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ENGAGED RESEARCH FOR ENVIRONMENTAL GRAND CHALLENGES:
ACCELERATING DISCOVERY AND INNOVATION FOR SOCIETAL IMPACTS

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PREPARED BY:

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Cover: Young citizen scientists examine Mexican butterfly weed.
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COASST Project.
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Engaged Research for Environmental Grand Challenges:

Accelerating Discovery and Innovation for Societal Impacts

Executive Summary

Meaningful collaboration among scientists and a broad swathe of stakeholders is essential to effectively address many of the societal challenges related to the environment, sustainability and equity. Broadly termed *engaged research*, this approach offers great potential both for advancing discovery and innovation (intellectual merit), as well as the translation of advances toward beneficial societal outcomes (broader impacts). This report seeks to provide clarity for funding agencies and researchers on: the societal challenges that require engaged research, the varied conceptualizations of engagement in the literature, and the benefits and pitfalls associated with engaged research. The report seeks to stimulate dialogue on designing and implementing engaged research to advance discovery, innovation, and societal benefit. The report draws on the experience of the environmental research and education community as represented by the Advisory Committee for Environmental Research and Education (AC-ERE).

The AC-ERE defines engaged research as *research conducted via meaningful collaboration among scientists and non-scientists, that explicitly recognizes that scientific expertise alone is not always sufficient to pose effective research questions, enable new discoveries, and rapidly translate scientific discoveries to address society's grand challenges*. Well-designed and implemented engaged research has the potential to advance new foundational discoveries, accelerate research translation, and broaden participation. These benefits are most often supported by the co-creation of research goals as well as the co-production of knowledge. Importantly, benefits flow from the credibility and relevance accruing to co-created research, the trust relationships developed between scientists and non-scientists, and the tangible outputs of collaboration including products, processes, and policies. Despite positive intent, engaged research also has the potential to cause harm by reinforcing inequitable power dynamics, causing fatigue among collaborators, inadvertently having negative impacts on collaborators (including researchers conducting engaged research), creating negative associations of science practices, undervaluing collaborator expertise, and underestimating demands on time and attention from all partners involved. Some of these pitfalls can be ameliorated by good design and careful implementation.

Principles for effective research design and implementation are still emerging, but include matching partners and modes of engagement with the scale and scope of the project goals; anticipating problematic power dynamics; allowing sufficient time for sustained engagement; and maintaining flexible processes that facilitate ongoing learning. Not every research problem demands an engaged approach. Engaged research should be considered only when it is required to effectively address the research goal, is practicable to implement, and can be conducted without harm to the participants. Developing new and enhancing emerging methodologies to scale up the practice of engaged research and its impact, by harvesting generalizable insights where applicable, are important frontier topics for future research investment. Equally important are methods for appraisal of engaged research, particularly in relation to stimulating foundational discovery, the translation of discovery into impact, broadening participation, and assessing short- and long-term impacts, positive and negative.

Environmental Grand Challenges

Environmental grand challenges are often described as wicked problems in which social, natural and technological systems are inextricably coupled in multiple, dynamic and irreducibly complex ways. Environmental problems such as climate change, biodiversity loss and human/environmental health connections are wicked in precisely this way: scientifically complex while also deeply engaged with human values and preferences. Wicked problems are typically characterized by (i) outcomes that are valued differently across society; (ii) differential benefits and burdens; (iii) scientific uncertainty; (iv) interactions that are unbounded in space or time; and (v) an urgency to act despite such uncertainty (Stern 2005).

In the domain of environmental wicked problems, Dryzek (1987), Funtowicz and Ravetz (1993), Cash (2000), and Stern (2005) have all articulated the benefits of combining technical and scientific analysis with inclusive deliberation. Various literatures in sustainability science — around analytic deliberation (Dryzek & Niemayer 2019), science where both uncertainty and potential impact are both high (Funtowicz & Ravetz 1993), public policy (Ostrom 1999; Brunner et al. 2005), public health (Israel et al. 1998) and co-production (Norström et al. 2020; Berkes & Folke 2000; Bremer et al. 2019; Lemos et al. 2012) — highlight the importance of collaboration among scientists, policymakers, decisionmakers, practitioners, private industry, and civil society. Documented benefits include the potential for new knowledge and innovation arising from different avenues of research as well as greater impact of research outcomes and opportunities for capacity development. These insights have emerged in parallel with the long tradition of community-based participatory and action research, particularly in ways that recognize Indigenous knowledge systems and local ecological knowledge (e.g. Vanek 1989; Hansen & Erbaugh 1987; Huntington et al. 2007; Johnson et al. 2015). All of these strands of research practice fall broadly under the rubric of engaged research.

Thus, there has developed a broad consensus that new modes of deeply collaborative research are essential to effectively harness and translate science and technology innovations to meaningfully address environmental grand challenges. A critical contributor to this endeavor is engaged research.

What is Engaged Research?

The terms used to represent engagement between researchers and stakeholders are varied — ranging from co-production (Ostrom 1996; Bremer & Meisch 2017; Mach et al. 2020), action research (Hult & Lennung 1980), participatory research (Cornwall & Jewkes 1995), adaptive governance (Folke et al. 2005; Brunner et al. 2005; Gunderson & Light 2006), collaborative and citizen science, (Conrad & Hilchey 2011), extension services (Anderson & Gershon 2003), and consultancy (Mach et al. 2020). Many activities that involve engagement are also undertaken by practitioners such as urban planners practicing collaborative design, engineers applying human-centered design principles, operational meteorologists creating culturally-tailored severe weather warnings, and public health professionals developing community-focused recommendations. Engaged activities encompass a broad swathe of stakeholders including communities, local and higher levels of government, non-profit and business enterprises. Herein, we offer a definition of engaged research that speaks to the breadth of NSF's mission and its focus on advancing scientific discovery for societal good, as follows:

> **Engaged research is research conducted via meaningful collaboration among scientist and non-scientist actors, that explicitly recognizes that scientific expertise alone is not always sufficient to pose effective research questions, enable new discoveries, and rapidly translate scientific discoveries to address society's grand challenges.**

What is Engaged Research? (Continued)

These environmental grand challenges require a synthesis of technical analysis and inclusive deliberation (Stern 2005) to advance human and planetary wellbeing in interconnected social-ecological-technological systems. There are important nuances in this definition, also illustrated by examples in Table 1, as follows:

- the term *actor* highlights that engaged research operates among people who act to shape goals, problem definitions, and responses;
- a scientist is defined as someone whose profession formally relates to systematic study aimed at furthering knowledge;
- non-scientist actors may participate as individuals, or as members, representatives or leaders from civil society, government, the private sector, or non-government organizations; and
- distinguishing between scientist and non-scientist does not imply a binary divide, but acknowledges a diversity of perspectives, epistemologies, and priorities.

We use these terms to provide specificity regarding those involved in the engaged research process, recognizing that the term "stakeholder" — people and organizations who are involved in or affected by activities or changes in a research domain — may include others who are not involved in the research process. Furthermore,

- actors vary by both scale and domain, and as a result engaged research can extend well beyond traditionally conceptualized community-based research;
- common modes of engagement advanced by practitioners do not constitute engaged research, unless they specifically advance scientific discovery; and
- collaborations largely among scientists focused on technical expertise would not be engaged research if non-scientists are not meaningfully engaged.

The phrase "meaningful collaboration" lies at the heart of engaged research. Key elements of meaningful collaborations are co-design of research, the co-production of knowledge, and co-dissemination (and co-evaluation) of the results (Bremer et al. 2019). The level of involvement and leadership roles of participants can vary. For example, one project may plan deeply contextual community-based research to generate hypotheses and identify knowledge and data gaps with a few communities engaged in the work, while another may bring together a consensus conference with practitioners to assess the transferability of local insights across different contexts (Rauschmayer & Wittmer 2006). Thus, engaged research does not have to be exclusively community-based; indeed, the involvement of practitioners and policymakers at multiple levels of government can yield high impacts. The scale, types of participants, and scope of engagement should match the scale and scope of the research question and the desired impact. In practice, participation is often shaped by who convenes the work.

Garden Mosaics Program.
Credit: Photo taken by Mark Whitmore

What is Engaged Research? (Continued)

Table 1. Examples of different types of research across the engagement spectrum.	
City sustainability officers engage with university researchers and national labs to chart zero-emission pathways, that are jointly visioned with various city departments and community groups	**Engaged research:** technical expertise of researchers melds with policy expertise of city sustainability officers who convene the group; dialogue with a range of stakeholders to address a specific goal.
University researchers collaborate with Indigenous communities to address an environmental risk or problem.	**Engaged research:** tribal partners and researchers are on an equal footing in co-developing research questions and project goals.
An environmental engineer collaborates with practitioners in a utility to take their laboratory-scale research to a pilot scale.	**Translational research:** can be engaged research if non-scientist utility personnel are engaged throughout, and/or additional community input is sought.
A scientist collaborates with communities to implement a survey on environmental health risk factors.	**Gray area:** only engaged research if the communities are involved in the design of the survey and perhaps also the dissemination of results.
Collaboration between a university scientist and a scientist in a software company.	**Not engaged research:** even if interdisciplinary, collaboration is among scientists and focused on technical expertise.
Environmental health practitioners engage communities in a design charette to reimagine their neighborhoods.	**Not engaged research:** this an example of good professional practice, and is not focused on scientific discovery.
A scientist disseminates their project findings through an exhibit at a local library, reaching a large swathe of the community.	**Not engaged research:** no specific actions or goal orientation by community members.

Citizen scientists monitor water quality on the coast of Rio Grande de Manati.
Credit: The Conservation Trust of Puerto Rico

Benefits of Engaged Research

The benefits of engaged research in advancing discovery and impact are increasingly well documented, as noted in Section 1 and illustrated in Boxes 1 and 2. Meaningful collaboration in engaged modes of research enhances relevance, broadens participation, and advances fundamental discovery, as elaborated below.

Enhancing relevance: Engagement with stakeholders can be viewed as a means to increase the impact of science on society. First, through meaningful sustained dialogue, scientists and non-scientists can share and understand differing perspectives, values, goals, and tradeoffs, distinguishing between what is significant for research and what is usable in decision making (Lemos et al. 2012). As a result, effective knowledge use, and consequently its societal impact, can be realized (e.g., Brunner et al. 2005; Tengö et al. 2014). This impact of actionable knowledge on society can be seen tangibly in the products of engagement broadly translated in society as well as in less visible but equally important outcomes related to building trust, empowerment, and innovation (Bremer et al. 2019). Second, engagement can influence traditional barriers to knowledge dissemination, such as credibility, saliency, and timeliness (Cash et al. 2006). Third, engaged research can empower non-scientist actors, through recognizing multiple forms of knowledge and enabling a greater degree of plurality (Johnson et al. 2015; Norström et al. 2020). All of these factors narrow the disconnect between the supply of and demand for science (McNie 2007).

Broadening participation: Increasing the diversity of stakeholders involved in the scientific process is both a critical input to and output from engaged research. A lack of diversity in traditional scientific processes has limited our understanding of fundamental science and engineering processes. In the broad space of environmental research, structural racism and classism may have impacted our understanding of a number of ecological and evolutionary patterns and processes (e.g., Schell et al. 2020). Given that society's grand challenges are characterized by unequal distribution of burdens and benefits, meaningfully engaging those most impacted by socio-environmental challenges, and particularly those often excluded from decision processes, becomes ever more important from the perspective of procedural ethics. Furthermore, engaging a plurality of actors is a critical aspect of effective knowledge use.

Advancing Discovery: Goal-oriented and meaningful engaged research has been shown to advance the frontiers of science and engineering, furthering basic discoveries and fostering innovation. For example, the mainstreaming of community-based participatory research in public health has shown that deeply engaging with community members can uncover key social and environmental determinants of health (Israel et al. 1998). Collaboration among researchers and practitioners has resulted in an entirely new conceptualization of cities as transboundary systems (Dhakal & Seto 2014; Stokes & Seto 2019; Haase 2015; Decker et al. 2000), which in turn has stimulated new methods of carbon accounting (Ramaswami et al. 2008, 2011). Collaborative research with Indigenous communities in Alaska led to the associated discovery of cyclogenetic effects shaping the tracks of cyclones in the Bering Sea (Lynch et al. 2003).

When engaged research is well-designed and appropriately implemented it almost inevitably results in the confluence of scientific innovation and tangible outputs to support societal goals. We highlight two case studies (Boxes 1 and 2) that exemplify both the process of meaningful engaged research, as well as the fundamental scientific advances and tangible outputs spurred by these efforts. Box 1 highlights key steps in a case of engaged urban research, and Box 2 provides an example of fundamental scientific discovery arising from coproduction with an Indigenous community.

Benefits of Engaged Research (Continued)

Box 1. Engaged Research with Cities: Case Study

Context and rationale: In 2005, the US Mayors Climate Protection Agreement sought to reduce city greenhouse gas (GHG) emissions below 1990 levels. However, there were no methods suitable for cities to track their emissions, considering most cities import electricity, cement, food, and other essential goods, as well as engage in substantial trade across cities and rural areas. The same year, the City and County of Denver was seeking technical expertise and public engagement on both GHG accounting and climate action planning. Researchers at the University of Colorado Denver reached out to the City and County of Denver to offer technical assistance, starting a collaborative engaged research project described briefly in this case study.

Project goal, partners, and iterative process: Engaged research was convened by the City and County of Denver, led by individuals at the Department of Environmental Health and the Mayor's Office, who worked with a team of scientists at the University of Colorado Denver alongside 24 stakeholders in an Advisory Council called Greenprint Denver (Greenprint Denver 2007). Greenprint Denver was charged to develop a climate action plan within an 18-month period. This established the project goals and identified a timeline with tangible outputs for the engaged research. The process was facilitated by a professional facilitator engaged by the city. Strategies and criteria for evaluation were co-developed by Greenprint Denver, along with city staff and the technical team of scientists. The Greenprint Denver meetings held every two months proposed mitigation strategies in various sectors, while the scientists and city staff further met every two weeks to co-develop methods to evaluate the strategies relative to the city's GHG footprint. All strategies were voted on at Greenprint Denver's public meetings, and eventually were reviewed and approved by the mayor, and adopted by the city.

Plurality of actors and broadening participation: The composition of Greenprint Denver represented the many stakeholders involved in mitigating GHGs, from energy, buildings, waste, and mobility, to airport and parks, as well as citizen groups and think tanks alongside staff from all city departments and the technical team (of scientists). The scientists also partnered with the city to broaden stakeholder engagement at neighborhood-level conferences; further community input was also invited online. A diversity of views was considered. There was convergence and dissent on aspects of the climate action plan, captured through a minority report when consensus was not achieved.

Advancing fundamental knowledge: The engaged research resulted in new questions on how cities should measure GHG emissions, given that cities import so much of their essential goods and services. This resulted in new carbon footprinting methodologies (Ramaswami et al. 2008; 2011), as well as mathematical theory development on urban carbon flows (Chavez & Ramaswami 2013), and eventually transformed how scientists think about cities, evolving into conceptualization of cities as transboundary local-to-global systems with teleconnections, which now anchors the concept of sustainable urban systems science.

Tangible outputs: In addition to advancing fundamental discovery, the project yielded tangible outputs, which included a GHG emissions calculator and a climate action planning tool, used by the City and County of Denver, as well as public-facing documents such as Denver's climate action plan and GHG inventory. At least four peer-reviewed research publications were co-authored by the technical team and city staff.

Scaling Up: The theoretical work and footprinting methods were tested by researchers in several other cities and countries (reviewed in Chen et al. 2019; Ramaswami et al., 2021), further advancing the science. Simultaneously, the tangible outputs, i.e., carbon footprinting protocols, were then road-tested by other cities, and have now become incorporated in ICLEI's US Community Protocol available for use by more than 500 cities (ICLEI USA 2019; Ramaswami 2021).

Box 2: Engaged Research with Indigenous Communities: Case Study

An increasing number of researchers are eager to find ways to support the inclusion of insights arising from Indigenous knowledge into a better understanding of environmental problems. Indeed, local, national, and international organizations have recognized Indigenous knowledge as essential to addressing complex environmental problems and many have demonstrated that such knowledge often facilitates decision-making in ways that are more diverse and adaptive. These positive outcomes are attributed to knowledge and practice rooted in a community's traditions, incrementally refined over time and transmitted between generations, highly contextual with regard to the natural resources in and features of a particular area.

From the point of view of many Indigenous communities, their knowledge and practices are vested with cultural, material, psychological, and spiritual significance. Indigenous peoples have understood that their ability to thrive is conditioned by their ability to sustain their cultural practices, and is linked to their dependence on their land and resources. Indigenous knowledges are not a panacea for the conflict surrounding the many regions of the world experiencing the impacts of climate change, but they can provide a pathway to 'seeing with two eyes' — that is, to articulate an agenda that reflects the aspirations of the wider community, Indigenous and non-Indigenous alike. In this context, engaging with Indigenous and other customary knowledge provides an opportunity to frame research in different ways, to ask different questions, and to apply a wider range of methodologies. For example, in the case of anthropogenic climate change, Utqiagvik, Alaska is a microcosm of things to come at lower latitudes. The details from Utqiagvik cannot be replicated exactly, even in other villages on the North Slope coast of Alaska. But decision makers elsewhere can capitalize on various similarities that have been observed in other local communities and can be expected to emerge elsewhere.

However, the most scientifically attributable impacts of anthropogenic climate change, such as increasing atmospheric temperatures and retreating sea ice, are not priorities for community decisions. In fact, following a series of discussions with community members, a research plan emerged that the least tractable and most critical of the environmental problems for the community as a whole was its vulnerability to coastal erosion and flooding from big storms (Brunner & Lynch 2010). The focus of the NSF-funded project that emerged was explicitly to support the community in their self-identified goals to reduce vulnerability arising from coastal flooding and erosion, by drawing upon the diverse disciplines in the research team. A number of important scientific insights were generated from this co-designed and co-produced research project. For example, without the Inupiat hypothesis that cyclones in the Bering Sea track the sea ice edge, researchers would not have conducted the experiments that demonstrated the scientific finding that cyclogenetic effects from Siberian coastal leads were most critical to developing skillful simulations of Bering cyclone tracks (see e.g., Lynch et al. 2003) Outcomes of the research included concrete aspects from relocating a planned hospital and designing appropriate storm evacuation routes, to decision support such as bringing "soft" coastal adaptation responses back on the table for consideration.

Pitfalls in Engaged Research

While engaged research offers much potential across discovery, impact and participation for societal benefit, there are many challenges that required explicit attention, including the entrenchment of established power dynamics, stakeholder fatigue, and other manifestations of the pressure placed on non-scientists, navigating differences among participants, and sustaining long-term engagement.

A major concern is a focus on power and how it may affect participants, process, and outcomes. As the literature on normative engagement has increased rapidly, so have concerns that engagement needs to attend to issues of power (Latulippe & Klenk 2020; Meehan et al. 2017). Scholars have called attention to how engagement can be critically affected by (i) inequalities between global North and global South participants (Vincent et al. 2020), (ii) differing valuations of Indigenous, traditional and practical knowledge (Whyte 2017; Kalafatis et al. 2019; Latulippe & Klenk 2020), and (iii) the potential for unequal distribution of costs and benefits (Meehan et al. 2017; Latulippe & Klenk 2020). However, there has been much less research on empirically evaluating engagement in terms of diversity and inclusion, especially with regard to tangible outcomes (Lemos et al. 2018).

Pitfalls in Engaged Research (Continued)

Power differentials depend also on who convenes the process. Scientists as convenors inherently have power in establishing the process, as well as often having higher socioeconomic status by virtue of education and income. As a result, scientists must consciously develop practices for power-sharing.

Another practical challenge is that of mutual undervaluation, whereby both community members/policymakers and scientists undervalue the types of knowledge and perspectives each brings to the process. Indigenous knowledge or differing cultural perspectives may be presumptively dismissed by the conventional scientific paradigm. To avoid this, an investment in relationships, often entailing long periods of iterative engagement with skilled facilitation, is needed.

Stakeholder fatigue, pressure to participate, and exclusion from participation are all particularly relevant in community-oriented engaged research (see, e.g., Mikesell et al. 2013). A range of challenges emerge, including identifying who represents the community, navigating differences among community member views, uncovering or adjusting for informal power relationships, and establishing equitable compensation across community members. The involvement of compensation may sometimes have an unintended coercive effect.

Despite positive intent, there has been relatively little evaluation of the ways in which engaged research can malfunction. One example emerges from Atlantic Canada, where local knowledges about climate change impacts were extracted from individual stories of flooding and sea level rise to pinpoint vulnerable areas in coastal communities (Klenk 2018). Among other problems, these community vulnerability maps created new vulnerabilities for community members as the maps were used to change arrangements around zoning and insurance. As a result, some community member livelihoods were rendered precarious because of the maps that they contributed to creating.

Another unintended impact is the potential downside that researchers who conduct engaged research may experience in mainstream academic and professional settings. Some have noted that the substantial time required for engagement may not be fully recognized by academic peers, and, the work may be viewed as less substantive or rigorous (Oliver et al. 2019). While well-designed engaged research might escape these stereotypes, the unique barriers and challenges faces by researchers who do collaborative research with communities and policymakers must be acknowledged and addressed.

Engaged research takes time to implement and involves substantial investments in time and social capital. The building of trust is a key task, and the loss of trust can rarely be recovered. An additional complexity is the importance of sustaining engagement across multiple actors without causing fatigue, which requires strategic thought and ongoing investments. For communities, governments and research funders, these issues are paramount both in terms of their social contract with society and in terms of efforts to broaden participation (Arnott et al. 2020). For example, funding models wherein local governments allocate funding to convene engaged research more directly empower them to establish suitable time frames and identify trusted research collaborators. Such practitioner-led initiatives, seen for example in NSF's Civic Innovation Challenge, can complement more traditional researcher-led grants.

Community members learn about the science behind a hunt for artifacts.
Credit: The Conservation Trust of Puerto Rico

Principles for Engaged Research

Given the above complexity and the diversity of scales, partners, and modes of engagement, there is substantial confusion among researchers, proposal reviewers and panels, and funders on how to assess and evaluate what engaged research means in different scientific disciplines and cross-cutting programs. On the one hand, part of the confusion may stem from the diversity of operationalization in different fields and practices. On the other hand, it may be precisely this diversity that enables the goals of fostering discovery, impact, and participation to be realized.

A recent perspective (Norström et al. 2020) has distilled the best practices into four principles, wherein engaged research should be:

- Context-based: The project is situated in a particular context, place, or issue.
- Goal-oriented: Goals are clearly defined, shared across participants, relevant to the problem.
- Pluralistic: Multiple ways of knowing and doing are recognized and accommodated.
- Interactive: Ongoing learning and frequent interactions are designed into the project plan.

In addition to these principles, it is important to address upstream thought processes on project rationale — whether engaged research is appropriate. Interactive processes need to include rules of engagement. Last, given NSF's mission to advance fundamental discovery, we also add criteria relating to discovery and appraisal. We outline six core aspects that provide a possible set of recommendations for designing, implementing and reviewing engaged research (Box 3), although many other aspects of engagement might be considered depending on the goals of the funding competition and context of the projects. Given the diversity of approaches that engaged research affords, and the importance of flexibility as the process unfolds, we recommend addressing the broad parameters of meaningful collaboration, without over-prescribing them. Therefore, rather than making specific recommendations, we propose questions that can serve to highlight key issues.

Principles for Engaged Research (Continued)

Box 3. Six core elements to organize thinking around engaged research design.	
Key Element	**Questions for Researchers**
Rationale	Why is engaged research suitable or necessary for the challenge at hand? How might conventional research tackle the same question? How will engaged modes address core knowledge gaps or provide opportunities for innovation? Will engagement support translation or accelerate use? Will the research design provide intrinsic opportunities for broadening participation?
Context-specific design	What is the specific location where the project is situated? What is the envisioned action arena? Is the action arena appropriate to the problem? How do the planned modes of engagement match the scale of the participants? Is the arena formalized around informing specific decisions? Is the scale of the arena, geographically or jurisdictionally, well matched to the problem space and the solution space? Do the spatial spheres of influence of the participants align with the problem? Are the modes of engagement suited to the scale?
Goal orientation	Is the overall goal co-developed with key partners? Does the project have clear goals and timelines? What will tangible outputs be? Has there been discussion of who owns research products? Who will disseminate them? Do key partners see sufficient value to commit resources, including time and attention, to the project?
Participation	Are all relevant stakeholders engaged? Are the roles and responsibilities of research participants clearly defined? Who plays a convening role? Who may be left out? Are the values, priorities and goals of all partners known or surfaced, including how they intersect with each other? What are some anticipated power dynamics among the partners? How can process design address these dynamics and avoid unintended consequences or undue pressure on participants?
Engagement process	Are the modalities of interaction clear to all participants? Is there an MOU or other documentation that clarifies the relationships and processes of engagement? Are processes in place to meet the needs of all participants, including providing compensation, childcare for evening meetings, or other specific needs to facilitate participation of different groups?
Appraisal	How will outcomes be evaluated? Will processes, procedures, and tangible outputs be appraised continuously throughout the project? Is there a shared vision for success? How will undesirable trade-offs be avoided? How are outcomes to be evaluated by partners?

Principles for Engaged Research (Continued)

These questions are not intended as a rubric against which research proposals should be judged. Rather, they comprise a useful set of considerations to aid in a rounded and thoughtful project development process. In announcements of opportunity, program managers can support these processes by:

- providing a definition of engaged research in programmatic context;
- articulating whether engaged research is a requirement and why;
- providing pathways for coordinating proposal development to ensure engagements at the design stage are productive and appropriate;
- clarifying broader impacts that include tangible societal impacts and broadening participation;
- supporting a diversity of potential partners that fit the project scale, goals, and desired outcomes;
- supporting the creation of a database of communities, organizations, and issues — including those who have opted out of engagement — to minimize pressure on potential partners;
- requesting explicit descriptions of both translated research outcomes and intangible benefits;
- requesting a separate implementation plan for engaged research;
- funding proposal development to support entry for researchers new to a given context or to engaged research more generally;
- asking for evidence of team readiness, leadership, and prior collaboration for large projects;
- making it possible to use federal funding to support the time of non-scientist participants;
- considering longer project timelines to allow for sustained engagement.

New Frontiers for Engaged Research

Given the many benefits of engaged research and the urgency to advance research that informs action, the AC-ERE recommends that NSF develop a robust portfolio of engaged research. Appropriate research themes include grand challenges across the spectrum of science and engineering for sustainability. These efforts should include supporting underserved communities worldwide and addressing problems of social justice and human rights. These efforts also cut across multiple areas of interest in NSF, such as climate change mitigation and adaptation, energy transitions, the food-energy-water nexus, infrastructure, urban systems, and health.

Furthermore, as teams propose engaged research projects, there is a unique opportunity to advance the science of engaged research itself. In particular, research is needed to explore how engaged research and/or the insights derived from engaged research can be scaled up to impact larger populations or study areas. Where contextual effects are dispositive, there is need for foundational development of alternative approaches such as networking, cross-fertilization, diffusion, or harvesting of insights. Theoretical and empirical grounding of both broadly scalable and deeply contextual applications of engaged research methodologies will prove useful for meeting rapidly growing needs for actionable knowledge to mitigate and respond to global sustainability challenges. Equally important is advancing methods to evaluate the outcomes of engaged research, particularly as they pertain to advancing foundational discovery, diversity and inclusion, and procedural equity.

References

Anderson, J.R. and F. Gershon (2003). Rural extension services. Policy Research Working Paper No. 2976. Washington D.C.: World Bank. Retrieved from https://openknowledge.worldbank.org/handle/10986/19154.

Arnott, J.C., Kirchhoff, C.J., Meyer, R.M., Meadow, A.M. and A.T. Bednarek (2020). Sponsoring actionable science: what public science funders can do to advance sustainability and the social contract for science. Current Opinion in Environmental Sustainability, 42, 38-44.

Bremer, S., Wardekker, A., Dessai, S., Sobolowski, S., Slaattelid, R. and J. van der Sluijs (2019). Toward a multi-faceted conception of co-production of climate services. Climate Services, 13, 42-50.

Berkes, F. and C. Folke, eds. (2000). Linking social and ecological systems: Management practices and social mechanisms for building resilience. Cambridge, United Kingdom: Cambridge University Press.

Bremer, S. and S. Meisch (2017). Co-production in climate change research: Reviewing different perspectives. WIREs Climate Change, 8(6), e482.

Brunner, R.D. and A.H. Lynch (2010). Adaptive Governance and Climate Change. Boston: American Meteorological Society, 424 pp.

Brunner, R.D., Steelman, T.A., Coe-Juell, L., Cromley, C.M., Edwards, C.M. and D.W. Tucker (2005). Adaptive Governance: Integrating Science, Policy, and Decision Making. New York: Columbia University Press.

Cash, D.W. (2000). Distributed assessment systems: An emerging paradigm of research, assessment and decision-making for environmental change. Global Environmental Change, 10(4), 241-244.

Cash, D.W., Borck, J.C. and A.G. Patt (2006). Countering the loading-dock approach to linking science and decision making: Comparative analysis of El Niño/Southern Oscillation (ENSO) forecasting systems. Science, Technology and Human Values, 31(4), 465-494.

Chavez, A. and A. Ramaswami (2013). Articulating an infrastructure supply-chain greenhouse gas (GHG) emissions footprint for cities: Mathematical relationships and policy relevance. Energy Policy, 54, 376-384.

Chen, G., Shan, Y., Hu, Y., Tong, K., Wiedmann, T., Ramaswami, A., Guan, D., Shi, L. and Y. Wang (2019). Review on city-level carbon accounting. Environmental Science & Technology, 53(10), 5545-5558.

Conrad, C.C. and K.G. Hilchey (2011). A review of citizen science and community-based environmental monitoring: Issues and opportunities. Environmental Monitoring and Assessment, 176, 273–291.

Cornwall, A. and R. Jewkes (1995). What is participatory research? Social Science & Medicine, 41(12), 1667-1676.

Decker, E.H., Elliott, S., Smith, F.A., Blake, D.R. and F.S. Rowland (2000). Energy and material flow through the urban ecosystem. Annual Review of Energy and the Environment, 25(1), 685-740.

Dhakal, S. and K. Seto (2014). "Chapter 12: Human Settlements, Infrastructure and Spatial Planning." In Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Working Group III, Dhakal, S. and K. Seto, Coordinating Lead Authors, with Bigio, A., Blanco, H., Delgado, J.C., Dewar, D., Humang, L. Inaba, A., Kansal, A., Lwasa, S., McMahon, J. Mueller, D., Murakami, J., Nagendra, H., and A. Ramaswami. Core Writing Team, Pachauri, R.K. and L.A. Meyer, eds. Geneva, Switzerland: IPCC, 151 pp.

References (Continued)

Dryzek, J. (1987). Rational Ecology: Environment and Political Economy. New York: Basil Blackwell.

Dryzek, J. and S. Niemeyer (2019). Deliberative democracy and climate governance. Nature Human Behaviour, 3, 411-413.

Folke, C., Hahn, T., Olsson, P. and J. Norberg (2005). Adaptive governance of social-ecological systems. Annual Review of Environment and Resources, 30, 441-473.

Funtowicz, S.O. and J.R. Ravetz (1993). Science for the post-normal age. Futures, 25(7), 739-755.

Greenprint Denver (2007). City of Denver Climate Action Plan. Retrieved from https://digital.auraria.edu/work/ns/3f734574-1513-4282-a522-0120520a8ae7.

Gunderson, L. and S.S. Light (2006). Adaptive management and adaptive governance in the everglades ecosystem. Policy Sciences, 39, 323-334.

Haase, D. (2015). Reflections about blue ecosystem services in cities. Sustainability of Water Quality and Ecology, 5, 77-83.

Hansen, D.O. and J.M. Erbaugh (1987). "The social dimension of natural resources management." In: Sustainable Resources Development in the Third World, Southgate, D.D. and J.F. Disinger, eds. Boulder: Westview Press, pp. 81-94.

Hult, M. and Lennung, S. (1980). Towards a definition of action research: A note and bibliography. Journal of Management Studies, 17(2), 241-250.

Huntington, H.P., Hamilton, L.C., Nicolson, C., Brunner, R., Lynch, A., Ogilvie, A.E.J. and A. Voinov (2007). Toward understanding the human dimensions of the rapidly changing arctic system: Insights and approaches from five HARC projects. Regional Environmental Change, 7, 173-186.

ICLEI USA (2019). U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Retrieved from https://icleiusa.org/us-community-protocol.

Israel, B.A., Schulz, A.J., Parker, E.A., and A. Becker (1998). Review of community-based research: Assessing partnership approaches to improve public health. Annual Review of Public Health, 19, 173–202.

Johnson, N., Alessa, L., Behe, C., Danielsen, F., Gearheard, S., Gofman-Wallingford, V., Kliskey, A., Krümmel, E., Lynch, A., Mustonen, T., Pulsifer, P. and M. Svoboda (2015). The contributions of community-based monitoring and traditional knowledge to Arctic observing networks: Reflections on the state of the field. Arctic, 68, 28-40.

Kalafatis, S.E., Whyte, K.P., Libarkin, J.C. and C. Caldwell (2019). Ensuring climate services serve society: Examining tribes' collaborations with climate scientists using a capability approach. Climatic Change, 157(1), 115-131.

Klenk, N. (2018). Adaptation lived as a story: Why we should be careful about the stories we use to tell other stories. Nature and Culture, 13(3), 322–55.

Latulippe, N. & N. Klenk (2020). Making room and moving over: Knowledge co-production, Indigenous knowledge sovereignty and the politics of global environmental change decision-making. Current Opinion in Environmental Sustainability, 42, 7-14.

References (Continued)

Lemos, M.C., Arnott, J.C., Ardoin, N.M., Baja, K., Bednarek, A.T., Dewulf, A., Fieseler, C., Goodrich, K.A., Jagannathan, K., Klenk, N., Mach, K.J., Meadow, A.M., Meyer, R., Moss, R., Nichols, L., Sjostrom, K.D., Stults, M., Turnhout, E., Vaughan, C., Wong-Parodi, G. and C. Wyborn (2018). To co-produce or not to co-produce. Nature Sustainability, 1, 722–724

Lemos, M.C., Kirchhoff, C.J. and V. Ramparasad (2012). Narrowing the climate information usability gap. Nature Climate Change, 2, 789-794.

Lynch, A.H., Cassano, E.N., Cassano, J.J. and L.R. Lestak (2003). Case studies of high wind events in Barrow, Alaska: Climatological context and development processes. Monthly Weather Review, 131(4), 719-732.

Mach, K.J., Lemos, M.C., Meadow, A.M., Wyborn, C., Klenk, N., Arnott, J.C., Ardoin, N.M., Fieseler, C., Moss, R.H., Nichols, L., Stults, M., Vaughan, C. and G. Wong-Parodi (2020). Actionable knowledge and the art of engagement. Current Opinion in Environmental Sustainability, 42, 30-37.

McNie, E.C. (2007). Reconciling the supply of scientific information with user demands: An analysis of the problem and review of the literature. Environmental Science & Policy, 10(1), 17-38.

Meehan, K., Klenk, N. and F. Mendez. (2017). The geopolitics of climate knowledge mobilization: Transdisciplinary research at the science–policy interface(s) in the Americas. Science, Technology, and Human Values, 43(5), 759-784.

Mikesell, L., Bromley, E. and D. Khodyakov (2013). Ethical community-engaged research: a literature review. American Journal of Public Health, 103(12), e7-e14.

Norström, A.V., Cvitanovic, C., Löf, M.F., West, S., Wyborn, C., Balvanera, P., Bednarek, A.T., Bennett, E.M., Biggs, R., de Bremond, A., Campbell, B.M., Canadell, J.G., Carpenter, S.R., Folke, C., Fulton, E.A., Gaffney, O., Gelcich, S., Jouffray, J., Leach, M., Le Tissier, M., Martín-López, B., Louder, E., Loutre, M., Meadow, A.M., Nagendra, H., Payne, D., Peterson, G.D., Reyers, B., Scholes, R., Speranza, C.I., Spierenburg, M., Stafford-Smith, M., Tengö, M., van der Hel, S., van Putten, I., and H. Österblom. (2020). Principles for knowledge co-production in sustainability research. Nature Sustainability, 3, 182-190.

Oliver, K., Kothari, A. and N. Mays (2019). The dark side of coproduction: Do the costs outweigh the benefits for health research? Health Research Policy and Systems, 17, 33.

Ostrom, E. (1996). Crossing the great divide: Coproduction, synergy, and development. World Development, 24(6), 1073-1087.

Ostrom, E., Burger, J., Field, C.B., Norgaard, R.B. and D. Policansky (1999). Revisiting the commons: Local lessons, global challenges. Science, 284(5412), 278-282.

Ramaswami, A., Hillman, T., Janson, B., Reiner, M., and G. Thomas (2008). A Demand-Centered Hybrid Life Cycle Methodology for City-Scale Greenhouse Gas Inventories. Environmental Science & Technology, 42(17), 6456-6461.

Ramaswami, A., Main, D., Bernard, M., Chavez, A., Davis, A., Thomas, G. and K. Schnoor. (2011). Planning for low-carbon communities in US cities: A participatory process model between academic institutions, local governments and communities in Colorado. Carbon Management, 2(4), 397-411.

References (Continued)

Ramaswami, A., Tong, K., Canadell, J.G., Jackson, R.B., Stokes, E., Dhakal, S., Finch, M., Jittrapirom, P., Singh, N., Yamagata, Y., Yewdall, E., Yona, L., and K.C. Seto (2021). Carbon analytics for net-zero emissions sustainable cities. Nature Sustainability, 4, 460-463.

Ramaswami, A. (2021). Coproducing urban carbon accounting for net-zero emissions sustainable cities. Springer Nature Sustainability Blog, May 13, 2021. Retrieved from https://sustainabilitycommunity.springernature.com/posts/coproducing-urban-carbon-accounting-for-net-zero-emissions-sustainable-cities.

Rauschmayer, F. and H. Wittmer (2006). Evaluating deliberative and analytical methods for the resolution of environmental conflicts. Land Use Policy, 23(1), 108–122.

Schell, C.J., Dyson, K., Fuentes, T.L., Des Roches, S., Harris, N.C., Miller, D.S., Woelfle-Erskine, C.A. and M.R. Lambert (2020). The ecological and evolutionary consequences of systemic racism in urban environments. Science, 369(6510).

Stern, P.C. (2005). Deliberative methods for understanding environmental systems. BioScience, 55(11), 976–982.

Stokes, E.C. and K.C. Seto (2019). Characterizing and measuring urban landscapes for sustainability. Environmental Research Letters, 14(4), 045002.

Tengö, M., Brondizio, E.S., Elmqvist, T., Malmer, P. and M. Spierenburg (2014). Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. Ambio, 43, 579-591.

Vanek, E. (1989). "Enhancing environmental resource management in developing nations through improved attitudes towards Indigenous knowledge systems: The case of the World Bank." In Indigenous knowledge systems: Implications for Agricultural and International Development. Warren, D.M., Slikkerveer, L.J. and S.O. Titilola, eds. Ames: Iowa State University, pp 162-170.

Vincent, K., Carter, S., Steynor, A., Visman, E. and K.L. Wågsæther (2020). Addressing power imbalances in co-production. Nature Climate Change, 10, 877-878.

Whyte, K. (2017). Indigenous climate change studies: Indigenizing futures, decolonizing the Anthropocene. English Language Notes, 55(1), 153-162.

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