Challenges Turning Environment and Sustainability Science Into Policy: An Interdisciplinary Review

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Chapter 8
Challenges Turning Environment and Sustainability Science Into Policy:
An Interdisciplinary Review

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ABSTRACT

In theory, there is a strong, two-way relationship between sustainability research and public policy that functions in synchrony to identify, understand, and ultimately address ecological problems for the greater good of society. In reality, such a cooperative relationship is rarely found. Instead, researchers and policymakers face a suite of challenges that prevent effective communication and collaborative pursuits, prolonging the period required to address environmental issues. In this chapter, the authors apply a novel interdisciplinary approach to identify key barriers and solutions to translating research into policy. In doing so, the authors present two separate discussions focused on the natural and social sciences. The authors also review established research-to-policy frameworks to develop the new "cohesive" framework. By addressing key barriers between researchers and policymakers, society will be better able to respond to the various environmental stressors that it faces today.

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INTRODUCTION

Researchers and policymakers have long been concerned with the slow transfer of new knowledge into policy. Commonly referred to as the 'research-policy gap', this phenomenon occurs when "the expanding body of research... [is] having little to no effect in practice" (Cohen, Higham, Gössling, Peeters, & Eijgelaar, 2016 p. 319). This is when "more research is [not] needed" (Hering, 2016 p.1), instead a weakness in the science-policy link reduces effective integration of knowledge into action (Pahl-Wostl, Jeffrey, Isendahl, & Brugnach, 2011). As a consequence of this gap, society often struggles to resolve problems in a timely fashion, because the prerequisite information and the mechanism to enact change are disconnected. This problematic gap is widely reported across academic and political sectors including transportation, health care, education, and the environment (see Cohen et al., 2016; Watson, 2005). While all these sectors are critical for a stable and just society, the evolving suite of environmental crises faced by society paired with society's own rapid development and intensification, renders the environment and sustainability (ES) research-policy gap a particularly urgent concern (Watson, 2005).

BACKGROUND

An ES research-policy gap forms when the scientific knowledge required to identify and address an ES issue exists, yet is not reflected in a society's policies. In many cases society values the environment as well as sustainable development — rightly believing future developments should "[meet] the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987 p. 15). Yet these values are not consistently reflected in policies and governance. For example, ES scientists have asserted for decades that climate change is largely due to carbon dioxide released during fossil fuel combustion, with transport alone contributing approximately 14% of the total greenhouse gas emissions (IPCC, 2013). The ES research outlining this issue is widely and freely available. Still, most societies have yet to implement any impactful policies to transition away from a fossil fuel-based transportation system (Covert et al., 2016), despite an increasing global interest in sustainable development (Waas et al., 2014).

While current interest in addressing the ES research-policy gap is high (e.g. Jerneck et al., 2011; Kowarsch et al., 2017), concerns over the limited societal impact of ES research are not new. Radaelli (1995) explains that environmental research "creeps [into] policy...via indirect, cumulative and diffuse processes" (p. 164). Others have claimed that research rarely impacts specific policy outcomes (MacRae, 1976) or

lies 'dormant' until important events catalyze policy change (see Sabatier, 1987). No matter the exact mechanism, the slow pace of these processes may be especially unhelpful in a time of climate and other environmental crises, whereby societies are taking huge risks if they count on research findings to be 'taken up' by way of gradual processes.

The barriers preventing research-policy transfers already identified in the ES literature are primarily concerned with communication between scientists and policymakers, with several frameworks proposed as solutions (Hulme, 2014; van der Arend, 2014; Watson, 2005). A consistent conclusion from this work is the need for increased 'interfacing' between researchers and policymakers alike, where science-policy interfaces (SPIs) are "organizations, initiatives or projects that work at the boundary of science, policy and society to enrich decision making" (Sarkki et al., 2015 p. 502-506). These interfaces can take a variety of forms including intermediary discussion forums, joint advisory panels, knowledge networks (*sensu* Dilling & Lemos, 2011), and the establishment of knowledge brokers or boundary organizations (Hering, 2016; van der Arend, 2014; Watson, 2005). While different frameworks purport the efficacy of specific SPIs as *the* solution to the ES research-policy gap (e.g. Hering, 2016; Kowarsch et al., 2017), there is no consensus yet as to which is best. Instead, researchers broadly agree that an SPI with perceived credibility, relevance, and legitimacy can improve the connection between science and policy (Cash et al., 2003). Still others have concluded that changes are needed in terms of how research is conducted in the first place, suggesting a need for sustainability science that spans the boundary of theory and practice, and addresses local perceptions of the research itself (e.g. saliency, credibility, and legitimacy, see Cook & Odom, 2013). While these are all excellent coarse-scale solutions, sustainability issues tend to cut across a range of disciplines with unique fine-scale barriers that need to be recognized and addressed if society is to bridge the ES research-policy gap.

Of the research disciplines addressing ES, two areas of academic study consistently play a prominent role — namely natural science and social science (Turvey, 2015). As ES issues are inherently underpinned by natural processes, natural science is required to delineate the mechanisms causing the issue as well as the mechanisms that could (physically) resolve it. Social science, conversely, is important because modern environmental issues are often triggered by anthropogenic activities (Steffen et al., 2015). Thus, to prevent further incidents or intensification of the issue at hand 'the human factor' needs to be identified, studied, and ultimately addressed (Victor, 2015). Jerneck et al. (2011) argues that there needs to be an equal emphasis on natural and social science in the quest for sustainable development and sustainability in general. Accordingly, the authors posit that by identifying and addressing the fine-scale research-policy barriers for both the natural and social sciences, the ES research-policy gap can be further reduced.

As graduates of Western University's Environment and Sustainability Collaborative Research Program, and scholars in ecology, human and physical geography, as well as chemistry, the authors draw on their own diverse academic backgrounds to provide a unique, interdisciplinary review of the primary problems and solutions most pertinent to the natural and social sciences. The authors were inspired to generate this review after attending frequent seminars and panels discussions with experts in various fields of sustainability that were consistently concerned with how little scientific knowledge has yet to be put into practice. In this chapter the authors outline the main barriers faced by natural and social science and provide potential solutions to facilitate effective translation of ES science to policy. It was not their goal to develop an exhaustive list of barriers, nor to identify barriers that solely apply to the ES research-policy gap. Instead, the authors identified three barriers of greatest concern for translation of natural and social research into policy. Furthermore, the authors review existing knowledge transfer frameworks between research and policy. They complete their overview by presenting a novel interdisciplinary framework to further ease the ES research-policy gap, concluding future scientific efforts need to be conducted with the input and guidance of multiple experts across multiple fields – including policy experts. While the research-policy gap is clearly experienced globally, the authors place much of their discussion in a Canadian context due to their own personal experiences and familiarity with the established systems therein.

THE RESEARCH-POLICY GAP IN THE NATURAL SCIENCES

In the past century, natural science research has successfully contributed to many significant environmental policies, particularly in Canada. For example, seminal research conducted in Canada's Experimental Lakes Area during the early 1970's demonstrated the clear role of phosphorus in major eutrophication events plaguing aquatic ecosystems globally (Schindler, 2006; Schindler, Armstrong, Holmgren, & Brunskill, 1971). Following this discovery, Canada and the United States signed the Great Lakes Water Quality Agreement in 1972, creating a policy with specific targets and mechanisms to drastically reduce point-source phosphorus loading into the Great Lakes basin. In recent decades, however, the research-policy gap has widened considerably in the natural sciences. As recently as 2012, drastic reductions in Canadian federal science funding programs were made, limiting environmental research programs and resulting in the closure of globally significant, federally funded research stations, like the aforementioned Experimental Lakes Area. Wide sweeping changes to environmental legislation propelled natural scientists to protest in record numbers, declaring the 'death of evidence' and a 'war on science' (Turner,

2013) in governmental decision-making processes. Clearly, novel contemporary science-policy barriers have developed in recent decades and are compounded by classical barriers that have remained unaddressed.

Natural Science Barrier 1: Limited Direct Impact on Public

The public tends to demonstrate high resistance to policies addressing issues that do not appear to directly affect them. It is difficult to enact policies that force changes on society when they are not currently experiencing negative consequences (Semenza et al., 2008; Wallinga, Rayner, & Lang, 2015). A case in point is the significant resistance against aggressive climate change policy over the past decades. An individual may not see the point of subsidizing renewable energy or implementing a carbon tax when the only perceived effects they feel on a daily basis are slightly warmer temperatures. It is also challenging to convey the impacts of an individual's action when the consequences feel distant (Pidgeon & Fischhoff, 2011). This distance could be geographical, where citizens find it hard to be sympathetic towards people from a different part of the globe. This distance could also be in terms of time, where people have trouble changing their habits immediately to deter consequences in the future or for future generations. This is particularly true for climate change, where the inherent complexity of atmospheric science makes it difficult to predict exact timelines (Lorenzoni, Nicholson-Cole, & Whitmarsh, 2007). It is important to note that the resistance to ES policies is compounded when there are perceived negative economic consequences associated with said policies. However, economic effects of ES policy are complicated and consistently difficult to anticipate (Riahi, Grubler, & Nakicenovic, 2007). Regardless, if society hopes to move forward on climate change and other environmental issues, it must convince itself to change its behaviour and policies — even when it is not currently experiencing any immediate negative impacts from its actions.

Proposed Solutions

While addressing public resistance to scientifically supported change is a complex issue, there are approaches that can make potential negative consequences resonate with citizens. One approach is to identify the personal hazards of the environmental issue for the public, primarily by conducting research that demonstrates local risks. For example, research by Carlson and McCormick (2015) demonstrated that US cities with established climate change response plans credit research conducted on local climate change impacts as an important driver. Cities like Boston, MA, Raleigh, NC, and Tucson, AZ, had resident academic institutions providing primary

data on local vulnerabilities to climate change, emphasizing potential local impacts if adaptive strategies were not developed and employed.

A similar approach was taken to address the ozone depletion crisis of the 70s and 80s. Academic research at the time clearly linked ozone depletion with an increased incidence of melanoma and non-melanoma skin cancers due to elevated ultraviolet radiation reaching the Earth's surface (Fears & Scotto, 1983). The public could clearly identify the potential personal consequences of ozone depletion, particularly in North America, and rightly called for appropriate policies to be put in place (Watson, 2005). Accordingly, politicians developed the Montreal Protocol and Vienna Convention to Protect the Ozone Layer, phasing out the use of ozone-depleting chlorofluorocarbons (CFCs). The successful translation of the ozone research program into policy was attributed, at least in part, to clearly linking the environmental issue with personal risk (Kaniaru, 2007; Watson, 2005). The positive effects of this policy implementation are still being observed to date, as the North American Space Agency (NASA) continues to quantify and report the recovery of the ozone layer over the Antarctic (Strahan & Douglass, 2018).

Another approach is reframing established environmental issues using trusted media sources and social opinion leaders to connect with the public (Nisbet, 2009). Reframing can place an environmental issue in a relevant social context that matches the values of the public. For example, initial climate change findings were intuitively framed as a pollution problem with dire environmental consequences — a strategy used successfully for past large-scale environmental concerns like acid rain. However, this framing was met with resistance by a North American public facing a struggling economy. In response, advocates reframed climate change adaptation as an economic stimulus opportunity, highlighting new job creation and stable employment opportunities (Nisbet, 2009; Nordhaus & Schellenberger, 2007).

Natural Science Barrier 2: Complexity and Uncertainty

Increasingly complex ES problems have widened the gap between scientific research and its implementation into effective policy (Carlson & McCormick, 2015). Both citizens and policymakers are generally uncomfortable with the inherent uncertainty often associated with complex issues. The problems addressed by natural science have increased considerably in terms of their complexity, whereas political systems have stayed relatively constant (Goldson, Gluckman, & Allen, 2014). This has led to difficulty in implementing natural science into policy, and a demand for more sophisticated protocols on how to navigate the differing paradigms across science, policy, and society (Smajgl & Ward, 2013). Scientists have the difficult and fundamentally important role of conveying the probabilistic nature of any complex issue, as well as the concomitant trade-offs of any course of action. Perhaps because

this type of communication is inherently challenging, it rarely occurs in practice. This leads to the public potentially overreacting when any problems arise with a given policy without fully understanding the depth of the issue (Goldson et al., 2014). There needs to be a mechanism in which scientists effectively convey the complexities of the science behind a policy in a way that the public can understand and appreciate.

Proposed Solutions

The complexity and uncertainty associated with many of today's environmental issues are generally unextractable from scientific research. Yet, effective communication of these complex ES problems by scientists to policymakers and the public alike is still achievable. Proposed solutions include developing a collaborative network between research teams, government organizations, and non-profit groups with vested interests in the ES issue at hand (Head & Alford, 2015). Such networks allow for a range of experts in relevant fields to discuss and consider each facet of a complex environmental issue. Concomitantly, the network creates a mechanism to effectively translate knowledge directly to engaged policymakers and members of the general public for further dissemination.

Efforts to improve the general understanding of the scientific process would also address this barrier of translating scientific research into policy. The myth that science is supposed to produce unequivocal proof is a fallacy that generates confusion surrounding environmental issues (Sarewitz, 2004). A general understanding that science can only generate evidence with inherent, but *acceptable* uncertainties would provide clarity for many issues (Oreskes, 2004). To address this problem, some now urge technical writers to adapt standardized language when discussing certain levels of scientific uncertainty as a potential solution (Walsh & Walker, 2016), akin to the standardized writing style and terminology adapted for the International Panel on Climate Change reports.

Natural Science Barrier 3: Natural Scientific Literacy

A classic science-policy barrier is the concerning lack of fundamental natural science literacy. Science literacy is widely acknowledged as an essential skill to fully participate as a democratic citizen (Eilks, Nielsen, & Hofstein, 2013), as public opinion can either impede or greatly stimulate policy development and implementation. Many countries that have historically been leaders in scientific engagement and literacy are currently experiencing a significant decline, described by some researchers as a science literacy 'crisis' (DeCoito, 2016; Woods-McConney et al., 2014). For example, between 2003 – 2012 Canada experienced a significant and sustained decrease in

high school students' scientific knowledge and problem-solving skills (Richards, 2014). In the United States research has demonstrated "that a substantial portion of the public does not know about basic scientific facts or the essential principles of experimental methods" (Gauchat, 2015, p. 725; National Science Foundation, 2018). As a result of this limited and declining scientific literacy, citizens now often cling to stand alone studies to support their pre-existing opinions, or mistake information written by non-scientists as credible science sources. The rise of social media as a valid information source has resulted in citizens that overestimate their ability to analyze complex issues, and as a consequence doubt the scientific community (Bauer, 2009). This public distrust limits the science-to-policy transfer, as the science lacks public support. This support hinges on the public's understanding and appreciation of the issue at hand, which is often seriously lacking (Miller, 2004). A good example is the ongoing debate on whether climate change is primarily a result of anthropogenic activities. This is an issue that frequently arises in political debate and is therefore discussed extensively amongst the public. The problem of limited scientific literacy shows itself when climate change deniers cite information from a few select studies or from social media sources, when the overwhelming scientific consensus indicates that humans are a main driving force behind recent climate warming (Pidgeon & Fischhoff, 2011). Until the public has a baseline of scientific literacy, policy will continue to be held back by the political pressures created by citizens.

Proposed Solutions

Issues surrounding scientific literacy in the general populace have been long-standing with little widespread success in terms of solutions. The rise of social media as an information source has prompted many researchers to consider social media platforms as not only a threat but also a potential solution to scientific literacy. Initial studies have demonstrated that such platforms are effective at engaging young adults in productive science-oriented debate, which in turn develops scientific literacy (Greenhow, Gibbins, & Menzer, 2015). Others have found social media sites create unique opportunities for experts to communicate directly with the general public. Such interactions increase the general interest in ES issues and create opportunities to advance scientific literacy (Fauville, Dupont, von Thun, & Lundin, 2015). That said this solution is passive, depending on the general public to engage with the scientific community and consume reputable science.

Other researchers argue that scientific literacy issues are secondary to other societal factors, such as group identity. Research by Kahan et al. (2012) demonstrated that groups with similar cultural ideologies can have similar opinions on ES issues, irrespective of scientific literacy. These results were purported to be driven by peer-pressure within the specific ideological groups, as opposed to a mastery of

scientific information (Kahan et al., 2012). This issue is further compounded by widespread group ideologies that inherently reject science engagement (Bennett & Hogarth, 2009). Instead the study of science is described generally as "important but not for me" (Jenkins & Nelson, 2005 p. 41). Consequently, as young adults many citizens do not seek out extracurricular science programs and limit their own science education to the bare minimum requirements, with life-long consequences (Bennett & Hogarth, 2009; Woods-McConney et al., 2014). In all cases grassroots movements within resistive groups are needed to disassociate the group's identity with a specific environmental opinion or capacity for science. Only after this dissociation can increasing scientific literacy potentially be effective.

THE RESEARCH-POLICY GAP IN THE SOCIAL SCIENCES

Historically, 'environment and sustainability science' has been housed almost exclusively in the natural sciences. Environmental researchers have recently increased their attention to social theory, in part because what counts as 'environmental' is also social, biosocial or natural-cultural (Ingold & Palsson, 2013). The ever increasing societal recognition of humanity's role in many modern environmental crises has further prompted many academics to investigate the theoretical and practical convergences between society and nature (Descola & Pálsson, 1996). While traditional scientific research still needs to take place to further our mechanistic understanding of environmental issues, social science is uniquely positioned to tackle research questions related to political and cultural barriers surrounding these issues (Hackmann & St. Clair, 2012).

Social Science Barrier 1: Funding

A major barrier preventing socio-environmental research from affecting policy and change is the relatively limited funding of social scientific questions, preventing their initial investigation. Across environmental and other research, social scientists often find it difficult to obtain funding when it is driven by 'pure' social research questions (Holm et al., 2013), despite a growing general acceptance that human activity is a key driver of environmental change (Palsson et al., 2013). This is particularly the case when the research does not have any apparent monetary value and/or when "quantitative purists" maintain that survey work is the only acceptable form of social inquiry (Johnson & Onwuegbuzie, 2004; p. 14).

In Canada, federal funding for research is divided amongst three Tri-Council granting agencies: Social Science and Humanities (SSHRC), Natural Sciences and Engineering (NSERC), and Health Research (CIHR). Similar to the way funding is

spread in the UK, Australia, and the United States, social science research is given a much smaller percentage of total funds — only 15% in 2014-2015. The total amount of funding provided in Canada in 2016 to projects with titles or keywords that included "environment" or "sustainability" was between 1.4 – 9.2% of all Tri-Council funding (SSHRC, 2016). Given the need for increased research looking at human dimensions of environmental disturbance, these figures are troubling.

Proposed Solutions

Naturally, the simplest solution is to encourage funding organizations to better support socio-environmental research. However, a lack of support in a particular research area is not in and of itself a good reason to increase funding. In order for environmental social scientists to put forth more successful granting applications, they must adhere to current systems and contexts in place today. For example, in light of Ontario, Canada's push to fund research that supports economic growth, academics should make clear to granting agencies the increasing costs associated with unabated climate change. These costs were first detailed by Stern et al. (2006), and Canadian-specific research has since echoed some of the conclusions, including one estimate that warming could cost Canada between $21 and $43 billion per year as of 2015 (National Round Table on the Environment and the Economy, 2011; see Nelson et al., 2014). With these types of trends in mind, socio-environmental academics may be better served to emphasize the potential for their research to either mitigate or adapt to global climate change.

Another potential funding avenue for socio-environmental research programs is outside of major traditional government agencies, such as internal sources (i.e. university funding), private industry, or non-profit organizations. One such non-profit group is the George C. Metcalf Foundation of Toronto, Ontario (http://metcalffoundation.com), which has funded socio-environmental research at York University, the University of Waterloo, and Western University in recent years. Although funding from industry in particular can present problems in terms of perceived bias, loss of control, and/or an increased commodification of research (Nelson, 2001; Perkmann et al., 2013), it is also known to create localized knowledge spillovers — an advantage co-located actors experience when accruing and accessing knowledge (D'Este, Iammarino, Savona, & von Tunzelmann, 2012).

Social Science Barrier 2: A Lack of Applied Research

Historically, social science has been largely disconnected from "the practical problems of policy" (Merton, 1949; p. 161), instead focussing more explicitly on social theory development. While theory development is of great importance, it has left a clear

informational deficiency for practical social issues. The value of such applied social research pursuits is outlined by Moran and Lopez (2016), who conclude that public involvement in academic research "can ensure that the investments results in public benefit" (pp. 1-2). By strengthening the 'science-policy' interface, it is this public benefit that socio-environmental researchers can advance, yet also use as leverage for additional funding in this area (see Social Science Barrier 1: Funding). The idea that social research should lead to public benefits has led to debates on the distinctions (or lack thereof) between applied social research and activism. Wadsworth (2005) describes the unease sociologists in particular have faced when beginning research that is intrinsically political in nature. In support of applied research, others have claimed that there is no such contradiction between an active commitment to problem resolution and quality scholarly research of that problem (Hale, 2001).

Proposed Solutions

Despite the extended history of social-academic research generally being unapplied in nature, there is some indication that this may be changing. Particularly in the social sciences, Hawkins, Langford, and Saunders (2015) found that applied research is increasing across six Canadian Universities. How exactly the academic community engages in more applied research activities leaves some room for debate. Palmer (2012) suggests social inquiry should begin by asking policymakers and community leaders what they need from the research community. An alternative solution is the involvement of the local community in the research early on. This could mean asking nearby residents to help shape the research questions that are important to them. This type of community-oriented, social science research has given rise to action-based practices like Community-Campus Partnerships (CCP; Boser, 2002), Participatory Action Research (PAR; McIntyre, 2007) or Community-Based Participatory Research (CBPR; Hacker, 2013). These applied research techniques strive to equalize the power dynamic between community participants and academic researchers by capitalizing on valuable local knowledge to invoke societal change and shape policy (Baurn et al., 2004; Freudenberg and Tsui, 2014). While these research programs have been primarily applied in healthcare studies (see Castleden et al, 2012, 2008), they would have great value in addressing the ES research-policy gap if adopted widely by the field. In fact, the main purpose of CBPR is to "[combine] knowledge and action for social change" (Minkler and Wallersetin, 2003), where by greater involvement of the public alters the mechanism for, and in turn leads to greater policy change (Freudenberg and Tsui, 2014; O'Fallen and Dearry, 2002).

While the benefits of applied, community-oriented research programs like CCP, PAR, and CBPR are clear, they are not yet widely utilized. Systematic and institutional norms of research funding and outdated university policies inadvertently discourage

this style of research (see Curwood et al., 2011; Schwartz, 2010; Schwartz et al., 2012; Sullivan et al., 2001). Even when such community-academia partnerships do manage to form, there are still biases that favour the interests of universities over local populations and a lack any reward structure for researchers conducting this style of study (see a Framework Forward; Hall, 2009; Hart et al., 2007). For these reasons and more, inviting academic 'outsiders' to partner in ES research may prove to be very difficult for some 'traditional' academics. Yet if the goal is to create usable knowledge that will affect change, it may be the right way forward.

Social Science Barrier 3: A Focus on 'The Individual'

Social scientists who address large scale, diffuse environmental issues, such as climate change, have largely focussed on human agency and lifestyles — what Shove (2010) calls the ABCs- Action, Behaviour, and Choice (see Ajzen, 1991). There has been a paucity of studies which go beyond agency in questioning how socio-political context or government initiatives can powerfully shape public response to environmental threats. Looking at environmental attitudes and behaviours as independent from the places and policies under which they emerge is akin to blaming farmers for a lack of agricultural output in times of drought (Halpern et al., 2004). Whether it is the physical or social, the environmental spaces in which humans live can greatly influence lifestyles and behaviours. As a result of this individual-focused research approach, there has been a limited capacity for social science to drive policy surrounding diffuse environmental issues, including climate change.

Proposed Solutions

In order to advance our understanding of the interaction between human lifestyles and large- scale environmental issues like climate change, social scientists must follow the advice of Shove (2010) and "go beyond the individual". Already there is a growing collection of broadly defined social science research that reveals environmental policy is shaping human and corporate behaviour across multiple categories (Ramkissoon, Smith, & Weiler, 2013; Steg, Bolderdijk, Keizer, & Perlaviciute, 2014). In these types of studies, researchers may often present a more tangible case for policy change, whereby researchers are critical of the context which drives damaging behaviour and not the behaviour itself. Though this type of critical appraisal of the policy systems created or modified by policymakers may be difficult to hear, it is a necessary approach if society is to move beyond current research strategies and develop more policy-impactful research.

An emerging example of research which does "go beyond the individual" in the Canadian context is found within the newly defined 'social acceptance of wind energy' literature. For example, recent research from Ontario, Canada revealed that the politics and implementation of green energy policy driving wind energy development is the major source of public resistance and opposition (Baxter, Morzaria, & Hirsch, 2013; Songsore & Buzzelli, 2015; Walker et al., 2018; Walker, Baxter, & Ouellette, 2014). The enormous power of two components of the green energy development processes: planning procedures and financial compensation increase our "understanding how [development] policies interact with social processes [e.g. support for wind energy] at the local level" (Walker et al., 2014: p. 730). This contrasts early literature that connected wind energy opposition with the 'selfish', 'ignorant', or 'uneducated nature' of rural residents.

A Framework Forward

Addressing discipline-specific barriers is necessary to bridge the research-policy gap. That said, such efforts will be most successful if they are scaffolded onto an effective framework that promotes an achievable change in how knowledge is transferred between researchers and policymakers. In the current framework, the majority of new scientific knowledge is produced in isolation of other ES scientific disciplines (ex. natural and social science) and policymakers, often in a *collinear* fashion (Sarkki et al., 2015; Weichselgartner & Kasperson, 2010) (Figure 1A). The authors van Kerkhoff & Lebel (2006) describe this framework as the 'trickle down' approach, where researchers believe high quality knowledge will be actively taken up and translated into action by policymakers and stakeholders. In this framework, ES researchers alone are responsible for identifying core ES problems faced by society, developing an appropriate research program to produce new information needed to address this problem, and interpreting the potential implications of this new knowledge for society (van Kerkhoff & Lebel, 2006). However, once the researcher has published new information their role in transferring knowledge into action is considered complete. It is the role of the end user to find and apply this new knowledge as action, with little opportunity to provide insights backs to the researchers on the ES problem selection, research design, or knowledge interpretation. As such, the collinear framework routinely fails to translate knowledge into action. Scientists are inherently biased towards developing research programs that will advance their own careers, with often limited direct applicability to policymakers and end users (van Kerkhoff & Lebel, 2006).

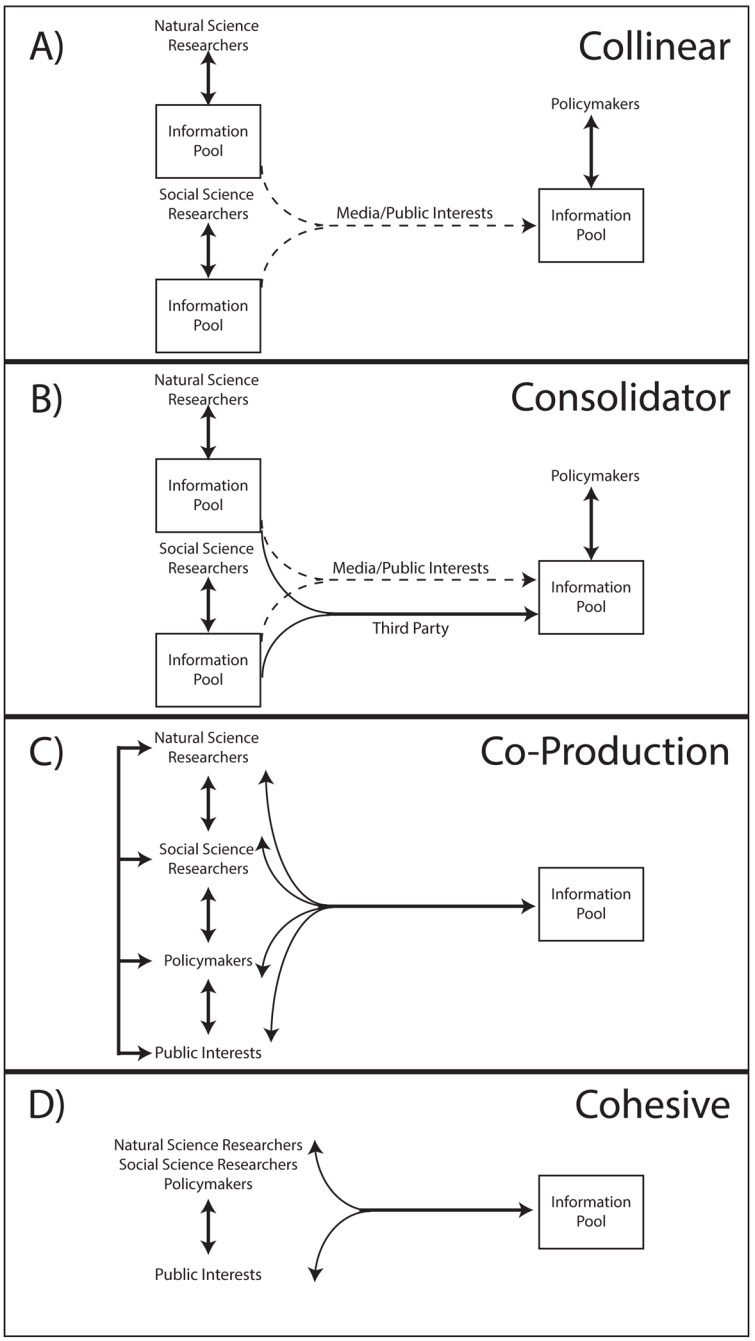
The academic reward structure is an important but under acknowledged cause of the ES research-policy gap, sustaining the current use of the collinear framework by academics despite its acknowledged flaws. Academia consistently rewards the

publication of research as well as grant income over less tangible benefits such as engagement with policymakers and end users (Cook & Odom, 2013; Knight et al., 2008). Hawkins et al. (2015) found little to no relationship between broader community involvement and academic promotion; instead, promotion and tenure were much more affected by overall academic output. Without proper structures in place that reward this type of engagement, time-stressed environmental scientists will find it difficult to prioritize networking with others — including policymakers (Knight et al., 2008).

In figure 1, the first framework, given in (A), is the collinear framework and serves as an example of the research-policy gap, where both researchers and policymakers have functionally independent information pools that they draw from and also contribute to, with minimal transfer between pools. The majority of the transfer that does occur is weak and is mediated by both the media and public interests. It is important to note the policymakers are accessing and applying scientific knowledge, but it tends to be predominantly produced by government research bodies and with only a subset of the wider scientific knowledge produced by the academic community. An observed solution to this gap (B) is the consolidator framework, which is the establishment of a strong information transfer link, mediated by a 'third party' able to interpret primary research into readily accessible terms for policymakers — however, policymakers are not able to provide any feedback directly to the scientific community. The third framework (C) is co-production, which harmonizes the information produced and utilized by researchers, policymakers, and the public into a single pool that is inherently accessible to end users. The final framework (D) is the cohesive framework proposed by the authors, where ES researchers and policymakers form temporally-stable, interdisciplinary teams housed within the same facilities to support the continuous, multi-directional dialogues needed to address the fine-scale ES barriers identified in this chapter, while conducting impactful ES knowledge generation. Similar to the co-production framework, policymakers and researchers still collaborate in an iterative fashion with the public to generate a shared knowledge pool, however, public partners would not necessarily be based out of the same facilities.

To ease the isolation effect between researchers and policymakers, some authors now recommend the involvement of a 'third party', or a *consolidator,* as an improved framework (Dilling & Lemos, 2011; Hering, 2016; Weichselgartner & Kasperson, 2010). The consolidator's role is to identify, coalesce, translate, and transfer ES science into plain language that can be easily taken up and applied by policymakers (van Kerkhoff & Lebel, 2006). Similar to the collinear framework, knowledge production in the consolidator framework is generally one directional (researchers to end users), with little opportunity for policymakers to directly inform research programs (van Kerkhoff & Lebel, 2006). Moreover, no efforts are made to synchronize the energies

Figure 1. Depiction of four different information transfer frameworks between primary researchers and primary policymakers



of ES academic disciplines like natural and social sciences. Instead this framework focuses on building bridges between researchers and policymakers (Figure 1B). Efforts have already been put forth to apply this framework by a variety of third party groups, such as information brokers and invested collaborative organizations, with some success (Dilling & Lemos, 2011; Hering, 2016). These groups, however, are the exception for most knowledge produced and are not the accepted norm. Moreover, it seems unlikely a consolidator framework will become widely adopted as researchers and policymakers report little interest in communicating through a third-party organization (Choi et al., 2016).

A more promising option to close the ES research-policy gap is the establishment of a *co-production* framework, where co-production is "the combination of scientific resources and governance capability that shapes the extent to which a society, at various levels, can operationalize relationships between scientific and public, private, and civil society institutions and actors to effect scientifically-informed social change" (van Kerkhoff & Lebel, 2015 p. 14). More simply put, co-production is the coordinated and synchronized production of new knowledge by experts and relevant stakeholders, including policymakers, with an emphasis on stakeholder interaction, useable science, and interdisciplinarity (Lemos & Morehouse, 2005; Wyborn, 2015). In contrast with the collinear and consolidator frameworks, the co-production framework mandates that knowledge production is non-linear, with stakeholders continually providing formative input throughout the entire knowledge production process (Lemos & Morehouse, 2005; Sarkki et al., 2015). The generated knowledge must be directly applicable to the end users' needs, including supporting policy formation. Finally, the co-production team must be interdisciplinary, working together in an iterative capacity with the same members until an integrative solution is produced and specific knowledge needs are met (Lemos & Morehouse, 2005). By generating new knowledge together, it ensures both ES researchers and policymakers are drawing from the same knowledge pool, effectively removing the research-policy gap (Figure 1C).

As part of the co-production framework, natural and social science academics should take a leadership role by applying interdisciplinary approaches in their own research programs. By doing so academics involve a range of experts needed to fully address the multi-faceted nature of many ES issues, while improving effective communication across their respective disciplines (Weichselgartner & Kasperson, 2010). In her description of what she calls actionable socio-environmental science, Palmer (2012) notes that scholars must go beyond their "collaborative comfort zone[s]" (p. 5) and engage in collaboration between the natural and social sciences. By applying this research model, academics are forced to produce publications understandable to all fields of study involved — often increasing the readability of the product to a wider audience. That said, the call for interdisciplinary research

programs does not mean the end of the classical, discipline-based expertise so familiar in academia (Lemos & Morehouse, 2005). As Holm et al. (2013) describes using the analogy of sports, the best teams are usually made up of exceptional, yet specialized individuals. Just as "a striker on a football (soccer) team would not have the same success as a defender" (p. 32), a successful collaborative research team requires a variety of academic partners, each with their own set of skills, knowledge, and expertise.

Many science-policy interface organizations constitute a successful actualization of the co-production framework (Wesselink, Buchanan, Georgiadou, & Turnhout, 2013). SPIs can include any "organizations, initiatives or projects that work at the boundary of science, policy and society to enrich decision making" (Sarkki et al., 2015 p. 502-506), and are generally optimized when they are perceived as credible, relevant, and legitimate (Cash et al., 2003). Broadly, they facilitate an iterative, multidirectional dialogue between researchers, policymakers, and the public to stimulate real change in society (Sarkki et al., 2015). These organizations can have many labels including the aforementioned Community-Campus Partnerships, Participatory Action Research groups, and Community-Based Participatory Research groups as well as Global Environmental Assessment groups (GEAs). Global environmental assessments are considered a particularly successful type of SPI and form of co-production, consistently transferring knowledge into action because of government buy-in and novel interdisciplinary synthesis products (Kowarsch et al., 2017). Specifically, GEAs are defined as "largescale, highly deliberative processes where experts are convened to distill, synthesize, interpret and organize existing scientific knowledge (on environmental issues) to inform decision-making" (Jabbour & Flachsland, 2017 p. 193). Particularly successful examples include the intergovernmental panel on climate change (IPCC) and the fifth Global Environmental Outlook (GEO-5) assessment, accredited with catalyzing the Paris Agreement and influencing the 2030 Development Agenda respectively (Kowarsch et al., 2017). Accordingly, some consider GEAs like the IPCC to be a model application of the co-production framework that when scaled appropriately, can serve as an ideal archetype for future co-production efforts.

While co-production is a laudable framework, it generally fails to address many of the key fine-scale barriers limiting natural and social science translation into policy, as identified above. Accordingly, the authors present the *cohesive* framework, which fully integrates new knowledge production with policy formation at leading academic centers, such as universities. In this framework, temporally-stable, interdisciplinary teams of ES researchers and relevant policymakers work within the same facilities (Figure 1D). This allows for a *continuous*, *low-latency*, sustained, and multidirectional dialogue between all parties. Policymakers can directly inform research programs, while scientists can personally resolve issues of data complexity

and uncertainty, perceptions of limited negative impact of ES issues on broader society, and advocate for improved natural science literacy and social science funding where appropriate. The authors are not proposing all ES policymakers be relocated to academic centers, but a subset of ambassadors should be strategically positioned at centers of ES research excellence across the country. In this framework researchers and policymakers still work in an iterative fashion in concert with the public to enact real change in society, but the interface between researchers and policymakers is strengthened and enriched. The cohesive framework inherently retains the key characteristics of the co-production model required to successfully develop new knowledge; however, it also creates a unique platform for multilateral political and scientific advocacy amongst partners. That said, cohesive knowledge production would not universally replace co-production efforts, but instead should be applied in a synchronous, network style approach to maximize research-to-policy efforts and efficacy.

The cohesive framework could theoretically take many potential physical forms, but the Institute for Watershed Science at Trent University, Peterborough, Canada provides an excellent example of a long-term, cohesive partnership between ES academics and government bodies within one facility (http://www.trentu.ca/iws/overview.php). This collaboration has the specific commitment to "conduct peer-reviewed, multi-disciplinary science" (Institute for Watershed Science, 2017). Over the past 26 years the institute has created an environment where government employees and academics work side-by-side producing over 20 successful research programs, numerous peer-reviewed publications, as well as policy-targeted new knowledge.

CONCLUSION

For society to be responsive and adaptive to the growing number of ecological crises that it faces, the ES research-policy gap must be minimized, if not closed. The researchers and policymakers working within the ES field are acutely aware of this great need, but also of the complexity, in closing the gap. As ES research is often inherently multi-disciplinary, researchers from different 'academic silos' often struggle to communicate with each other, further impeding their capacity to communicate with citizens and policymakers. The situation is further complicated by the unique research-policy barriers that core ES academic disciplines face. The main barriers and solutions applicable to the natural sciences are not shared by the social sciences. In the natural sciences researchers consistently struggle to communicate the importance and complex nuances of their research and the ES issues at hand to the general public and policymakers alike. Social science researchers, conversely, often lack the necessary funding to pursue ES inquiry, perhaps as a consequence of

a history of less-applied study focused on the actions of the individual. Still, none of these barriers should be viewed as insurmountable. Many of these barriers can be addressed by researchers themselves if they adopt slightly modified practices, such as searching out non-traditional funding sources, or targeting empirical research programs to quantify the local impacts of an environmental issue. That said, shifting new knowledge production away from the traditional collinear framework could have truly transformative impacts on the research-policy gap. By adopting the co-production framework researchers and policymakers can work together to identify, study, and address key ES issues for society. By implementing the cohesive framework researchers and policymakers will be able to directly resolve fine-scale research-policy barriers, while still working in an iterative fashion with the public to generate new knowledge. Only by transitioning away from the collinear framework and tackling core research-policy barriers will policymakers see more on-demand, policy-poignant knowledge, while academics see a better application of their research. Such a seamless research-policy relationship is no doubt required if we are to ensure a stable, safe, and healthy environment for future generations.

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KEY TERMS AND DEFINITIONS

Co-Production: The production of new knowledge by an interdisciplinarity team, involving end users in a multi-direction dialogue throughout the production processes to generate usable knowledge.

Cohesive Production: The production of new knowledge by a temporally-stable, interdisciplinary team of researchers and policymakers housed within the same academic facilities, able to conduct continuous, low latency, and multidirectional dialogues to resolve fine-scale research-policy barriers, while still working in an iterative fashion with the public.

Collinear Production: New knowledge production and dissemination conducted primarily by research experts, with limited input or feedback from end users on the utility or quality of the final product.

Consolidator Production: A one directional transference of research products to end users via a third-party organization that coalesces and translates useful new knowledge into a readily accessible format for end users.

Environment and Sustainability Research: New knowledge production on the functionality of our past and current socio-ecological systems, as well as the development of improved future systems.

Knowledge to Action: The transference of new knowledge into impactful societal change.

Research-Policy Gap: The limited integration of available research into policy.