

# Hybridizing Sustainability Metric Applications with Local Stakeholder Inputs: A life cycle assessment with a co-design demonstration

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**Maggie Cascadden**   
University of Alberta, Canada

**Kylie Heales**   
Miami University, USA

**Matt Kingston**  
University of Alberta, Canada

**Pia Heidak**  
Pforzheim University, Germany

**P. Devereaux Jennings**   
University of Alberta, Canada

## Abstract

Sustainability standards have been criticized as being complex and overlapping, with unclear metrics and messy timelines—all of which have led to sustainability shortfalls. As part of the special issue on addressing sustainability metric shortcomings, we develop a hybridizing protocol for sustainability standards that elicits community stakeholder ideological predispositions, preferences, ratings, and heuristics and injects them into a prioritized, vetted metric in order to reduce immediate and longer-range life cycle impacts of corporate operations in the local ecosystem. We demonstrate our method using a quasi-field experiment, conducted by expert intermediary facilitators, in which community members co-design oil sands wetland reclamation and their choices are integrated into life cycle assessments (LCAs) of wetland designs and remediation products. Hybridizing LCA with local co-design not only generates an effective wetland-material choice, but reduces life cycle impacts and increases the likelihood of community acceptance.

## Keywords

community stakeholders, life cycle assessment, organizational sustainability, sustainability standards

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## Corresponding author:

P. Devereaux Jennings, University of Alberta, Edmonton, AB T6R 0H7, Canada.  
Email: [dev.jennings@ualberta.ca](mailto:dev.jennings@ualberta.ca)

Environmental sustainability has gained increasing attention in mainstream organization theory (Bansal & Song, 2017; Hoffman & Georg, 2018). Despite significant efforts by researchers and policymakers to conceptualize sustainability goals and set up effective implementation programs, we are falling short as a society in reducing greenhouse gas emissions, protecting water resources and habitats, and preserving species—as noted more generally in assessments of organizational sustainability research (Ergene, Banerjee, & Hoffman, 2021; Williams, Whiteman, & Parker, 2019) and more specifically in this special issue call on overcoming sustainability standard measurement problems (Wijen, Hiatt, Durand, Walls, & Reinecke, 2022).

From these organization studies perspectives, the shortfall is partly due to the distance between somewhat visionary futures as goals versus the applied metrics for current improvements (Augustine, Soderstrom, Milner, & Weber, 2019; Walls, Phan, & Berrone, 2011) as well as to decoupling between higher-level goals and procedures versus lower-level practices (Gond & Brès, 2020; Sandholtz, 2012). These within-standard problems are exacerbated by around-standard ones: namely, insufficient market incentives for firms to adopt and apply standards (Delmas & Toffel, 2008; King & Lenox, 2000), the lack of non-market mechanisms for firms to comply or conform with standards (Bansal & Song, 2017; Hoffman, 1999), and poor governance arrangements to help organizations do so (Bowen, Newenham-Kahindi, & Herremans, 2010; Savage et al., 2010).

Recent work in organization theory has tried to address both types of problems. In the case of the within-standard problems, researchers have advocated overarching standard creation processes, which improves collective understanding and alignment within sustainability frameworks (Reinecke, Manning, & Von Hagen, 2012; Schüssler, Rüling, & Wittneben, 2014). They have also explored nesting mechanisms to deal with multiple standards or jurisdictions in local applications (Arnold & Loconto, 2021; Rawhouser, Cummings, & Hiatt, 2019) and translation in fields as a means of refining and loosely coupling standards and procedures with local practice (Hedberg & Lounsbury, 2021; Kim, Bansal, & Haugh, 2019; Whiteman & Cooper, 2016). Nevertheless, there has been insufficient study of the prioritization and selection of metrics by firms, intermediaries, and local stakeholders (Chatterjee, Durand, Levine, & Touboul, 2016; Rawhouser et al., 2019;) as well as of on-the-ground application of the selected metric(s) (Chatterjee, Ghosh, & Leca, 2023; Slade Shantz, Kistruck, Pacheco, & Webb, 2020; Wijen et al., 2022).

In the case of around-standard problems, researchers have proposed and examined sets of market and non-market forces that enhance practice adoption and corporate sustainability (Delmas & Toffel, 2008; Hahn, Pinkse, Preuss, & Figge, 2016); These include more precise, flexible, and decentralized enforcement of regulation (Chatterjee & Toffel, 2010; King, Lenox, & Terlaak, 2005), reshaped markets and market incentives (Durand, Hawn, & Ioannou, 2019), and new forms of non-market governance, such as multi-stakeholder agreements (de Bakker, Rasche, & Ponte, 2019; Odziemkowska & Dorobantu, 2021). But how an existing organization strikes a balance between market and non-market forces with these new forms of local stakeholder engagement during sustainability metric application is still unclear (Bacq & Aguilera, 2022; Hengst, Jarzabkowski, Hoegl, & Muethel, 2020).

In keeping with this special issue call, our paper synthesizes and extends current efforts to resolve within- and around-standard application problems. We build a hybridizing protocol that links, in an integrative fashion, a standard's broader, longer-term sustainability goals with local application and targets (Chatterjee et al., 2023; Hengst et al., 2020; Perego, Kennedy, & Whiteman, 2016; Reinecke & Ansari, 2015). Our hybridizing protocol also reduces decoupling by incorporating local stakeholders into the selected metric's application using co-design as a collaborative approach (Einfeld & Blomkamp, 2022; Gruber, De Leon, George, & Thompson, 2015). Our variant of co-design depends on expert intermediary involvement as facilitators (Lee, Hiatt, &

Lounsbury, 2017; Liu, 2021; Sharkey et al., 2023). Intermediaries coordinate and interpret the results from a quasi-field (A/B) experiment with local stakeholders to surface preferences, ideological positions, and longer-range goals (Raaijmakers, Vermeulen, Meeus, & Zietsma, 2015; Slade Shantz et al., 2020). These elements are then input into the sustainability standard metrics and generate more contextualized recommendations for local ecosystem improvements.

We demonstrated our hybridizing protocol using life cycle assessment (LCA), an ISO 14040/44 standard's metric, on remediation of oil sands processed water in Alberta wetlands. The protocol is generalizable to local applications of other standards, such as LEED, ISO 9000, evolving COP emissions systems—standards used in manufacturing, building, and resource processing industries (Wijen et al., 2022; Young, Dhanda, & Hollenhorst, 2023).

## Sustainability Standards and Local Application

Standards refer to “a rule for common or voluntary use, by one or several people or organizations” (Brunsson, Rasche, & Seidl, 2012, p. 616). Sustainability standards are typically benchmarks and methods for improved operations within an industry or field, established through regulation (Chatterjee & Toffel, 2010; Terlaak, 2007), negotiation (Ansari, Wijen, & Gray, 2013; Schüssler et al., 2014), or diffused voluntary practices (Howard-Grenville, Nelson, Earle, Haack, & Young, 2017; King & Lenox, 2000). These standards sit within frameworks for administration and interpretation. Examples of such frameworks are Fairtrade, ISO, LEED, and the country-level applications of the Paris Agreement (Delmas, 2002; Rawhouser et al., 2019; Reinecke et al., 2012; Schüssler et al., 2014). The frameworks contain quantitative and/or qualitative metrics for application, along with targets to be hit.

The existence of multiple, somewhat similar, competing standards to the focal one of interest, however, can be a problem (Delmas, 2002; Reinecke et al., 2012). It may encourage a firm to not prioritize the focal standard, or the standard's ratings may not converge with those of other metrics (Arnold & Loconto, 2021; Chatterjee et al., 2016). Two strategies for resolving the multiple standards issue are, first, to nest standards or their practices within each other and, second, to translate more carefully across standards in order to develop local practices reflecting either the focal or composite standard (Arnold & Loconto, 2021; Brunsson et al., 2012). Relatedly, expert evaluators may decide on a particular set of relevant standards and manage their use around the focal standard (Sharkey et al., 2023). Indeed, a firm or expert may choose to select only particular focal standard elements and results, depending on local pressures for compliance (Terlaak, 2007). Still, variations in transparency and local pressure are likely to undermine this nesting and focusing process (Wijen, 2014); as well, expert intermediaries are often not motivated to clean up this confusion among standards (Gond & Brès, 2020; Howard-Grenville et al., 2017).

The focal or specific standard has targets that, ideally, are nested within a broader set of standards; the sustainability targets are well defined and relatively shorter term, such as greenhouse gas (GHG) emission levels under EPA regulations. These, in turn, are linked to more aspirational and longer-term targets, like the 2-degree Celsius global warming target. Given that ecosystem temporal scales are typically quite long, shorter-term targets need to be linked to longer-term ones, and longer-term targets to distant futures. This creates a need for “temporal stretching”—various ways of working on the shorter-term goals while seeing, and trying to attain, the longer-term outcomes (Augustine et al., 2019; Kim et al., 2019). However, such temporal stretching may unwittingly create space for oppositional imaginaries about the future (Augustine et al., 2019) and contestation around forms of clock time to achieve these states (Reinecke & Ansari, 2015). To address such problems, sustainability advocates have called for and investigated jointly negotiated, better-specified targets and scenarios (Ansari et al., 2013; Hoffman & Jennings, 2018; Schüssler et al., 2014).

Yet even these scenarios can still suffer from a clash of interpretation around the metrics results and their implications (Haigh, 2019), and also from a lack of flexibility to incorporate new environmental science, community understanding, or policy changes (Howard-Grenville et al., 2017).

The application of a focal or nested standard requires an administrative framework and set of procedures to link the standards across levels to local practice (Arnold & Loconto, 2021; Reinecke et al., 2012; Williams et al., 2019). Broad standards typically have more steps, hence a broader and taller set of administrative linkages than narrower standards. Yet broader standards are typically important for addressing grand challenges (Chatterjee et al., 2023; Ostrom, 1990). Not surprisingly, the length of linkages and their complexity leads to the decoupling of higher-level procedures from lower-level practices (Gond & Brès, 2020; Sandholtz, 2012). Doing a better job of moving higher-level and broader scale to the local level and narrower scale requires multiple iterations and engagement to rethink actions and to find ones that are locally achievable, while addressing the societal-level issue (Chatterjee et al., 2023; Rawhouser et al., 2019; Schüssler et al., 2014). Moving not just from the top-down but from the bottom-up, with more emergent local standards, such as those for grass-fed beef (Weber, Heinze, & DeSoucey, 2008) or farmers' market products (Hedberg & Lounsbury, 2021), helps anchor standards in local communities of practice and interpretation. Unfortunately, the local nature of such standards may make them overly narrow and less generalizable to other locales or domains. Chatterjee et al. (2023) recently abduced a double-weaving process that combines both a top-down and bottom-up processes as one scales out new standards. However, adjusting and combining top-down and bottom-up processes in existing sustainability standard frameworks in a way that sharpens metric application still needs more research and in situ application.

*Expert intermediaries.* Intermediaries can help sort among overlapped standards, link shorter- and longer-range goals, and improve local application of standards. Intermediaries represent some broader field concerns and pressures, such as those from governments, NGOs, or local consumers (Lee et al., 2017; Sharkey et al., 2023). Expert intermediaries are those with official roles in standard frameworks or special training in a standard's metric and its evaluation. An example is risk assessors for regulated products (Maguire & Hardy, 2013; Wijen, 2014). Such expert intermediaries can be tasked with auditing the sustainability metric application, thereby overcoming some temporal stretching and decoupling problems (Rawhouser et al., 2019). They may also be trained to improve translation and local application via facilitation. These experts rely heavily on communication processes and multiple rounds of engagement (Grushina, 2017; Herremans, Nazari, & Mahmoudian, 2016).

However, expert intermediary advice may be ignored by firms (Gond & Brès, 2020) or experts may be shut out of key stages of a standard's development or application (Schüssler et al., 2014; Williams et al., 2019). Experts are also prone to pursuing their own interests and those of the local firms they serve (Gond & Brès, 2020; Liu, 2021). In the case of multi-locational firms, expert activities are difficult to police (Sharkey et al., 2023; Whiteman & Cooper, 2016). Thus, further improvement upon the use of experts in sustainability standard auditing and facilitation is another with-standards issue.

### *Responses to standards applications by corporations and communities*

Sustainability standard metrics and their application are affected not just by the many aforementioned within-standard problems, but by around-standard ones. Standards are typically designed to address market externalities, such as air pollution, or to regulate competitive behaviors that are generating dangerous byproducts or excess waste (King & Lenox, 2000; Young et al., 2023). Yet corporate responses to standards and metrics tend to vary. Each firm's response depends on the

combination of market and non-market pressures exerted on the organization (Bansal & Roth, 2000; Chatterjee & Toffel, 2010; Delmas & Toffel, 2008). Market pressures include the degrees of competitive rivalry and market success, which influence corporations' abilities to adopt new technologies and absorb the costs of externalities (Durand et al., 2019; Terlaak, 2007).

Non-market pressures come from government regulators, NGOs, local communities, the press, local elites, and owning families (de Bakker et al., 2019; Odziemkowska & Dorobantu, 2021). The more institutionally legitimate the group, the greater the pressure on the firm (Chatterjee & Toffel, 2010; Delmas & Toffel, 2008). This is especially true of government actors, who, if empowered, usually successfully push for stronger regulatory compliance (Grandy & Hiatt, 2023; Hoffman, 1999).

Unfortunately, even in a more stabilized oligopolistic market sector, with competitive pressures for diffusing new technologies and practices and institutional pressures from government-backed regulations, the pressures are often insufficient for meeting sustainability standards or using sustainability metrics (Rawhouser et al., 2019; Wijen et al., 2022). Ironically, these sectors are the very ones where resource use is prominent and tragedies of the commons endemic (Ostrom, 1990)—sectors such as mining, forestry, fishing, energy generation, and chemical production.

**Stakeholder engagement.** When sustainability standards and metrics are difficult to implement, market and non-market pressures need some aligning and additional pressure exerted (Bacq & Aguilera, 2022; Delmas & Toffel, 2008). One important way of doing this is by engaging with stakeholders (Bowen et al., 2010; Hendry, 2005; Perez-Batres, Doh, Miller, & Pasani, 2012). Several types of stakeholder approaches and engagement methods have been proposed and investigated by organization scholars (Andriof & Waddock, 2017; Fung, 2006; Parmar et al., 2010). The foundational approaches emphasize identifying different stakeholders and their power, then applying tactics that fit different stakeholder subgroups (Freeman, 1984; Hendry, 2005; Mitchell, Agle, & Wood, 1997). As a rule, stakeholders with more power or legitimacy, who also care about the issue, require more direct, careful engagement (Clement, 2005; Parmar et al., 2010).

More recent stakeholder work, especially on sustainability standards, has emphasized the aim of improving society and the natural environment and thus the need for a stakeholder ethos based on mutual benefit and cooperation (Bacq & Aguilera, 2022; Young et al., 2023). As a result, instrumental approaches (Jones, Harrison, & Felps, 2018), which have been argued to still be useful for modifying corporate practice, have been eschewed in favor of normative—particularly collaborative—approaches (Bowen et al., 2010; Savage et al., 2010). Collaboration with stakeholders involves having well-developed communication lines between the company and stakeholders to develop, assimilate, and apply new knowledge (Grushina, 2017). Still, even among the collaborative approaches, there is a wide range of governance arrangements, from minor consultation to full inclusion (Bowen et al., 2010; Fung, 2006). The extent of collaboration depends on the mandate of the consulting groups and willingness of participants to share their concerns and positions openly, something that itself may need to be negotiated (Herremans et al., 2016).

A related problem is whether the participants, if included, have sufficient knowledge to understand the technical aspects of the standards and their metrics and suggest modifications compared to intermediaries, even if the participants possess more localized, historical, and embedded knowledge that could be beneficial (Gond & Brès, 2020; Perego et al., 2016; Rawhouser et al., 2019; Reinecke et al., 2012). Indeed, as noted by Sharkey et al. (2023, p. 27), future research needs to “consider how the impact of information from one intermediary shapes how information from another intermediary is received.”

## Integrating Community Co-Design with Sustainability Metric Application

To address the sustainability shortfalls due to existing sustainability standards and their metrics, we think it is important to overcome some of these persistent within- and around-standard problems, and to do so in an integrative fashion (Hahn et al., 2016; Hengst et al., 2020). The first set of steps would be to start with the around-standard problems, by considering both the existing market and non-market pressures on the firm pertinent to (non)conformity or (non)compliance with standards (Delmas & Toffel, 2008; Durand et al., 2019). Based on this situation assessment, the analyst would then turn to the standards themselves and select the most relevant, vetted one(s) in the firm's field for consideration (Arnold & Loconto, 2021; Reinecke & Ansari, 2015; Young et al., 2023). Ideally, the prioritized (focal) metric(s) would be one that could be used in various situations and is translatable via database benchmarking and metric value adjustments (Perego et al., 2016; Rawhouser et al., 2019). Additionally, the standard's application would have decision-making criteria attached to it and to the ratings generated by the metric (Chatterjee et al., 2016). Furthermore, in keeping with organizational decision-making and institutional research, we argue that the heuristics need not be wholly rational nor based solely on optimization, but rather able to incorporate behavioral heuristics that reflect local stakeholder choice processes (March, 1994; Tenbrunsel, Wade-Benzoni, Messick, & Bazerman, 2000).

The second set of steps would be to engage with local community stakeholders and expert intermediaries in a balanced fashion—one that respects the need for inputs and the technical knowledge involved in the metric. To do so, we propose using a co-design method as part of the metric's application (Einfeld & Blomkamp, 2022; Fung, 2006; Gruber et al., 2015). Co-design involves community stakeholders in the possible corporate pollution-abatement designs that the metric will help generate and assess (Arnold & Loconto, 2021; Grushina, 2017; Wijen et al., 2022). One novel way to conduct co-design would be to use a field experiment or "A/B test" in which a more traditional—"town hall"—type consultation would be conducted with stakeholders and compared to a co-design type engagement method (Fung, 2006). Such quasi-field experiments have been advocated recently in the organizational literature (Raaijmakers et al., 2015; Slade Shantz et al., 2020).

The third set of steps would be to inject the co-design stakeholder knowledge and predispositions into problem identification, options, selected designs, and longer-range goals for the sustainability metric (Domingues, Marques, Garcia, Freire, & Dias, 2015; Hengen, Sieverding, & Stone, 2016; Tenbrunsel et al., 2000). This hybridizing analysis would be conducted by the expert facilitator or, alternatively, by a different intermediary trained to do such modeling. If done by the former, it would imply that the person(s) is acting as a boundary spanner from inside the corporate-community design process to the formal assessing and vetting group that will examine the metric's application.

The final set of steps would be to have an auditor or assessing body double-check the procedures and hybridized results to confirm that they still conformed to the standard's protocols and best practice (Howard-Grenville et al., 2017; Rawhouser et al., 2019). If the results and procedures complied sufficiently, then the corporate-community representative, expert facilitator, or auditor would generate a report based on the hybridized model results (Sharkey et al., 2023). That report would then be reviewed and discussed by the local corporate-community groups in order to begin generating implementation possibilities (Perego et al., 2016; Williams et al., 2019).

These four sets of steps capture our integrative "hybridizing" method (Battilana & Lee, 2014; Hahn et al., 2016; Hengst et al., 2020). They are summarized in a process flow diagram below (Figure 1). Panel A displays the initial steps of assessing the market and non-market pressures on the firm(s) for compliance or conformity and identifying the relevant sustainability standard for

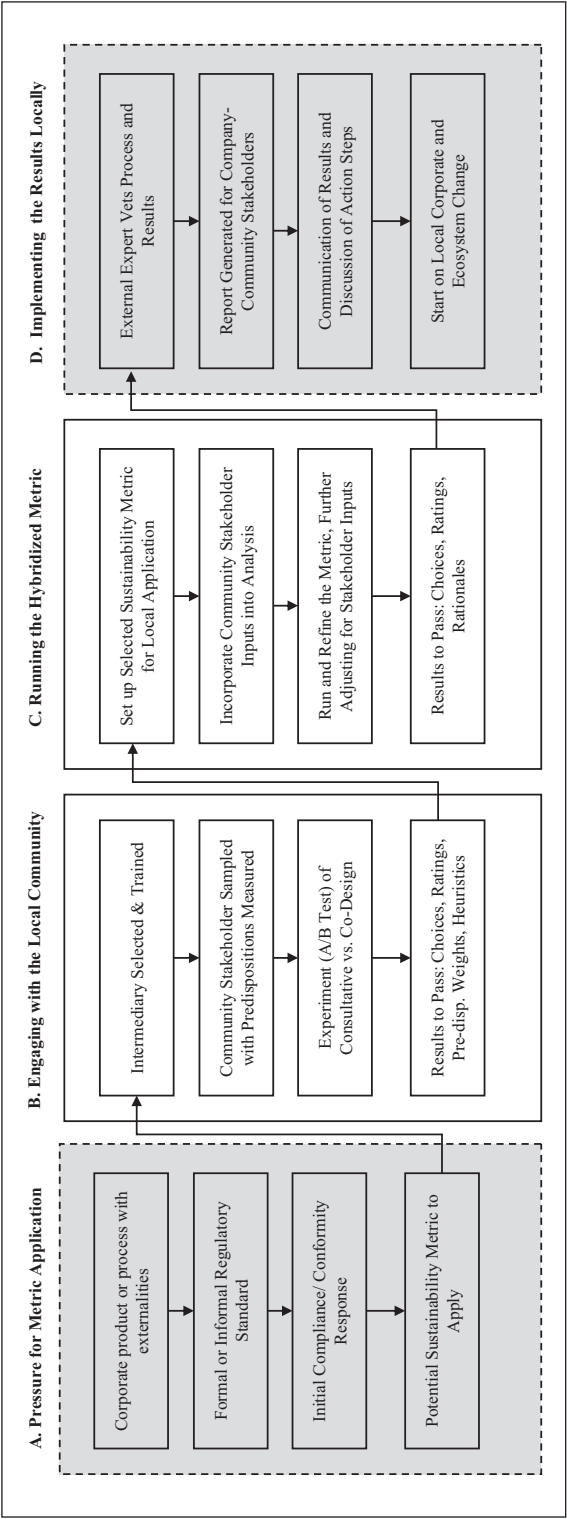


Figure 1. Hybridizing protocol for a sustainability metric's local application.

application. Panel B shows the second steps of using co-design, potentially with a quasi-field experiment, to engage with local community stakeholders using an expert facilitator. Panel C contains the metric's application and hybridization of the results. Panel D ends with an auditor or standard's body vetting results, report generation, and development of implementation possibilities. The most novel steps are in panels B and C, hence displayed in white rather than shaded gray and the focus of our demonstration below.

As a demonstration of this hybridizing protocol, we employ life cycle assessment (LCA) as a standard to be applied locally. LCA is a widely recognized sustainability metric (Busch & Orlitzky, 2019; Nilsson-Lindén, Diedrich, & Baumann, 2021), vetted by various certification bodies (ISO, 2006/2024; UNEP, 2024), used by corporations in product and process development (Jiang & Bansal, 2003; Young et al., 2023); additionally, it is capable of being integrated into other sustainability frameworks, such as circular economy systems (Larsen, Tollin, Sattrup, Birkved, & Holmboe, 2022).

We examine the use of LCA in efforts to reduce pollutants in oil sands processed water (OSPW) generated by oil extraction companies in Alberta. Oil sand is mined and bitumen separated from water, sand, and clay using chemicals and steam. The resulting OSPW is partially remediated in outfall pipes and holding ("tailings") ponds before being released into local rivulets and wetlands, but further treatment is needed (Debenest, Turcotte, Gagné, Gagnon, & Blaise, 2012; Wu, De Visscher, & Gates, 2019). An example of a small wetland is depicted in Panel A of Figure 2 (COSIA, 2024). Local communities depend on the oil sands economically yet are worried about these polluted wetlands (Government of Alberta, 2022; Weber, 2014). Hence, stakeholder views about oil sands operations are often contentious (Lefsrud & Meyer, 2012; Nikiforuk, 2010). Therefore, this region contains market and non-market pressures on firms for sustainability metric application and involves local stakeholder translation. Furthermore, there is not yet an overall vetted water quality framework for the region, instead water quality guidelines and objectives, with regulatory checks on OSPW run-off. This makes the case interesting and somewhat representative for both extant and new sustainability standards.

### *Study 1 – An experiment to co-design wetland remediation*

At the heart of our process flow model is a field (A/B test) experiment with stakeholders (see Figure 1, Panel B). Our treatment (B-test) condition is the use of co-design to engage community stakeholder groups (Einfeld & Blomkamp, 2022). Our baseline (A-test) condition is the standard method of corporate engagement with community members: via consultative meetings with separate groups or community hall gatherings. In this method, the metric and its application are explained by expert facilitators, who often represent the corporation, and scientists, then loosely discussed with the group (Fung, 2006).

Community stakeholders from the wider oil sands region were solicited using online advertisements and local bulletin board postings. Inquiries were made by 304 individuals, which we narrowed to 115 participants after screening for length of time living in Alberta and willingness to engage on site (not online). During the initial screening, we measured participants' ideological predispositions regarding environmental and economic issues using a short survey (Online Appendix Table 1). This information was not used to disqualify participants. Participants were paid \$15 for their time after completing the experiment.

Stakeholders were then randomly divided into 24 small (4 or 5 person) groups, each facilitated by an intermediary with knowledge of the wetland design and remediation. They were given information about the oil sands wetland reclamation designs and remediation materials (for options, see Online Appendix Figure 1) then listened to a standardized presentation from

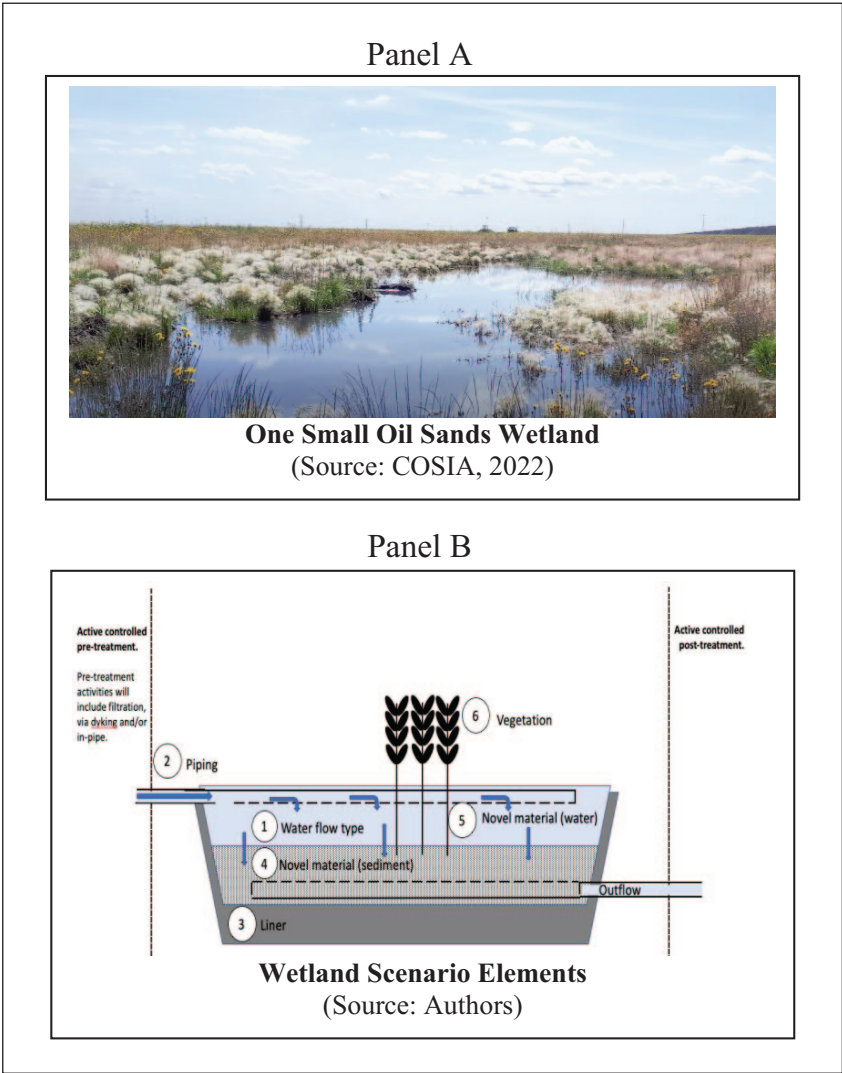


**Figure 2.** Oil sands wetland and scenario design.

Main Treatment: 1. Water flow design (surface/subsurface; vertical/horizontal), 2. Input and output end-of-pipe filter (none), 3. Liner (yes), Main Treatment: 4. Novel sediment material (BC/CF), 5. Novel water materials (none), 6. Vegetation (local only – sedge).

the facilitator. The key elements of the design are in Figure 2 (Panel B). The four wetland reclamation designs were the subsurface vertical (SSV), the subsurface horizontal (SSH), the surface horizontal (SH), and natural appearing but still constructed (NC) designs. These designs appeared in the literature (Corbella, Puigagut, & Garfi, 2017; Kadlec & Wallace, 2008; McQueen et al., 2017), with the SSV being the one recently defended as having the highest remediation potential (Simair et al., 2021). Each wetland was outfitted with remediation materials: biochar, chicken feathers, nano cellulose, and/or nano photocatalysts, ranging from less to more novel in nature (Bhuiyan, Tak, Sessarego, Harfield, & Hill, 2017; Casadesús et al., 2019; da Silva Medeiros et al., 2022; Future Energy Systems, 2024).

In the co-design condition, the group had 20 minutes, after the standardized presentation, to collectively discuss and build a preferred design with a selected material, relying on modest informational and reflective inputs from the science-informed facilitator. Afterwards, the group was given a few minutes to select its overall preferred design and material. Then individuals rated the designs, including their own, and materials. The scoring sheets are described in Online Appendix Table 1, and included measures for perceived environmental (E), economic (Ec), and social (S) effectiveness (Walls et al., 2011; Young et al., 2023). These steps allowed for face-to-face engagement and joint selection of wetland designs and materials with the facilitator loosely coordinating the process.

In the town hall condition, after listening to the overview presentation and reading the wetland design vignette materials, individuals had 15 minutes to choose among the four potential wetland designs and types of remediation materials and rate their choices. Then the town hall group discussed these items for a few minutes and selected an overall preferred design and material, by vote, with the help of the facilitator. This set of steps reflected a more standard consultation (top-down, informational) procedure used by companies and/or local government bodies with community members.

**Results.** The sample characteristics of the 115 experiment participants were comparable to those of Alberta's population, though slightly skewed towards younger, female, and better-educated respondents (comparisons available on request). Attention checks and a second review of demographic information reduced the sample to 112 stakeholders.

**Design choices.** As anticipated, the wetland designs preferred by stakeholders in the experiment varied significantly ( $X^2=34.53$ , 3df,  $p<.05$ ). Roughly half of the individual participants in the co-design treatment condition favored the naturally constructed (NC) wetland (32/76, with ties counted), with the horizontal surface (SH) design a distant second choice (18/76, with ties counted). Interestingly, the co-design stakeholders, for the most part, did not select their own unique designs as a first choice but preferred the NC design instead (19 for NC out of 32 who had NC as a first or tied choice). When asked why, in the open-ended exit questions, several responded that even after discussion they were not confident in their knowledge underlying their design creation to select it. When asked about their preference for the NC design, co-design participants said that it seemed to blend lower- and higher-tech features and various ecological and economic concerns well. Indeed, an examination of the co-designs crafted by groups showed an effort to blend such features and use lower-tech (fewer water piping and sediment adjustment) features.

Individual town hall stakeholders also favored (voted for or had average higher scores for) the NC design (28/67, with ties counted) and, as a second choice, the SH design (18/67, with ties counted). We had thought the individuals would favor designs signaled by facilitators as more vetted by recent studies and favored by the local firms (i.e., the SSV or at least SH designs). Their ratings were, in fact, more diverse, and in exit interviews, their reasons for the choice stated in the exit survey items were more mixed than those in the co-design groups.

Further exploration of the differences at the group level helped confirm this aggregated individual pattern. As expected, we found co-design groups rated the NC designs higher than the SSV (NC=4.14 vs. SSV=3.65,  $p<.05$ , in Table 1). We also found that co-design groups rated their NC designs more highly than the town hall groups (NC=4.14 vs. NC=4.08,  $t=1.515$ ,  $p<.10$ , in Table 1). While co-design groups may not have been confident enough to choose their own designs after the modest amount of experimental training, it appears they were still more willing to rate naturally constructed designs more highly and with less variance in response than the town hall groups. In any case, the NC design is clearly the preferred wetland choice to pass along to Study 2.

**Table 1.** Mean Difference in NC vs. SSV Wetland Overall Evaluation by Groups.

|            | Engagement Type | N  | Mean              | Std. Deviation | Std. Error Mean |
|------------|-----------------|----|-------------------|----------------|-----------------|
| <b>NC</b>  | Co-design       | 55 | 4.14 <sup>c</sup> | .506           | .068            |
|            | Town            | 57 | 4.08              | .583           | .077            |
| <b>SSV</b> | Co-design       | 55 | 3.65***           | .544           | .073            |
|            | Town            | 57 | 3.36              | .565           | .075            |

<sup>c</sup> $p < .10$ , \*\*\* $p < .001$  in one-tailed t-test of independent subsample means

As part of the co-design process, teams were also asked to choose adsorbent materials for sediment or water elements in the wetlands (#4 or #5 in Panel B of Figure 2). Among the co-design teams choosing NC wetlands, three preferred biochar (BC) as a sediment; one preferred chicken feathers (CF), and two preferred even more experimental materials than CF (nano cellulose in sediment or nano photocatalysts in water). The 12 co-design groups chose biochar only slightly more often than chicken feathers. Hence, in Study 2 we focused on the choice of biochar (BC) versus chicken feathers (CF), with CF being the more scientifically novel and experimental product and BC the more standard yet still effective one.

*Stakeholder preferences.* As a next step, we assessed ideological predispositions to help create decision weights for Study 2's hybridized LCA. We wanted to capture whether participants had more polarized versus blended views of economic versus environmental priorities, given that these are recognized tensions underlying local political views (Lefsrud & Meyer, 2012; Nikiforuk, 2010). We examined the participants' scores on predisposition scales developed elsewhere in the literature (Banerjee, Iyer, & Kashyap, 2003; Dunlap, Van Liere, Mertig, & Jones, 2000), as shown in Figure 3.

In the overall sample, we found that community stakeholders were less concerned with environmental than economic issues (4.18 vs. 5.30 on the 7.0 scale,  $p < .001$  in a one-sample means t-test). We also found that the variation around the mean was lower for the environmental predisposition (ideology) scale than the economic one. It seemed, therefore, that there was some tension between the environmental and economic ideologies, but it was not as extreme as portrayed in local commentary on them (e.g., Nikiforuk, 2010).

In keeping with our theoretical concern, to capture the more modal, central predispositions of stakeholders rather than the extremes that polarize groups, we began by z-scoring each scale's range to make the cross-scale scores comparable. Figure 3's boxes show approximately where these z-scores fell in terms of the original raw score distributions. We then generated a difference score between the two normalized predisposition scales' scores. Individuals within two standard deviations on that combined difference scale score were categorized as having a more modal, somewhat blended set of ideological preferences about the environment and economics ( $N=97$ ). Those participants with scores outside the range ( $N=15$ ) were considered polarized and their scores were not used to create the weights for LCA choices, though these participant choices were included in the sample.

Finally, we computed and weighted the environmental (E), economic (Ec), and social (S) evaluations of blended ideology stakeholders in the co-design condition. We argued that in the co-design conditions, blended ideology stakeholders would have further mixed their predisposed views about design and materials into their choices, creating even more modal values worth passing to Study 2. The blended, co-design stakeholder modal scores for the E, Ec, and S dimensions are presented in Table 2. Blended ideology stakeholders who went through the co-design treatment ended up

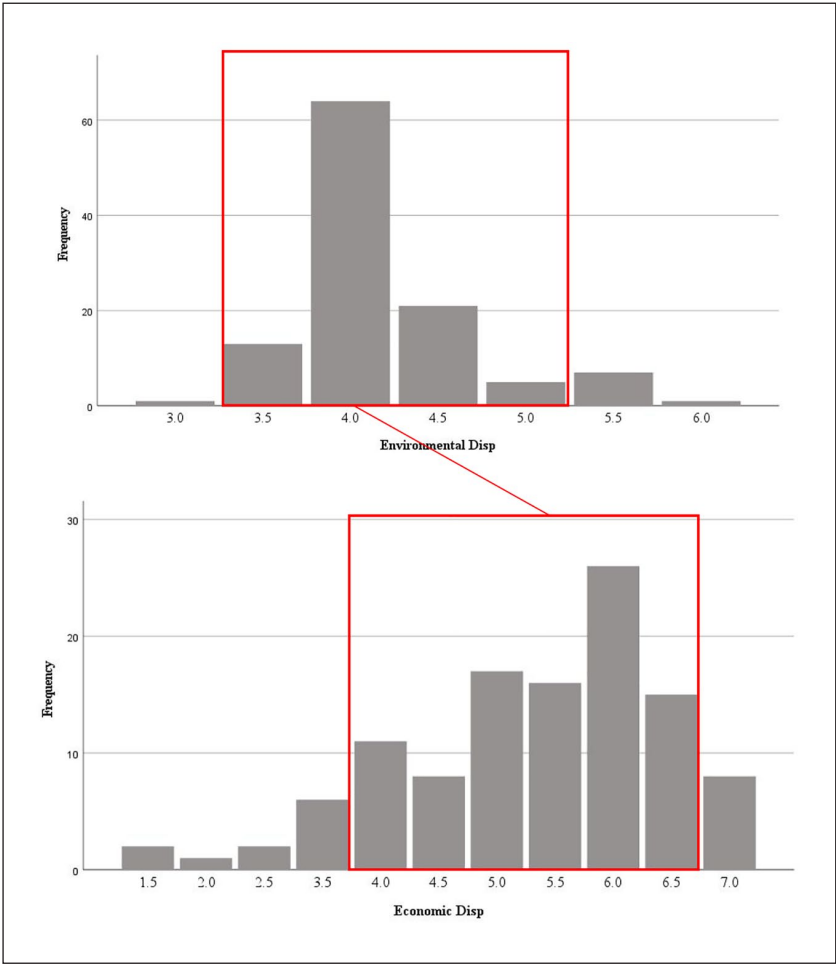


**Figure 3.** Local individual ideological dispositions about the natural environment and economics.

weighing the environmental (.84) and the social dimension (1.76) higher than the economic one (−.84). The re-anchored weights are shown in the last column of Table 2 and were passed forward to Study 2.

*Underlying choice heuristics.* Our scoring and weighting methods allowed us to focus on blended ideology stakeholders and generate a weighting scheme. However, as stakeholder theory notes and sustainability criteria models recognize, selection among reweighted options is not always clear. Some options may appear to be quite similar; options may also seem to be multidimensional. Rather than presuming a rational calculus, as is often done in LCA modeling, we re-examined the stakeholder responses to our open-ended exit questions about why they rated designs and materials the way they did and what they thought of the process. About two-thirds (19 of 31) of co-design treatment/NC wetland stakeholders responded to these questions. Most co-design stakeholders were hopeful yet pragmatic: “I think it will achieve the desired results within reasonable resource constraints. I expect the general public will not know much about this project at all” (Part. 022-CO-004).

**Table 2.** Local Ideologies by Treatment Group for Weights (Normalized).

| Criteria                 | Ideologies | Town Hall NC Weight <sup>a</sup> | Co-Design NC Weight | Co-Design NC Re-Weight <sup>b</sup> |
|--------------------------|------------|----------------------------------|---------------------|-------------------------------------|
| <b>Environmental (E)</b> | Blended    | -1.8                             | .84                 | 1.68                                |
|                          | Polarized  | 4.47                             | 2.4                 |                                     |
| <b>Economic (Ec)</b>     | Blended    | 1.68                             | -.84                | 0                                   |
|                          | Polarized  | -6.83                            | -2.10               |                                     |
| <b>Social (S)</b>        | Blended    | -1.14                            | 1.76                | 2.60                                |
|                          | Polarized  | -5.08                            | -.80                |                                     |

<sup>a</sup>Weights are z-scores of avg. env, econ, social scores for ideology subsamples.

<sup>b</sup>Score are simple addition of +.84 to all columns values of co-design NC weights.

Similarly, “I think the environment will be remediated but not in the quickest way possible in order to save some costs” (Part. 010-CO-006). As part of this realism, they downplayed the wider impact, “[there will be] little significant effect on society at large, but reasonable improvement in water and soil quality for those living near the wetland” (Part. 008-CO-004).

To the facilitators examining the experiment transcripts in light of their own experiences with the groups, two things seemed clear. First, the time horizon of the stakeholders in the experiment, at least regarding the design effects, was relatively short term, even if hopeful about longer-range effects. Second, the responses relied on a “good enough” rationale. Such a rationale is more consistent with a satisficing rather than an optimizing heuristic (March, 1994). Satisficing seeks to balance various objectives and means by being flexible and realistic about targets and timing—it is important to hit a minimum threshold on some outcome measures and then gradually proceed to others and their target measures. When satisficing, more than one design or material may be chosen, and near choices can be substituted. In contrast, an optimizing heuristic focuses on rapid, continuous, upward adjustments of overall performance on multiple dimensions to hit ever more difficult targets with one best choice that maximizes a joint outcome (Chen & Delmas, 2011). This short-range, open-ended focus with a satisficing heuristic was important to pass forward to Study 2 to help hybridize the more formal sustainability metric.

## Study 2 – Hybridizing LCA results with co-design inputs

The key steps in Panel C of Figure 1 are around the modification and application of the formal sustainability metric in situ. We began by setting up the standard version of the metric; i.e., the life cycle assessment. To do so, we followed the procedures outlined in ISO 14040/44 (2006/2024). We defined the goal and scope of the project, system boundaries, key inventory items, primary analysis method, and impacts of interest, and solicited expert interpretation of our results, consistent with ISO 14040/44’s conceptual model for LCA application. The goal of our modified LCA was to compare and select between the stakeholder community’s and the corporate experts’ preferred wetland designs (NC vs. SSV, respectively) and novel and standard adsorptive materials (CF vs. BC, respectively). When combined, the LCA research design created a two-by-two comparison: NC-CF vs. NC-BC vs. SSV-CF vs. SSV-BC.

The scope of the LCA, for the purpose of our illustrative methodology, was limited to examining the remediation of one well-known pollutant in OSPW: lead (Debenest et al., 2012). The functional unit of the compared product systems was OSPW lead absorbance by a wetland with CF or BC sediments, operating for one year. The system boundaries were from cradle to gate: from

gathering and transporting raw materials from local farms, to processing in a university lab (which could be scaled for company use), to applying the material in a test wetland in the oil sands, then operating for one year. One co-author, a professionally trained LCA expert and intermediary, set up, vetted, and ran these models in *openLCA* (GreenDelta, 2024).

More specifically regarding the remediation materials (in Figure 4), agricultural waste in the form of compacted chicken feathers for keratin and canola refuse for biochar was collected locally and shipped to the lab for preparation. The chicken feathers were ground, separated, chemically treated, and gathered in bins for transportation and application. The canola straw was charred and steam-activated in a pyrolysis oven, gathered in small bins for transportation to the wetland, and applied as a subsurface sediment. The test wetlands depicted in the LCA model were based on Figure 2: a single wetland pond, 10m × 10m × 1m in volume, with continuous inflow of standard concentration OSPW and year-round operation. Remediation materials were applied as a sediment layer and represented the primary source of adsorption. Further details and assumptions are in Online Appendix Table 2.

A life cycle impact assessment (LCIA) was then generated, detailing the inputs, outputs, and environmental effects of the wetland designs and two remediation materials. Data for the inventory were gathered via direct observation of lab and wetland procedures and consultations with lab and wetland personnel. Consistent with LCA best practices, the life cycle inventory of items and their values were constructed with a moderate level of depth, including key materials, volumes, temperatures, and activated chemicals for the oil sands and the impact on the vertical subsurface wetland design. The life cycle inventory was assessed by our expert co-author using *openLCA* version 1.11, based on the assumptions and inventory information in Online Appendix Table 2. (The full inventory tables are available upon request.) The LCIA subcategories for each novel material were then generated using ReCiPe 2016 Endpoint (H). The findings were reviewed by the researchers, further refined through iteration with lab members and consulting field information, and double-checked by an external quality control LCA expert.

As a final step, we applied the weights and decision criteria from the blended ideology co-design stakeholders to reassess the adjusted LCIA metrics for chicken feathers and biochar in the naturally constructed wetland and its materials (Domingues et al., 2015; Hengen et al., 2016). The decision reweights allowed us to adjust the LCA using stakeholder priorities, which differed from those in the baseline town hall expert-company condition. Our satisficing criteria and the expressed goals of the stakeholders were then used to help select among those adjusted LCA options.

**Results.** The test wetlands for simulation were set up so that the main benchmark toxin, lead in OSPW, was fully remediated within the first month of operation (see Online Appendix Table 2 for LCA assumptions). The subsurface vertical design and biochar remediated the toxin most quickly, but both designs—with either sediment being used—fully remediated the OSPW within the month. In light of these direct impact results, the question then became what might be the wider and longer-term impacts of the designs and materials?

LCA's forte is assessing such impacts. The impacts of the two designs and materials were estimated using *openLCA* and are shown in the first four columns of Table 3. The last four columns compare the LCA impacts of the SSV and NC wetlands, controlling for material (BC or CF), and of the materials, controlling for wetland design (SSV or NC). To keep the coefficients positive (>1.0), we switch the column comparisons (numerator and denominators), standard practice in LCA analysis. A value greater than 1.0 can be interpreted as a greater negative impact for the item in the numerator versus in the denominator.

In the last four columns of results, we can see from the many positive coefficients that the expert recommended subsurface vertical piping design (SSV) quickly remediates lead in OSPW but is far

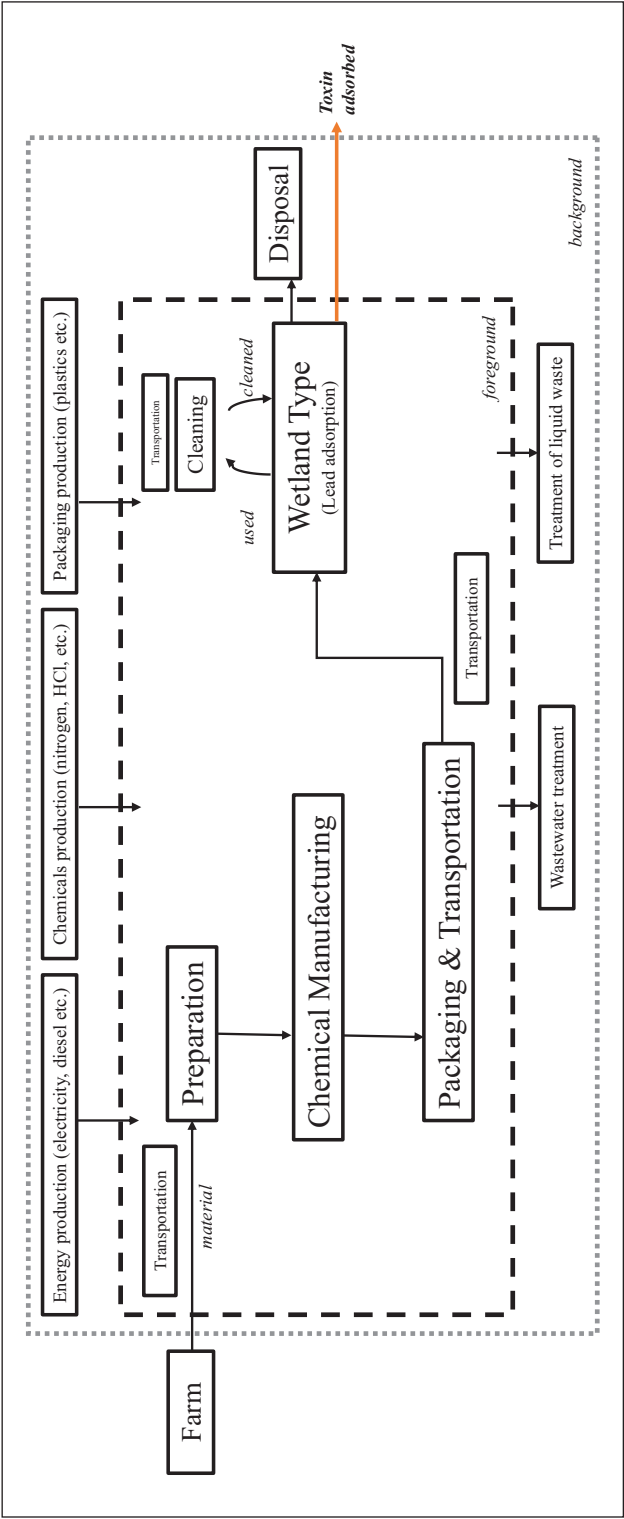


Figure 4. An LCA conceptual model for analyzing OSPW treatment in wetland designs.

**Table 3.** OpenLCA Analysis Estimated Effects for Wetland Designs (SSV and NC) and Remediation Materials (BC, CF)<sup>a</sup>.

| LCIA Impact Parameters                    | Unit       | SSV Wetland |             | NC Wetland  |             | Wetland Diff. <sup>b</sup> |               | Material Diff. <sup>b</sup> |          |
|-------------------------------------------|------------|-------------|-------------|-------------|-------------|----------------------------|---------------|-----------------------------|----------|
|                                           |            | BC Endpoint | CF Endpoint | BC Endpoint | CF Endpoint | SSV-BC/ NC-BC              | SSV-CF/ NC-CF | SSV CF/BC                   | NC CF/BC |
|                                           |            | BC Endpoint | CF Endpoint | BC Endpoint | CF Endpoint | SSV-BC/ NC-BC              | SSV-CF/ NC-CF | SSV CF/BC                   | NC CF/BC |
| Water consumption, terrestrial ecosystems | species/yr | 7.84E-08    | 2.19E-07    | 2.08E-09    | 3.82E-08    | 5.73                       | 37.69         | 2.79                        | 18.37    |
| Water consumption, human health           | DALY       | 1.29E-05    | 3.60E-05    | 3.42E-07    | 6.29E-06    | 5.72                       | 37.72         | 2.79                        | 18.39    |
| Water consumption, aquatic ecosystems     | species/yr | 3.51E-12    | 9.79E-12    | 9.31E-14    | 1.71E-12    | 5.73                       | 37.7          | 2.79                        | 18.37    |
| Terrestrial ecotoxicity                   | species/yr | 4.69E-09    | 9.94E-09    | 4.76E-09    | 5.94E-09    | 1.67                       | 0.99          | 2.12                        | 1.25     |
| Terrestrial acidification                 | species/yr | 9.20E-07    | 1.38E-06    | 4.77E-08    | 8.87E-08    | 15.56                      | 19.29         | 1.5                         | 1.86     |
| Stratospheric ozone depletion             | DALY       | 2.25E-07    | 2.92E-07    | 1.03E-08    | 2.98E-08    | 9.8                        | 21.84         | 1.3                         | 2.89     |
| Ozone formation, terrestrial ecosystems   | species/yr | 2.86E-07    | 4.56E-07    | 4.92E-08    | 6.88E-08    | 6.63                       | 5.81          | 1.59                        | 1.4      |
| Ozone formation, human health             | DALY       | 1.99E-06    | 3.12E-06    | 3.36E-07    | 4.70E-07    | 6.64                       | 5.92          | 1.57                        | 1.4      |
| Mineral resource scarcity                 | USD2013    | 0.11299     | 0.45065     | 0.03003     | 0.12864     | 3.5                        | 3.76          | 3.99                        | 4.28     |
| Marine eutrophication                     | species/yr | 2.35E-10    | 4.15E-10    | 1.82E-12    | 3.61E-11    | 11.5                       | 129.12        | 1.77                        | 19.84    |
| Marine ecotoxicity                        | species/yr | 9.16E-09    | 1.06E-08    | 2.09E-10    | 6.07E-10    | 17.46                      | 43.83         | 1.16                        | 2.9      |
| Land use                                  | species/yr | 7.74E-08    | 1.06E-07    | 2.06E-08    | 2.85E-08    | 3.72                       | 3.76          | 1.37                        | 1.38     |
| Ionizing radiation                        | DALY       | 5.41E-08    | 1.22E-07    | 7.78E-09    | 2.79E-08    | 4.37                       | 6.95          | 2.26                        | 3.59     |
| Human non-carcinogenic toxicity           | DALY       | 5.00E-04    | 0.00055     | 6.33E-06    | 2.59E-05    | 21.24                      | 78.99         | 1.1                         | 4.09     |
| Human carcinogenic toxicity               | DALY       | 3.90E-04    | 0.00049     | 1.25E-05    | 3.51E-05    | 13.96                      | 31.2          | 1.26                        | 2.81     |
| Global warming, terrestrial ecosystems    | species/yr | 4.12E-06    | 5.90E-06    | 1.38E-07    | 3.48E-07    | 16.95                      | 29.86         | 1.43                        | 2.52     |
| Global warming, human health              | DALY       | 1.36E-03    | 0.00196     | 4.59E-05    | 1.20E-04    | 16.33                      | 29.63         | 1.44                        | 2.61     |
| Global warming, freshwater ecosystems     | species/yr | 1.12E-10    | 1.61E-10    | 3.78E-12    | 9.52E-12    | 16.91                      | 29.63         | 1.44                        | 2.52     |
| Freshwater eutrophication                 | species/yr | 1.46E-06    | 1.51E-06    | 8.08E-09    | 1.93E-08    | 78.24                      | 180.69        | 1.03                        | 2.39     |
| Freshwater ecotoxicity                    | species/yr | 4.47E-08    | 5.20E-08    | 9.09E-10    | 2.92E-09    | 17.81                      | 49.17         | 1.16                        | 3.21     |
| Fossil resource scarcity (Ec)             | USD2013    | 67.61       | 146.67      | 5.20527     | 13.40718    | 10.94                      | 12.99         | 2.17                        | 2.58     |
| Fine particulate matter formation (E)     | DALY       | 8.90E-04    | 0.00137     | 6.39E-05    | 1.20E-04    | 11.42                      | 13.93         | 1.54                        | 1.88     |

<sup>a</sup>SSV = subsurface vertical (optimal wetland), NC = naturally constructed (satisfactory wetland); BC = biochar (standard adsorbent), CF = chicken feathers (novel adsorbent).

<sup>b</sup>The comparisons are to create positive, greater than 1.0 values, meaning a greater (worse) impact for the condition in the numerator versus the denominator.

**Table 4.** NC Wetland's Top Five Ranked LCA Impacts Weighted, and Reflux Adjustment Effects<sup>a</sup>.

| Table 3 Order | LCA Impact Parameters                    | Dim.  | CF/ BC       | Concern Rank | Dim. Wght. | R-Wght.     | Reflux, NC CF/BC |
|---------------|------------------------------------------|-------|--------------|--------------|------------|-------------|------------------|
| 10            | Marine eutrophication                    | E     | <b>19.84</b> | <b>1</b>     | 1.68       | <b>33.3</b> | <b>19.06</b>     |
| 3             | Water consumption, aquatic ecosystems    | E     | <b>18.37</b> | <b>2</b>     | 1.68       | <b>30.9</b> | <b>6.51</b>      |
| 1             | Water consumption, terrestrial ecosystem | E, Ec | <b>18.37</b> | <b>2</b>     | 1.34       | <b>24.6</b> | <b>6.51</b>      |
| 9             | Mineral resource scarcity                | Ec    | <b>4.28</b>  | <b>3</b>     | 1          | 4.3         | 3.36             |
| 2             | Water consumption, human health          | S     | <b>18.37</b> | <b>2</b>     | 2.6        | <b>47.8</b> | <b>6.51</b>      |
| 14            | Human non-carcinogenic toxicity          | S     | <b>4.09</b>  | <b>4</b>     | 2.6        | <b>10.6</b> | <b>3.61</b>      |
| 13            | Ionizing radiation                       | S     | <b>3.59</b>  | <b>5</b>     | 2.6        | 9.3         | 2.33             |

\*Key Impact Dimensions: E=environmental (in green), Ec=economic (in white), S=social (in blue).

<sup>a</sup>Top five factor ranks in bold.

worse in terms of LCA impacts than the naturally constructed (NC) design. For several impacts (marine and freshwater eutrophication, water consumption, and toxicity), this is substantially so. However, when it comes to the more novel chicken feathers (CF) versus standard biochar (BC) material, the reverse is true: CF has greater negative impacts in both the SSV and, especially, the NC design. The negative impacts of chicken feathers compared to biochar are especially noticeable for water consumption, marine eutrophication, and human non-carcinogenic effects.

To hybridize the results, we need to also consider stakeholders' assessments of environmental (E), social (S), and economic (Ec) dimensions and how the LCA results might be weighted by these. We have used LCA's own labels in Table 4, such as "human health" to link to the "S" (social) weights and "terrestrial ecosystem" to the "Ec" (economic) ones (full results in Online Appendix Table 3). We then use our blended ideology predisposition reweights from Study 1 for each category (E, S, Ec) to amplify particular LCA impacts. In the reweighted estimate columns, we see that *water-related items* (e.g., water consumption for aquatic and terrestrial systems) become even more salient for local stakeholders than in a standard LCA.

A final step in our hybridizing protocol (Panel C in Figure 1) is to use the results for feedback and learning to adjust the model (ISO 14040/44, 2006, 2022). Based on feedback about water consumption, we simulated a redesign of the material and wetland in the life cycle to lower water usage rates (parameters available upon request). We did so by reducing the amount of municipal (freshwater) input into the "reflux" process by using river water, which could then be treated in situ or reused as gray water. As one would hope, in the reflux condition, LCIA estimates for the three types of water consumption impacts dropped substantially compared to the original results from Table 3. This change, as a result of using the hybridizing method, represents a systems improvement along environmental, social, and economic dimensions.

### Reporting and acting on the hybridized LCA results

Following a standard's application, the metric's results are normally checked by the standard's recommended evaluator, summarized in a report, and then discussed by relevant parties to derive implications and develop a program for on-the-ground changes (ISO, 2006/2024; UNEP, 2024). As

shown in Figure 1's Panel D, we envision a similar process for our hybridizing protocol. In our demonstration, we secured a third-party expert LCA intermediary to review and sign off the hybridized LCA process and wetland results, as per ISO 14040/44's recommended protocols. (Sign-off attached to this paper.) We then fed those results back to some of the stakeholders, upon request, and to science, government, and corporate representatives in two workshops. All parties seemed to support the increased interest in naturally constructed alternatives and using more novel materials from the labs.

However, the method and timing of communication and re-engagement with the wider set of regional stakeholders still needs to be conducted and requires further consideration. On the one hand, prior engagement with community stakeholders, based on extant research (Einfeld & Blomkamp, 2022; Fung, 2006) and our team's experience, should make wider engagement and implementation somewhat easier. On the other hand, prior engagement, particularly at high levels, could raise expectations. Failure to meet those expectations could result in greater resentment and resistance than in a more top-down, group-by-group method. In fact, some of our stakeholder experiment's Stage 2 explorations of violated expectations suggested that this would be the case (further details available upon request). At the very least, anticipating, or checking on, the generated levels of expectation for designs and speed of change is recommended.

The final step in Figure 1, Panel D is working with community stakeholders and corporate-government representatives to implement the results in a toxic release program and via modification of the current water quality and wetland objectives. In this regard, our study has added to several others of local wetlands and water quality and to wider implementation responses by the government and firms under way in the local region.

## Discussion of Contributions and Limitations

In keeping with the special issue theme of overcoming the shortcomings with organizational sustainability standards, we designed and demonstrated an integrative method for applying recognized sustainability metrics locally with stakeholders and adjusting the metric's results using stakeholder concerns in order to improve implementation and ecosystem health. The key steps in our hybridizing protocol were captured in Figure 1 and presented in our hybridized stakeholder-LCA application. We now turn to a discussion of our work's contributions, implications, and limitations.

### *Contributions and implications*

The primary area of contribution of our research is to the organizations-related literature on sustainability standards and metric applications and issues. One issue is the decoupling across administrative linkages that run from recognized standards down to firm-level application (Gond & Brès, 2020; Rawhouser et al., 2019; Walls et al., 2011). Further, multiple, evolving metrics must be navigated along the way, from these higher to lower levels, and then applied locally (Arnold & Loconto, 2021; Reinecke et al., 2012). Our method encourages the use of a prioritized framework and metric, such as LCA under ISO 14040/44, that can then be stepped down to the local level but is also open enough to allow for wider community input in addition to that from local corporations or other stakeholders. Many metrics purport to being open in principle to translation and local engagement, but in practice are missing the methodology for capturing and passing forward community inputs via formal analysis to higher-level frameworks (Arnold & Loconto, 2021; Perego et al., 2016). Our hybridizing protocol helps fill that gap, particularly when using an adjustable metric such as LCA. Furthermore, our method, because it entails metrics that map onto more generic pollution processes, such as water contamination, can fit into other system assessments and standards

(Gond & Brès, 2020; Grushina, 2017). This includes other LCAs and circular economy models (Williams et al., 2019).

Sustainability metrics also suffer from shorter- versus longer-term goal misalignments, different clock times, and contested efforts—all of which lead organizations to stretch in uneven ways from present operations to future objectives or imaginaries (Augustine et al., 2019; Kim et al., 2019; Reinecke & Ansari, 2015; Wijen, 2014). Our hybridizing method recognizes this “temporal stretching” issue and advocates for the use of metrics, like LCA, that have multiple, agreed-upon system dimensions in order to lay out pathways for linking the now to the then. The economic dimension items, after all, typically have a shorter timeline than the more purely environmental ones (Chatterjee et al., 2016; Reinecke & Ansari, 2015). Integral to the success of our method is learning and adjustment to the designed system as it attempts to hit near-term targets. This adjustable nature helps address problems emergent from shifting targets or modified imaginaries.

A related contribution to the standards literature is around the use of expert intermediaries within sustainability frameworks. When stepped down across levels, many metrics rely on expert intermediaries from outside the application process who act as auditors or evaluators (Sharkey et al., 2023; Whiteman & Cooper, 2016). In our hybridizing method, we advocate the selection and/or training of facilitators familiar with the region, with LCA, and with the underlying science of the applied products. That way the facilitators can collect, interpret, and input stakeholder data into the metric, and use the results as feedback with stakeholders for further adjustment. The facilitation process thereby further ties the field-level metric to its local application and the experts act as boundary spanners between the local application to non-local evaluation (Grushina, 2017; Lee et al., 2017; Liu, 2021).

*Implications for LCA research.* Our hybridizing protocol has useful implications for our focal sustainability standard, life cycle assessment. LCA specialists have tried to incorporate location context—especially stakeholder preferences—in various ways. The best known are in multiple criteria decision analysis (Zanghelini, Cherubini, & Soares, 2018) and in social life cycle assessment (S-LCA) (Andrews, 2009; Costa, Quinteiro, & Dias, 2019; UNEP, 2024). However, both these approaches have issues that our hybridizing method helps overcome.

Multi-criteria decision analysis has had difficulty integrating criteria across dimensions and settling on contextually applicable decision-making heuristics (Campos-Guzmán, García-Cáscales, Espinosa, & Urbina, 2019). In the name of optimization, overly-rational rules are typically used to determine cross-dimension or choice trade-offs (Domingues et al., 2015). In our hybridizing protocol, we recognize the various types of behavioral heuristics those groups employ, such as the satisficing one here. This makes it possible to blend in ideology preferences as weights, soliciting co-design stakeholder decision selections, and then use the metric to identify sufficient or threshold (“good enough”) choices. In this way, we open up LCA’s “black box” (Gundes, 2016), allowing for a more transparent identification of inputs, flows, and behaviorally driven decisions.

Social life cycle assessment (S-LCA) is an effort to combat LCA’s technical and corporate biases. It relies on LCA methodology but starts by identifying broader stakeholder categories, then crafts measures of life cycle impacts by category with the help of local industry and/or community stakeholders. The impacts are ranked, normalized, and rolled up into a weighted set of comparative options (Andrews, 2009; Costa et al., 2019; UNEP, 2024). However, S-LCA’s categories are tailored to the specific industry or community under study: for example, developing country worker inputs into a textile production S-LCA (Benoît Norris et al., 2020). Our methodology offers less customized, hence more generalizable, results. It relies on a wider, random regional stakeholder sample of diverse community members and tries to capture their underlying predispositions and preferences in measures, not just their ranked category preferences. At the same time,

our hybridizing method relies on technically defensible, often-used adjustments to LCA, such as additions to the option set, reweighting, modified heuristics, and easier changes from feedback. In this way, the hybridizing method and its results can plug more easily into frameworks such as ISO 14040/44 than S-LCA's can (e.g., see Huertas-Valdivia, Ferrari, Settembre-Blundo, & García-Muiña, 2020).

### *Stakeholder theory*

Stakeholder theory is a secondary area of contribution of our work. In stakeholder theory, market and non-market forces pressure firms to change (Delmas & Toffel, 2008; Perez-Batres et al., 2012). Older stakeholder theorists (e.g., Freeman, 1984; Mitchell et al., 1997) focused on non-market pressures to illuminate the importance of externalities and counter-balance strong market forces. In newer stakeholder approaches, the sets of stakeholders and firms responding to the pressures are categorized and contingencies are made for specific stakeholder types, such as shareholders or local community members. Some pressures and responses may be more moral or normative in nature, others more instrumental (Jones et al., 2018; Parmar et al., 2010). However, where each stakeholder type lands on the moral-instrumental spectrum is debatable, as is how to optimally balance stakeholders at opposite ends of the spectrum. In other words, blending those on the extreme is not easy (Bacq & Aguilera, 2022; Kaplan, 2020).

In our hybridizing protocol, we approach this challenge by measuring ideological (instrumental and moral) differences. In our illustration, we employed predisposition scales to assess the economic versus environmental benefit of wetlands and sediment products for community and firm members. This allowed us to capture ideological preferences for potential options, develop weights, and create a more behavioral-based calculus of trade-offs. To do this, we truncated the sample of participants to form those weights (but not for main inputs to the choice). We argued that this dampens the effects of polarization on option selection, weights, and trade-offs—in a way, putting on “institutional guardrails” around some of the contestation (Howard-Grenville et al., 2017; Smith & Besharov, 2019). Further, stakeholders from different ideologies engage during co-design, so using options and weighted choice criteria generated this way also increases the chance for blending ideologies.

Current stakeholder theory is also quite concerned with how to locally apply extant standards, from the top down (Arnold & Loconto, 2021; Reinecke & Ansari, 2015), and how stakeholders can help scale out local practices into new standards and frameworks, from the bottom up (Chatterjee et al., 2023; Howard-Grenville et al., 2017). In our hybridizing methodology we argued that, in the extant standard(s) case, it was better to first focus on the corporate-government groups' interests and interpretations and one or two prioritized standards. Next, we suggested engaging with the local community via diverse, randomly selected stakeholders—and feeding their inputs back into the decision-making and metric application team. This group, with community support, would then help scale out the application. We believe that this hybridizing method is flexible enough, given that it is a bundling of essential steps, for researchers and practitioners to take and use bundled pieces of it as they find useful, as well as re-sort some of the steps within any particular bundle. What is essential is hybridizing the sustainability metric with diverse, partially blended stakeholder options and preferences.

A final, related contribution to stakeholder theory is the identification and combination of intermediary types to support successful local standard application (Sharkey et al., 2023). Stakeholder theory has considered facilitators, auditors, and evaluators as intermediaries (Perego et al., 2016; Whiteman & Cooper, 2016). These intermediaries typically require training in the focal metric, which makes the intermediaries part of the evaluation or rating system, yet they need to work

inside the metric application or generation process (Sharkey et al., 2023). In our hybridizing method, we advocated for using intermediaries as boundary spanners: they should facilitate metric application and pass on the hybridized metric method and results for independent, outside auditing (Lee et al., 2017; Liu, 2021). Being well trained in the metric (in our case LCA), such intermediaries make it more likely that the method and results will align with external audits. Of course, this type of boundary spanning also requires maintaining trust with community-corporate stakeholders during the process and afterwards, when waiting for feedback (Howard-Grenville et al., 2017). Feeding back results and continuing to engage with efforts to scale out the designs is important for retaining community and corporate support.

### *Limitations and future opportunities*

Like any research, this effort to combine stakeholder co-design with a sustainability standard application has important limitations. The first set of limitations are around scope conditions and degree of generalizability. While the steps outlined in Figure 1 could (and should) be applied to other sustainability standards' tools and metrics locally, our study focused on modifying and applying one specific metric (LCA) in one region. Nevertheless, this metric is widely recognized and applied (ISO 14040/44, 2006/2024), and the region is a well-known oil and gas hub where international and national firms operate (Lefsrud & Meyer, 2012); hence it provides some representative generalizability. In terms of scope, however, we do acknowledge potential difficulties in applying our hybridizing steps to more complex life cycles (Perego et al., 2016; Wijen, 2014) or to broader fields with more levels (Arnold & Loconto, 2021; Rawhouser et al., 2019). In those situations, additional stakeholders and regions may need to be included, prompting further adjustments to the hybridizing steps for the LCA. This presents an opportunity for other researchers to use and extend the hybridizing protocol.

The second set of limitations concerns the specification of the types of stakeholders in our study. Although we included a wide range of oil sands community members via our solicitation method, we did not control for their specific work or living location in our analyses. We plan to use MANOVAs and similar techniques to explore the impact of these differences on preferred wetlands and materials, along with ratings differences. Despite including many types of stakeholders in the study and their preferences, we did not, for this method and write-up, include information on the experts who created the wetland and novel materials—scientists, lab technicians, funding agencies—nor the facilitators. We limited their inputs to assumption data (Online Appendix Table 2) for the LCA's estimation and to assistance in interpreting the results. While we believe these expert stakeholders' views and backgrounds might influence the hybridizing process, their impact is likely less direct than one might assume. The facilitators followed scripts to avoid intervening too much in the co-design or town hall choice processes. The lab personnel and other experts, focused on developing novel materials and tests, indicated that they intend to hand off materials and design possibilities to corporations and government for application. Encouraging these internal science stakeholders to engage more directly in the field application process would be a constructive next step for sustainability metric researchers.

A third limitation concerns our use of blended, rather than polarized, ideology weights. This approach may seem at odds with the direct democracy ideal underpinning co-design (Einfeld & Blomkamp, 2022) and could miss problematic local resistance (Lee & Lounsbury, 2015; Simons, Vermeulen, & Knoben, 2016). We argue that we respected the ideal of direct participation by using randomized, representative stakeholders in each group and by considering the choice of design and material in co-design teams that included more ideologically extreme members. However, we do acknowledge that we chose blended ideology stakeholders' weightings and decision criteria to

dampen political debate around near choices and redesign decisions (Grandy & Hiatt, 2023; Wijen et al., 2022). While researchers and practitioners may include a different mix of stakeholder predispositions and preferences (hence decision options and weights), we encourage reliance on the co-design condition because it fosters a sense of sharing and collaboration as part of direct democracy.

A final, deeper limitation is that the hybridizing methodology for sustainability metrics remains a somewhat realist theoretical approach. LCA presumes an objective, external world to measure; yet organizational approaches to stakeholder dynamics typically emphasize the socially constructed and contested nature of metrics (Lee et al., 2017; Wijen, 2014). Our hybridizing protocol attempts to steer a middle path: at the heart of it are stakeholders' socially constructed views of their preferred designs and materials, which we incorporate into the realist-framed sustainability metric to modify. We then iteratively refine the metric and its application based on stakeholder feedback. This tension between socially constructed and realist approaches can enrich both perspectives and benefit the improvement of both the biosphere and social spheres (Jennings & Hoffman, 2017), though it must be done transparently and in good faith.

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### ORCID iDs

Maggie Cascadden  <https://orcid.org/0000-0002-7696-6384>

Kylie Heales  <https://orcid.org/0000-0003-3575-2619>

P. Devereaux Jennings  <https://orcid.org/0000-0002-8186-9853>

### Supplemental material

Supplemental material for this article is available online.

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## Author biographies

**Maggie Cascadden** is a PhD candidate at the Alberta School of Business, University of Alberta, Canada. She has a master's in resource and environmental management (planning). Her research interests lie at the intersection of organizations and communities. She is asking questions about how institutional perspectives can help us tackle grand challenges.

**Kylie Heales** is an assistant professor of entrepreneurship in the Farmer School of Business at Miami University (Ohio). Her research interests are at the intersection of entrepreneurship and organizational theory where she studies how institutions shape and affect entrepreneurial activities, outcomes, and behaviors. Kylie has a PhD from the University of Alberta and an MBA from Duke University.

**Matt Kingston** is an instructor at the Alberta School of Business in Strategy, Entrepreneurship, and Management, and is a research assistant in the Faculty of Agricultural, Life & Environmental Sciences at the University of Alberta. He works on projects within the University of Alberta's Future Energy Systems, with a focus on life cycle assessments, novel sustainable materials, and stakeholder engagement. Matt holds an MBA in sustainability, and teaches Corporate Sustainability in the MBA program.

**Pia Heidak** (MSc) is a research fellow at the Institute of Industrial Ecology at Pforzheim University, Germany, and a PhD candidate at the Karlsruhe Institute of Technology, Germany. Prior to pursuing her current academic studies, she was a consultant specializing in life cycle assessment and related software tools. Her

research interests lie in the sustainability assessment of metal mining, employing techniques such as monetization, (prospective) LCA and the integration of economic accounting for considering value chains.

**P. Devereaux Jennings** is a professor of strategy, entrepreneurship and management at the Alberta School of Business. He is a Co-PI in Future Energy System (FES) research group, a co-coordinator of the Interpretive Data Science (IDeaS) Group, and former director of the Canadian Centre for CSR. He has published research on a wide variety of organizational topics, ranging from institutional approaches to the natural environment to AI ecosystem dynamics. He received his PhD and MA from Stanford University and his AB from Dartmouth College.