers has a significant effect on an author's citation rate and probability of publishing in high-impact journals, which in turn can alter the trajectory of an author's career [95].

Ultimately, there is ample evidence that scientific reputation affects how policy makers perceive and respond to scientific engagement, as well as how scientists choose to engage with policy making. The literature review conducted during the preparation of this report did not uncover any studies which attempt to quantify this effect, however. Without this evidence, it is difficult to conclude how to contextualize reputational risks among the many other factors affecting science-policy engagement. Additional study of this topic is needed to determine the degree to which concern over reputational harm has actually limited scientific engagement with policy making, or compromised the ability of well-supported scientific evidence to appropriately inform policy making.

Conclusion

Policy makers are facing an increasingly complex slate of problems; science can be a critical tool for developing solutions to them, or at least supporting a more robust and comprehensive understanding of the problem. The value of scientific engagement with governance, as well as many of the foundational principles for making such engagement effective have been well understood for decades, and effective engagement between scientists and policy makers has dramatically improved many aspects of human life [96]. Despite this, science has had limited success applying its own tools to continue advancing this understanding. Academic institutions provide some guidance and training in these communications to their students, and an ever increasing number of scientists indicate an interest in, or facility with engaging in public policy making. Still, much of the literature in this space derives from anecdotal accounts of personal experience. Many of the conceptual constructs in communications studies or other social science disciplines may offer insight into science-policy interactions, but rigorously testing them is complex and uncertain at best.

In this paper we have synthesized much of the existing evidence-based study of science policy communications and attempted to evaluate the degree to which it is based on evidence as opposed to wisdom. Where there is evidence about the effectiveness of science-policy engagement strategies, we find that it aligns with generally-accepted best practices. Some principles, such as a preference for simple inclusionary language and de-emphasizing peer-reviewed articles as a primary means of communication, have been confirmed by evidence. Others, such as the most effective medium of communication or the use of personal narrative in science-policy engagement, are less well supported. We emphasize that a lack of evidence supporting a particular recommendation does not necessarily mean it is incorrect or ineffective, however the salutary effect of following the guidance of empirical evidence should apply to the study of scientific engagement in public policy just as much as it does when policy makers look to science to inform their decisions.

In this paper we distilled guidance on effective science-policy interaction down to eight specific recommendations, in three categories and identified the literature that supports each, with an emphasis on studies based on empirical evidence. We also discuss another topic of critical importance, the effects of scientific reputation on both scientists and the policy makers they seek to engage with. While it is clear that reputation plays a significant role in shaping the nature and effectiveness of scientific engagement with policy makers, there is little if any evidence regarding the magnitude of its effect. Future research into this area could help better elucidate the degree to which perceived reputational risks are matched by real-world consequences, and help scientists make more informed decisions about policy engagement.

Data Summary

Products of Research, Data Format and Content, Data Access and Sharing

No primary data were collected. This study is a literature review, with all sources from published documents.

All sources are cited and can be accessed through journal databases.

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Appendix: Collected Recommendations

For convenience, we have collected the core principles for effective science-policy communication, and the related recommendations into a single section. The following text copies the material from the body of the paper.

1. Clear, effective communication

a. Pick an appropriate venue or medium

Recommendations for Selecting the Proper Venue or Media Space

- **Social media has value as a scientific communications tool, but may not be highly effective for reaching policy makers.** Much research on social media's impact on science-policy communications focus on the impact social media usage has on changing public opinion, not the minds of crucial policy makers.
  - *Evidence: Professional anecdotes (e.g., Union of Concerned Scientists 2017* [3]*)*
- **Policy briefs or synopses are better than peer-reviewed journal articles for reaching policy makers but neither are as effective as in-person communication.**
  - *Evidence: Interviews with/surveys of policy makers and politicians (e.g., Lalor and Hickey 2013* [9]*, Haynes et al. 2012* [5]*)*
- **Meet policy makers where they are (e.g., internal reports)**. Policy makers often rely first on internal sources of information, then their immediate professional networks, and only after they have exhausted those outlets do they turn to academics and other research outfits for policy-relevant information.
  - *Evidence: Surveys of civil servants (e.g., Oliver et al. 2017* [12]*)*
- **Use "interface" organizations to get your research in front of the right people in a way that is faithful to your scientific findings.**
  - *Evidence: Professional experience (e.g., Dunwoody and Ryan 1983* [15]*) and policymaking trials (e.g., Osmond et al. 2010* [14]*, Perrier et al. 2011* [16]*)*

b. Use simple language and minimize jargon

Recommendations to Improve Language Simplicity

- **Minimize use of jargon or terms of art as much as possible.** Some jargon can be useful for educating the audience, if it's defined clearly, used repeatedly, and serves a role that is both essential and obvious to the audience. Readability tests can be useful for making scientific writing more accessible but are not adequate for boiling down substantive complexity.
  - *Evidence: Interviews with policy makers (e.g., Haynes et al. 2011* [25]*)*
- **Pictorial representations of complex information are more digestible than written text.**
  - *Evidence: Experiments (e.g., Powell et al. 2015* [97]*).*

c. *Minimize, but do not avoid, uncertainty*

Recommendations for Communicating Uncertainty

- **Embrace the value of data and statistics in conveying information to policy makers.**
  - *Evidence: Interviews with legislators (e.g., Dodson et al. 2015* [31]*)*
- **Convey findings in terms that provide context about uncertainty.** This includes using terms like "estimate," visualizing uncertainty (e.g., confidence intervals), and communicating absolute risk instead of relative risk ratios.
  - *Evidence: Experiments with the public (e.g., Covey 2007* [35]*) but little on the civil service*

2. Audience-focused messaging

a. *Know your intended audience's background and expectations*

Recommendations for Identifying Audience Background and Expectations

- **Understand that civil servants are looking for different information than politicians and their staffers.** Politicians (e.g., legislators) are more interested in conclusions and impact than civil servants, who may prioritize methodology, outcome metrics, and citations. Focus presentations to policy makers on what the science says they should do; those who care about methods can be connected to that material (e.g., sent a copy of the paper).
  - *Evidence: Professional experience (e.g., National Academies of Sciences 2017* [40]*)*
- **Understand the timing and context around a given subject.** Public policy is often deadline-driven, and subject to limitations on legal authority, budget, or politics. Messages to policy makers should understand these constraints and provide messages that are framed and focused on the goals of their audience.
  - *Evidence: Bielak et al. (2008)* [98]

b. *Frame your message so your audience can relate*

Recommendations for Framing Messages so Audiences Relate

- **Make explicit the connection between your work and its direct impact on your audience.** policy makers generally care most about issues that are directly under their control or directly affect their constituents. Identifying the mission, duties, and constituency of different political actors can help build a rapid connection to them and maximize their interest in your work.
  - *Evidence: Professional anecdotes (e.g., Stecula and Merkley 2019* [51]*)*
- **Test your messaging on an audience similar to those you are trying to reach**. While it's good practice to test a policy-focused presentation or communication on your research colleagues, their experience and perspective may not reflect that of the

policy makers that comprise your target audience. An audience that's unfamiliar with the topic will likely allow for more effective practice and feedback.

- *Evidence: The value of practice, especially practice that is highly representative of actual performance, is well-established.*

- **Narrative science can broaden the appeal of your research by reinforcing the external validity of your work.** People often respond to stories, which provide context and relatable elements to what may otherwise be abstract. If a narrative can be crafted around your message, it may be helpful to do so.
  - *Evidence: Spoel et al. (2008)* [55]*, Dahlstrom (2010)* [99]*, Dahlstrom & Ho (2012)* [57]*, Dahlstrom (2014)* [54]*, Ghuman & Kumari (2013)* [100]

3. Outcome-awareness

a. Identify and focus on desired goals

Recommendations for Identifying and Focusing on Goals

- **Identify a beneficial outcome, based on current science, and focus communication there.** Why was this line of scientific inquiry begun in the first place? Does a given finding indicate that policy makers need to pay attention to a niche or underappreciated problem? Is there information they need to consider when shaping policy? Is there a specific action or outcome that is strongly influenced by the evidence?
  - *Evidence: Professional experience (e.g., Dahlstrom and Ho 2012 [57])*

b. Sustain engagement over time, with a diverse set of policy makers

Recommendations for Maintaining Engagement

- **Find critical policy making venues, or policy makers and reach out to them before a formal process begins.** Legislative and regulatory processes typically have multiple opportunities for outside expertise to be considered, but these are often long before a policy change is reported in the media or enters public consciousness. The best time to have science make an impact on policy is early, while all parties are still open to new information and perspectives.
  - *Evidence: Interviews with policy makers and politicians (e.g., Koch and Zerback 2013* [65]*)*

- **Understand the timeline for policy processes and make suggestions at an appropriate time**. Realize that there are times in a policy process that are designed for, or highly amenable to outside input. By the time key votes occur, most stakeholders have solidified their position. Engaging early and understanding the timeline is critical to ensuring that scientific advice is positioned to be effective.
  - *Evidence: Kingdon (1984* [101]*)*

- **Build relationships with key policy makers.** Scientific advice can often be very useful outside of a formal policy process. By building relationships with key staff, elected officials, or community groups, scientists can become a resource for these communities and over policy-relevant advice at times when the audience is highly receptive.
    - *Evidence: Surveys of civil servants (e.g., Oliver et al. 2017* [12]*)*

c. Make recommendations specific and actionable

Recommendations for Making Specific and Actionable Recommendations

- **Understand the political environment in which a policy maker or politicians operate.** Approach policy makers with an eye on the costs, legal or regulatory authority, and overall feasibility of a given programmatic prescription, and approach politicians with an understanding of the politics surrounding a given proposal.
    - *Evidence: Surveys of policy makers and politicians (e.g., Haynes et al. 2012* [5]*, Petticrew 2004* [67]*)*
- **If diagnosing a policy predicament, come prepared with feasible solutions to the identified problem(s).** It is preferable to present policy makers with solutions when identifying an existing problem. Rely on strategies, like those recommended by implementation scientists, to assess the viability of your proposed solution.
    - *Evidence: Professional experience (e.g., Damschroder et al. 2009* [73]*)*

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