MEETING THE CLIMATE EMERGENCY

UNIVERSITY INFORMATION INFRASTRUCTURE FOR RESEARCHING WICKED PROBLEMS

DONALD J. WATERS

CNI SENIOR SCHOLAR
ORCID: 0000-0002-9550-5620
EMAIL: DJW@40OVERBROOK.COM

INITIAL DRAFT FOR COMMENT
NOVEMBER 1, 2024

COALITION FOR NETWORKED INFORMATION
WASHINGTON, D.C.

TABLE OF CONTENTS

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INTRODUCTION

The United States and other nations around the world today face a complex set of interrelated and increasingly urgent issues that impede human flourishing. Climate change arguably heads the list. Heatwaves, drought, wildfires, desertification, flooding, species extinction, and other effects of the unabated emission of greenhouse gases play a role in causing or exacerbating the occurrence of food scarcity, pandemics, forced migration, and armed conflict. Alone and in combination, these challenges, in turn, expose and amplify still other social ills, such as inequality and racism.[1]

Although scientific understanding of the causes and effects of climate change has been growing since the nineteenth century, public awareness of the magnitude of the problem is relatively recent. One observer has wryly suggested that growing media coverage in the 1980s gave the greenhouse effect "its IPO on the market of anxieties."[2] Since then, climate change has attracted massive scientific investments, mainly in the nation's universities with funding from the National Science Foundation and other government agencies.

Yet as scientific knowledge about the causes and mechanisms of climate change has dramatically increased, so too has the public's anxiety, in large part because interdisciplinary and publicly engaged understanding of the social and cultural dimensions of this complex issue has lagged. Solutions—in the form of concrete steps that would reduce greenhouse gases and mitigate their deleterious effects—have correspondingly remained elusive. In this essay, I report on the results of a two-year research project sponsored by the Coalition for Networked Information. I suggest how a strategic redeployment of resources within the research and information infrastructure of the nation's universities would help improve how these institutions serve the public interest and address what is rapidly becoming a climate emergency. It is my hope that the observations in this report might also provide insights for how universities could contribute more effectively to the solution of other complex social issues.

What is Climate Change?

Strictly speaking, climate change refers to long-term shifts in atmospheric and oceanic temperatures and in related weather patterns. Based on decades of intensive biological, chemical, and physical research, earth and climate scientists have found the evidence "incontrovertible" and are "unequivocal" in their conclusion that human activity, particularly the burning of fossil fuels that emit greenhouse gases, is warming the globe, and producing increasingly

1 See, for example, Jay, *et al.* 2023: 18-19.
2 Libsky 2023: 63. An IPO is an Initial Public Offering in the stock market.

extreme and socially disastrous weather events.[3] The recently published Fifth National Climate Assessment in the U.S. summarized several of the basic scientific findings as follows:

- "Present-day levels of greenhouse gases in the atmosphere are higher than any time in at least the past 800,000 thousand years, with most of the emissions occurring since 1970."
- "Global temperature has increased faster in the past 50 years than at any time in the past 2,000 years."
- "The rate of sea level rise in the 20th century was faster than in any other century in the last 3,000 years."
- "The current drought in the wester U.S. is now the most severe drought in at least 1,200 years and has persisted for decades."[4]

Researchers date these and related changes to the mid-eighteenth century, when James Watt's coal-fired steam engine helped launch an extended period of Western and global industrialization that continues to the present day. In 2000, atmospheric chemist, Paul Crutzen, and biologist, Eugene Stoermer, hypothesized that the effects of this era of human activity on the climate and the environment have been so profound that they will be evident in the geological record for millions of years. The two scientists proposed further that the mid-eighteenth century likely marked the end of one geological epoch, the Holocene, and the start of a new, human-dominated one, for which they coined and popularized the term, the "Anthropocene."[5] After several decades of investigating the Crutzen/Stoermer hypothesis, the International Commission on Stratigraphy recently determined that the evidence in the geological record is currently insufficient to designate the Anthropocene as a geological epoch. [6]

The Climate Emergency

Even without a formal geological definition, the Anthropocene has appeared widely, and largely metaphorically, in academic and public discourse. Such usage invokes the proposed (but now rejected) primary meaning of the term as a geological epoch to emphasize the human causes and magnitude of global warming and its various effects, some of them irreversible, on the planet and its inhabitants. With equally ominous overtones, still other phrases from climate science have crept recently into everyday usage. These include "polar vortex," "bomb cyclone," "heat dome," and "atmospheric river."[7]

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3 Marvel, *et al.* 2023: 2-4; Intergovernmental Panel on Climate Change 2023:4.
4 Jay *et al.* 2023: 17.
5 Crutzen and Stoermer 2000.
6 Subcommission on Quaternary Stratigraphy 2019; Waters and Turner 2022. See also Steffan *et al.* 2015 and Lenton 2016. For the recent decision, see Voosen 2024 and Kolbert 2024
7 See Menon 2023.

To the implicit alarms conveyed by these terms and expressions, one must add the explicit ones contained in the drumbeat of dismaying reports from climate scientists over the last several decades. One of the latest landed in early 2023 from the experts on the UN-sponsored Intergovernmental Panel on Climate Change. The chair of this panel warned, as many other experts have before him, that "we are walking when we should be sprinting" to slash greenhouse emissions and contain global warming.[8] As David Lipsky has written, there is a common theme pervading all these reports. "If the reports came with gift bags, and the gift bags contained ball caps, those caps would have been stamped with the word 'Urgent.'"[9]

Given the increasingly urgent need that they have repeatedly demonstrated, climate scientists have been hugely frustrated by the lack of action. In 1986, atmospheric chemist, Sherwood Rowland, who helped link the emission of hydroflourocarbons to the depletion of the earth's ozone layer, may have best expressed the sense of exasperation of his and succeeding generations of climate scientists. "After all," he asked, "what's the use of having developed a science well enough to make predictions, if in the end all we're willing to do is stand around and wait for them to come true?"[10]

By the 2020s, the predictions were clearly coming true. Each successive year has proved to be "the hottest on record" and the number of climate-related disasters are accumulating. One group of researchers asserted that this evidence proved that "the science-society contract is broken." Its members went on to contemplate taking a radical step. "We have fulfilled our responsibility to provide robust knowledge. We now need to stop research in those areas where we are simply documenting global warming and maladaptation."[11] In a similar vein, another group of scientists recognized that "saying 'urgent'…isn't really enough."[12] "Life on planet Earth is under siege," they wrote. "We are now in an uncharted territory," and they gathered more than 15,000 signatures from scientists worldwide declaring a full on "climate emergency."[13]

Sources of Inaction

What factors have contributed to the inaction that has provoked these rising levels of frustration and alarm among climate scientists? First is the peculiar, almost paradoxical relationship between what researchers consider proven about climate change and what remains uncertain. While climate change research has clearly established the relationship between fossil fuel emissions and global warming and has generated increasingly confident predictions about rising temperature and its likely effects, it still does not provide certainty about when exactly the promised disasters will strike, what form

8 Plumer 2023.
9 Lipsky 2023: 69
10 Quoted in Brodeur 1986: 83.
11 Glavovic *et al.* 2022: 832; see also Lahsen 2023: 169.
12 Tim Lenton, quoted in Osaka 2023.
13 Ripple, Wolf, Gregg, *et al.* 2023: 841. See also Ripple, Wolf, Newsome, *et al.* 2020.

they will take when they occur, and how severe they will be. In other words, climate change research promises uncertain certainties or what social scientists have come to call "predictable surprises."[14] The "surprise" side of this paradoxical expression alludes to the substantial scientific questions about what is still unknown about climate dynamics and points to the need for further basic research. It also injects into the public discourse a nontrivial level of doubt about whether that additional research will support or impeach the seemingly convincing evidence of prior research that has given rise to urgent calls to action.

A second factor contributing to climate inaction is simple inertia. What should individuals do when faced with this kind of choice: on the one hand, should they make long-term investments to avoid climate disasters when it is not clear when or where these events will occur; or, on the other hand, should they give priority to immediately pressing needs? Generally, they opt to kick the can of future investment down the road. They tend to rely on their confidence in what they know to be true in the short-term and to discount a future in which there is any kind of uncertainty.[15]

A third source of inaction results from active political opposition. At every step in the construction of the growing scientific consensus, so-called climate deniers have challenged or rejected the causes and effects of global warming. Well-funded by the energy industry and following a playbook honed by the tobacco industry as it tried to sow doubts about the harmful effects of smoking, they have exploited open scientific questions and mounted formidable and systematic "disinformation" campaigns to undermine public confidence in the scientific results and thereby delay or block actions to reduce greenhouse gas emissions.[16]

In addition to flooding the media with specious counterarguments, these deniers have also seized opportunities to malign the credibility and reputations of the climate researchers themselves. In the "Climategate" scandal at the end of 2009, hackers stole several thousand emails and documents from a server at the Climatic Research Unit at the University of East Anglia in Britain. Deniers cherrypicked a subset of the stolen emails, which they alleged showed that scientists had engaged in a widespread conspiracy to manipulate and falsify climate data. Even though multiple, subsequent investigations found no evidence of fraud or scientific misconduct, media reports about the allegations did their damage and public confidence in climate science at the time plunged.[17] The recent COVID-19 pandemic further eroded the public trust, as attacks on the credibility of public health experts spilled over to other areas, seeking to undermine the findings of scientific experts more broadly, including those in climate science.

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14 Bazerman 2006.
15 See, for example, Slawinski, Pinske, *et al.* 2017.
16 Oreskes and Conway 2010; Lipsky 2023, but also see Howe 2012.
17 Sheppard 2011; McKie 2019.

The "Wickedness" of Climate Change

A fourth factor is also at play in making solutions so annoyingly elusive. As a scientific, social, and cultural issue, climate change is a "wicked" problem. Wickedness is perhaps the most important factor because it helps make sense of the other factors mentioned above: the inherent and relentless skepticism that underlies and propels all serious scientific inquiry, the psychological disposition to avoid uncertainty, the economic calculations about future risk, and the politics and culture of resistance. The notion of "wickedness also challenges as too simplistic the assertion of a "science-society contract" in which science supposedly stands disinterestedly apart from society in its constructions of a problem and assumes a straight, and unquestioning line from these formulations to wider social and cultural actions to achieve policy-based solutions.

As a problem, climate change is "wicked" neither in the sense of being evil nor in the Bostonian sense of being extreme, such as "it's wicked cold" or "she's wicked smart." Instead, the term has a technical meaning formulated in the 1970's in the context of complexity studies. Those who coined the term wrote that a problem is wicked when it is "'vicious' (like a circle) or 'tricky' (like a leprechaun)." Wicked problems are difficult to define. They lack clear measures of success, and they are rarely solved. "At best they are re-solved—over and over again."[18]

Although resolving climate change is often compared to the complexities of a moonshot, the comparison is otherwise not an apt one. The goals of a moonshot are unambiguous with clear measures of success. Either NASA lands on the moon, or it does not. Not so with climate change. The components of both the problem and its possible solutions are deeply lodged in complex physical, biochemical, political, legal, economic, psychological, cultural, and other systems. Each of these—the logic of scientific research, the psychology of risk taking, the economics of investing in the future, the politics of denialism—follow their own dynamic but are also open and interdependent and therefore subject to influence from each other, which in turn can "wickedly," like a leprechaun, change the nature and definition of the problem.

For example, building models of climate change in terms of oceanic or atmospheric variables may be useful and certainly affect social and cultural behavior. However, if one approaches the issues from the perspective of the political, legal, economic, psychological, or cultural drivers that encourage firms or individuals to add pollutants to the air or water or deter them from doing so, the nature of the problem takes a different shape.[19] The operation

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[18] Rittel and Webber 1973: 160-167. See also Crowley and Head 2017 for a thoughtful retrospective on the concept of "wicked" problems and especially on its utility in the sphere of environmental policy.

[19] See, for example, Clarke, Nichols, *et al.* 2018.

and interaction of these and other drivers may result in conditions that equally affect and confound the atmospheric and oceanic models requiring them to be "re-solved."

Is there no hope?

The complexity of these interrelated scientific, social, and cultural issues once prompted economist Henry Jacoby of M.I.T.'s Sloan School of Management to observe that "If you said, 'Let's design a problem that human institutions can't deal with,' you couldn't find one better than global warming."[20] However, does this level of "wickedness" mean there is no hope?

Kate Marvel, a climate scientist, and a principal author of the recently published report of the Fifth National Climate Assessment, wrote in a New York Times op-ed that she "was sick of admonishing people about how bad things could get" with climate change. However, she also felt that she was no longer "screaming into the void." The new Assessment on which she worked had finally been able to document signs of "genuine progress:"

> In the last decade, the cost of wind energy has declined by 70 percent and solar has declined 90 percent. Renewables now make up 80 percent of new electricity generation capacity. Our country's greenhouse gas emissions are falling, even as our G.D.P. and population grow.

To continue and accelerate these actions, Marvel called for, among other things, "large-scale changes in infrastructure."[21]

Marvel did not spell out exactly what she meant by infrastructure. However, the examples of progress she mentioned point in several obvious directions. For example, the nation's power grid infrastructure clearly needs significant scientific, engineering, and other attention. As solar and wind projects come online, the challenges of connecting them to the existing grid are becoming increasingly apparent: transmission lines must be added or replaced; more sophisticated inverters are needed to convert the direct current these sources generate to existing standards of alternating current; and grid managers require more effective storage and other strategies to address fluctuations in the availability of power when the sun is not shining or the wind is not blowing.[22] Another dimension of infrastructure is the construction and distribution of charging stations needed across the nation's network of roads and highways to support a shift to all-electric vehicles.[23]

To help develop and support these components, still another part of the infrastructure to which Marvel refers must surely include the research

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20 Quoted in Lemonick 1995.
21 Marvel 2023. See also Jay *et al.* 2023: 8-12.
22 See, for example, Charles 2023 and Haegel, Verlinden, *et al.* 2023.
23 For a useful overview of the relevant issues, see Hamdare, Kaiwartya, *et al.* 2023.

apparatus of the nation's universities. Indeed, writing in *Science* less than a month after Marvel's piece appeared, two policy experts identified university-based research as key for continuing to build a collective understanding of the causes and effects of climate change as well as helping to create a broad public capacity for action. To address the "wicked" nature of climate change, all parties—researchers, government agencies, industry, and local citizens—need to be engaged and capable of "understanding the challenge; weighing options; designing plans; and then coordinating, communicating, and implementing them." The special role of research universities in this capacity building effort, the authors said, is to help identify, develop, articulate, and otherwise bring to bear "multiple forms of knowledge" in a variety of disciplines, not just those in the climate sciences.[24] How could research universities more effectively meet this critical public obligation?

[24] Klinsky and Sagar 2023.

RESEARCH UNIVERSITIES AND WICKED PROBLEMS

In the United States, there are approximately 4,000 accredited, degree-granting institutions of higher education. Of these, the Carnegie Classification has identified a subset of only about 280 doctoral institutions that engage in "high" or "very high" levels of research activity. These are the so-called R1 and R2 research universities.[1]

In his 1963 Godkin Lectures at Harvard, Clark Kerr coined the term "multiversity" to describe the size, scope, and complexity of research universities, especially a subset of the R1s.[2] Three decades later in *The Idea of the University*, the distinguished religious historian, Jaroslav Pelikan, examined the components of these complex institutions. Their core "business," he observed, comprised not only research across a wide range of fields, but also graduate and undergraduate teaching, faculty publication, and professional education. In addition, he highlighted the library as a source of information expertise that serves as a "genuine and full partner" of the other components in the research university. Given the rapid changes underway at the time in information technology, Pelikan might have also mentioned the rising importance of academic computing services.[3]

In exploring how universities could more effectively address wicked problems like climate change, I now seek to build on the description in the last chapter of the wicked nature of the climate emergency. I begin by placing research on climate change and other wicked problems squarely within the range of university activities that excite and serve public interests. I then explore in turn: the priority that universities give to investment in STEM research and the inadequacy of those investments in the face of wicked problems; the further need for university investment in several key information resources; and some of the mechanisms that universities are employing to mobilize research using these resources. In subsequent chapters, I propose that information experts in libraries, information technology organizations, and related groups could measurably improve the scale and quality of university research into wicked problems by reshaping their service strategies.

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1 Carnegie Classification of Institutions of Higher Education 2021.
2 Kerr 1963: 1-34.
3 Pelikan 1992: 117. For the full discussion of "the business of the university," see pp. 71-133.

Public Interest in Taming the "Wild Beasts of the Earth"

Highly competitive, the R1s and R2s differentiate among themselves by the scale and quality of the resources they invest in their core functions—research, teaching, publication, professional education, and information services—and by the priorities they assert in allocating resources to these functions. One set of priority decisions routinely concerns seemingly mundane, local matters related to teaching, such as admission standards, class size, faculty course loads, and degree requirements. However, research universities rarely make these choices lightly. Lurking within them are questions of intense and persistent public interest: How equitable is student access? Are costs rising too fast? Is public funding sufficient or even adequate? Are student completion rates high enough? Is a university degree worth it?[4] In addition to these questions, research universities regularly face public scrutiny over the relative priorities they give in research and teaching to various knowledge domains in the humanities, social sciences, and the sciences.

Public controversies over these various priority-setting decisions routinely play out in state and federal legislatures, the press, and in opinion surveys.[5] Because such debates contribute to a sense that the institutions are besieged with controversy, they can easily shift attention to why universities are "always in crisis," and away from how they can best contribute to knowledge and public well-being.[6] As the political thinker, Hannah Arendt, once observed, "it is somewhat difficult to take a crisis in education as seriously as it deserves. It is tempting indeed to regard it as a local phenomenon, unconnected with the larger issues of the century."[7]

In *The Idea of the University*, Jaroslav Pelikan built on Arendt's formulation and vividly explained how closely intertwined are perceived crises in higher education with the "larger issues of the century." He invoked the ultimate crises of the Apocalypse and emphasized the serious nature of these "larger issues" by reference to the Four Horseman. In their teaching, research, and related activities, he argued, research universities regularly address the public interest in the threats and realities of War, Famine, Pestilence or Disease, and Death riding on "the wild beasts of the earth." Pelikan went on to identify the "wild beasts" with the forces of nature, the climate changes "set into motion by human agents…that threaten the future of the earth."[8] As recent events around the world and on campuses across the country confirm, the

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4 See, for example, Bowen and Tobin 2015: 1, and more generally, Bowen, Kurzweil, and Tobin 2005.

5 For reports on several recent opinion surveys, see: Fishman, Nguyen, and Woodhouse 2022; Fischer 2022; and Kelderman, Elias, and O'Leary 2023;

6 Hanna Gray in Shapiro, Cole, *et al.* 2012: 192. See also Pelikan 1992: 13 and especially Schapira 2023, whose book is based on the premise that the history of the university "could just as aptly be described as the history of the 'crisis of the university'" (p.8).

7 Arendt 1961: 174, also quoted in Pelikan 1992: 13.

8 Pelikan 1992: 21.

Horseman all are currently very active and universities simply cannot avoid confronting them.

The Inadequacy of Investments in STEM

Because research universities are large, multifaceted, and highly decentralized operations, the process of setting priorities and allocating resources to tame the "wild beasts of the earth" and other wicked problems is complicated. For the principles involved or a summary of the desired outcomes, one can rarely turn to university mission statements. They usually comprise little more than bland pledges of broad commitment to three familiar goals: research teaching and civic service.[9] Instead a more sophisticated approach is needed.

Ithaka S+R has mastered such an approach in a series of recent and revealing studies. One of these recently focused on "Aligning the Research Library to Organizational Strategy." After detailed consultations with selected university leaders and decision-makers, the authors reported that one of the top priorities for research universities is to engage more deeply with the interests of the public, especially in their home states. They also reported that another top priority for research universities is to increase investment in the STEM fields of science, technology, engineering, and medicine.[10]

These twin goals—attend to the public interest and invest in STEM—are crucial in guiding universities in their support of research on a variety of compelling topics, including wicked problems. However, some caution is in order. As discussed above in the Introduction to this report, university investment in STEM has proven necessary but not sufficient for climate change research. A similar reservation applies in the case of research university efforts to tackle another of Pelikan's four horsemen: the wicked problem of pestilence as manifested during the recent COVID-19 pandemic.

When the COVID virus first appeared, academic researchers, particularly in biomedicine, joined almost immediately in large-scale, international efforts to contain it. They collaborated with scientists in government and industry to gather samples of the pathogen, fully sequence its genome, and conduct experiments leading to the rapid development of vaccines, treatments, and other ways to control and prevent COVID infections.[11] However, with the spread of COVID, members of historically marginalized groups began suffering bad outcomes at much higher rates than other groups in the United States and elsewhere. With the rollout of the new vaccines, these differential outcomes did not diminish but compounded and extended to other groups.[12]

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9 See, for example, Keohane 1993: 101-102, and Prosser and Turner 2004: 237n3.
10 Cooper, Hill, and Schonfeld 2022: 8-11.
11 See, for example, Collins, Adam, *et al.* 2023.
12 See for example, Raine, Liu, *et al.* 2020 and Bollyky, Castro, *et al.* 2023.

Despite the impressive contributions that STEM researchers made to address the pandemic, their success extended only so far.[13] In this case, as in efforts to address the complexity of climate change, STEM research can falter badly when it fails to recognize the wickedness of the problem it seeks to address. As we noted in the last chapter, one of the defining features of wicked problems is the lack of clarity and consensus about the desired outcomes and the tradeoffs among them. Just as relying on medical experts who sought to minimize COVID deaths by shutting everything down until the public achieved a level of vaccinated immunity could not adequately resolve the pandemic, so too wicked problems are generally resistant to solutions proposed by one group of experts seeking to optimize outcomes from their own perspective. Philosophers of science and science policy experts have developed a variety of models to understand the demands on scientific research when information about desired outcomes is lacking and additional perspectives are needed.[14] Two of these models are especially useful to highlight in this context.

Information Resources for Wicked Problems

One model describes "Post-Normal Science;" the other "Mode 2 Knowledge Production."[15] Both models recognize the general practice of scientific research in which investigators confront problems that are susceptible to solution within the boundaries of a relatively narrow set of disciplinary knowledge and methods. However, both also focus attention on a separate set of research problems that require a very different approach. According to the models, these problems are wicked in nature: they are issue-driven; there is considerable uncertainty about likely effects; the value of possible solutions is in dispute by various interested parties; and yet the stakes are high, and decisions urgently needed. To address these kinds of problems, researchers must define and investigate them in ways that are accountable to and include the knowledge of groups beyond their native discipline. Researchers cannot rely solely on their own disciplinary-based resources but must incorporate the expertise of "extended peer communities."

Why then have university investments in STEM research had such limited impact on the wicked problems of climate change and the COVID pandemic? According to the Post-Normal and Mode 2 models, the answer is, at least in part, that universities have insufficiently supported the research into these complex "issues of the century." They have failed to invest adequately in developing and bringing to bear relevant and substantial knowledge and information from two key sources outside the STEM domains. University-based research on wicked problems inevitably falls short in the absence of effective mechanisms for the productive,

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13 Reynaud, Zhang, *et al*. 2021, Gorman 2023, and Thorén and Gerlee 2024.

14 For a useful review and comparison of alternative models, see Hessels and van Lente 2008: 742-748.

15 On Post-Normal Science, see Funtowicz and Ravetz 1993 and 1994; Ravetz 1999 and 2006. On Mode 2 Knowledge Production, see Gibbons, Limoges, et.al 1994 and Nowotney, Scott, and Gibbons 2003.

interdisciplinary engagement of STEM researchers with (a) the practical experience of members of the public and (b) the relevant political, economic, organizational, historical, linguistic, philosophical, religious, and other cultural expertise of researchers in the social sciences and humanities.

Although essential to fruitful research into the nation's wicked problems, these two kinds of interdisciplinary engagements have proven difficult, in part, because of the political and economic hold of STEM fields over the priorities of research universities.[16] Strategic investment in STEM fields comes all too often at the expense and, increasingly to the great alarm, of researchers in the social sciences and especially the humanities.[17] Of course, the deep, structural bias toward STEM is largely the result in the U.S. of long-term patterns of federal and state support for research universities. The reliance of research institutions on funding from these sources makes it difficult for university leaders to broaden their perspective and to change course from a one-STEM-solution-fits-all-problems approach.

Mobilizing the Necessary the Resources

But change is not impossible. As one observer keenly noted about university governance, "the real life of a university takes place in its departments, schools, libraries, museums, centers, and institutes,"[18] In such a decentralized and dynamic environment, as two others have written, it is the job of university leaders to provide an "organizational machinery" that not only facilitates strategic decision-making in these units, but also provides "a compelling set of incentives to pursue system-wide goals."[19] The room for maneuver lies within this machinery and its set of incentives as researchers, information experts in libraries and other units, and university leaders negotiate over priorities and available resources.

There are at least two recent, notable, and instructive examples of how universities have constructed institutional machinery to mobilize public and interdisciplinary knowledge resources to the common goal of addressing wicked problems. In the first example, the notion of "grand challenges" plays a key role; the second highlights a response to the need for a so-called "Fifth Wave" of universities. Following a brief review of these examples, I then offer more specific examples from my interviews with climate change researchers and turn to the question of how information experts in university libraries and other related units could help improve the scale and quality of university research into wicked problems.

- **Grand Challenges**

Challenges have a long history in academic research as a way of framing difficult problems and offering inducements, such as prizes or grants, to motivate investigators to find solutions. Beginning in the 1980s, researchers

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[16] See Lahsen and Turnhout 2021 and Overland and Sovacool 2020.
[17] See, for example, Newfield 2016: 82-104.
[18] Turner 1996: 295.
[19] Bowen and Tobin 2015: 183-184.

in computer science, engineering, and other STEM disciplines, as well as a variety of funding agencies, began routinely to characterize the research agenda of their disciplines as composed of "Grand Challenges." Defined as difficult but compelling and solvable problems, Grand Challenges became a rallying cry for investigators to join with others in their field and seek innovative breakthroughs that would address the identified set of problems.[20] In 2012, Tom Kahlil and Cristen Dorgelo, respectively the Deputy Director for Policy and Assistant Director for Grand Challenges in the White House Office of Science and Technology Policy (OSTP), adopted this definition, and declared Grand Challenges to be "an important element of President Obama's Strategy for American Innovation."[21]

In 2017, after they had both left OSTP, Kahlil and Delgado helped organize and lead a workshop on University-Led Grand Challenges. Hosted by the University of California, Los Angeles (UCLA), participants included representatives from UCLA and 19 research universities. By the time of the workshop, the meaning of "Grand Challenges" had shifted from the disciplinary focus of the OSTP definition and became synonymous with wicked problems. To meet the special requirements of Grand Challenges in this revised sense, the workshop participants recognized that their institutions would have to make a corresponding "paradigm shift" in their operational machinery and incentive structures. Not able to rely on traditional models of discipline-based research support, they identified the need to leverage centers and institutes as places on campus able to bring interdisciplinary knowledge to bear not only from STEM fields but also from a broad range of other fields across the campus and from the wider community as well.[22] Following the 2018 workshop, one of its participants, the University of Texas at Austin, embarked on a Grand Challenge initiative on climate change. According to a detailed report of its work, published in 2023, the university adopted the operational changes identified in the workshop and succeeded in generating substantial research contributions from faculty in the humanities and other fields as well as from the local community.[23]

- **The Fifth Wave**

Arizona State University also took part in the Grand Challenge workshop. However, the remarkable efforts of Michael Crow, the president of Arizona State University, and his colleagues predated the UCLA meeting and, since then, have gone well beyond its recommended changes. According to Crow, the ineffectiveness of research universities in, among other things, confronting wicked problems such as climate change and the COVID pandemic calls for a new model—a "fifth wave" in the evolution—of organizational machinery and incentive structures of the research university.[24]

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20 For more detailed discussions of this history, see Omenn 2006, Hicks 2016, and Kaldewey 2018.
21 Dorgelo and Kahlil 2012.
22 Popowitz and Dorgelo 2018.
23 Lieberknecht, Houser, *et al.* 2023.
24 Arizona State University 2021.

A key distinction of Fifth Wave universities is that they seek excellence in teaching and research by being broadly inclusive and operating at a large scale. Over the last 20 years, ASU has progressively restructured itself as a prototype of this new model. It has increased the size and diversity of its student enrollments, while simultaneously improving both retention and graduation rates. In addition, its research expenditures have grown substantially.[25] To support this expansion and ensure that its students and researchers effectively respond to the public interests in climate change and other major issues, ASU has explicitly recognized and embraced the imperatives of Mode 2 Knowledge Production. Although it maintains discipline-based departmental structures, ASU has deliberately given high priority to creating and building capacity in schools, centers and institutes that are problem-oriented, interdisciplinary, and public-facing.[26]

Further evidence of mobilization

As the Grand Challenge workshop and ASU's investment in its Fifth Wave transformation clearly demonstrate, some university leaders are not only acutely aware of the public interest in wicked problems such as climate change. They are also becoming alert to the special characteristics of these problems and the need to reconsider and recalibrate accordingly how they support their research operations. Most institutions will almost certainly continue to call for major investments in STEM fields as a general institutional priority. However, the wicked nature of climate change means that they must additionally invest in creating the machinery and incentives to mobilize deep, extensive, problem-oriented collaborations that join researchers from the social sciences, humanities, and STEM with interested members of the public.

To help gauge the success of university leaders in making this additional effort, I identified climate research centers and institutes at a variety of R1 and R2 universities. I included a mix of public and private institutions located across the country from the east coast to Alaska. I then interviewed researchers and administrators affiliated with these centers and institutes, as well as librarians and other information specialists.[27] What I found, as illustrated in the list below were numerous, encouraging examples in these centers and institutes of interdisciplinary and community-engaged research focused on climate change and related environmental problems.

- A sociologist and a data specialist are identifying and mapping the location over time of chemical waste left by industry as well as small businesses, such as gas stations and car repair shops. Their purpose is to document changes in land use and trace the cultural, political,

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[25] Guthrie, Mulhern, and Kurzweil 2015: 7. For current data, see Arizona State University n.d.

[26] Crow 2010 and Crow and Dabars 2017 and 2020.

[27] See Appendix A for a list of those who kindly agreed to speak with me.

and economic efforts to mitigate or, in many cases, simply conceal the hazards.

- An engineer and urban planner, in partnership with the state office of Climate and Energy and with zoning officers in dozens of local communities, are collecting and analyzing zoning ordinances from local government websites to determine how communities regulate and affect the deployment of solar and wind power.

- An historian and data scientist, in collaboration with community-based agencies, are gathering and analyzing scientific documentation of weather events, local community disaster declarations, and insurance data to evaluate locations across the country that might serve as possible "climate havens."

- A team that includes a sustainable systems engineer, an aerospace engineer, and air traffic controllers are redesigning landing, takeoff, and taxiing routes to conserve fuel.

- A conservation ecologist, local officials, and other stakeholders, including members of indigenous communities, in coastal North Carolina are documenting local values and perspectives and then integrating them into tools to help make decisions about whether and how to preserve cultural monuments endangered by weather events and rising sea levels.

- A political scientist in collaboration with an ecologist and local indigenous communities in artic regions are co-developing research strategies to understand local climate changes and make decisions about possible mitigation and adaptation strategies.

- In various cities, a law professor has established partnerships with local community stakeholders and other university researchers to create laboratories for governing city resources affected by climate change as a commons.

How to accelerate research on the climate emergency

The question I asked in all my interviews was: how could university libraries, campus technology organizations, and other information resource organizations best position themselves to support and accelerate these research efforts that are now so dependent on building and integrating knowledge across different fields and communities? Not everyone had an answer. In part, many are either self-reliant or rely for help on their graduate students for information and information technologies and are unaware of other possible sources of support.

Underlying this lack of awareness in many cases is a rather dated conception of campus information organizations. In 1992, when Jaroslav Pelikan identified the library as a "genuine and full partner" in the business of the university, its primary role was to assemble, preserve, and provide access to a large local collection of books and serials for faculty research and student learning. The World Wide Web was just being established and Pelikan neglected to include in his account what were then relatively small but growing campus organizations that provided computational and internet-based information services.

Now, three decades later, research libraries still manage local collections, but their role has greatly expanded and diversified. They license electronic materials for local campus access. In addition, and often in concert with experts in campus information technology organizations, university offices of research, and other related academic support organizations, libraries are also now responsible for helping their partners in university teaching and research to navigate a rich scholarly environment of local and networked sources, tools, and services. In the research domain, their service strategies have increasingly focused on providing support for collecting, analyzing, curating, and providing broad access to data and other primary source information.[28]

Faculty perceptions of the value of the library and information technology organizations have not entirely caught up with these changes. At the same time, the role of these organizations is still in flux and could be better targeted to the needs of researchers investigating wicked problems. Based on the foregoing considerations in this and the previous chapter, and given what I have learned in my interviews, I now propose that university libraries and related information resource organizations consider modifying their research service strategies to ensure that they encompass four interrelated areas. These service strategies should seek first to:

- Focus attention on university-supported institutes and centers that conduct interdisciplinary research on climate change.

Then within the centers, they should aim to:

- Foster the translational and methodological skills required for interdisciplinary climate change research that cuts across fields in STEM, the social sciences, and the humanities;
- Engage members of the public in defining and co-producing research on climate change; and
- Enhance the support for the collection, analysis, and curation of data and other primary source information to accommodate the scale and

[28] For useful overviews of these changes, see Dempsey and Malpas 2018 and Lippincott 2023. The White House Office of Science and Technology Policy has had a powerful role in shaping university and research library approaches to data access. See especially Nelson 2022.

nature of interdisciplinary and public contributions to climate change research.

In following chapter, I address the topic of institutes and centers. In the fourth chapter, I turn to the other three issues.

SUPPORT FOR CLIMATE CHANGE RESEARCH IN UNIVERSITY CENTERS

Research infrastructure in the nation's universities is complex and multilayered. At one level, it comprises core, common services, such as electricity, plumbing, transportation, and the internet. It also includes the specific physical plant of buildings on campuses, as well as the array of laboratory equipment and other technologies, such as research computers, software, and databases used in these structures. In this report, my focus is on yet another layer of the research infrastructure: the organizations in which the research process operates. Which individuals interact to define, manage, execute, and support the research process? How are their roles and responsibilities defined by their expertise and by the groups to which they belong?

A key unit in the university's organizational infrastructure for conducting climate change and other wicked problem research is the research center or institute. Another key unit—the library—has considerable information systems expertise that could contribute to and help accelerate wicked problem research. However, libraries have largely focused their resources on a third critical unit—the university department—instead of research centers and institutes. What are the forces behind these organizational relationships and, what factors could help change the research focus of libraries and help strengthen the ability of universities to address climate change and similar pressing issues?

To help answer these questions, I begin in this chapter with a brief review of changes over the last three decades in library collections and the research support role of librarians. I then distinguish the roles of faculty departments from those of research centers and institutes before offering some criteria for identifying the types of centers and institutes where researchers and information specialists might fruitfully join forces in advancing the university's strategic interest in addressing wicked problems like climate change.

Libraries and their collections

Librarians have long played a key role in the university research infrastructure. In what is now regarded as their "traditional" roles, they have regularly worked with faculty in their departments to identify materials of research interest and then acquire, organize, preserve, and provide access to these materials. They have also worked with these faculty and university administrators to set building priorities so that there would be sufficient room on campus to house and use these collections.

By the 1970s and 1980s, these roles came under increasing economic pressure. With the changes in information technology beginning in the late 1960s and through the 1980s, manual card catalogs became a growing burden to maintain, and libraries responded by investing in substantial efforts to digitize their card catalogs and make these metadata available to faculty and students online. Moreover, even though rising prices, especially for journals, made it difficult for library acquisitions to keep pace with the rate of publication, the inexorable growth of the collections meant that library directors and other university leaders were almost always occupied with building new libraries (or extensions to existing ones), or planning the next construction project.[1] And to compound these pressures, the steady, physical deterioration of existing research collections came to light during this period and caused great alarm.

Since the nineteenth century, publishers had been printing books and journals on acidic paper. Over time, the acid in the paper reacts with water in the air, breaks down the cellulose, and causes the items to discolor, become brittle, and effectively to self-destruct. During the 1980s, stimulated by the work of the Commission on Preservation and Access, and with support from the National Endowment for the Humanities, libraries began copying brittle books and journals to microfilm as the most effective technique to preserve the intellectual content of the physically deteriorating items.[2] However, the microfilming effort brought sharp criticism. Not only did researchers express a general distaste for microfilm, many scholars also specifically objected that preservation microfilming destroyed the physical items and, with them, valuable evidence of the changing historical relationships among authors, editors, publishers, typesetters, readers and others involved in the production of knowledge.[3]

By the early 90's, careful research had begun to show that strict control of temperature and humidity could dramatically slow the embrittlement process and help save both the endangered content and the physical items.[4] Given these findings, universities began a massive wave of renovating existing library buildings with air conditioning to help preserve their collections. Investments in both existing and new buildings also increasingly began to incorporate off-campus shelving, a controversial but economically advantageous innovation originally intended to address library collection growth but one that also eventually yielded huge preservation benefits.

In the 1970s, the University of California (UC) established two regional shelving facilities, one to serve the UC campuses in the northern part of the state, the other in the south. Harvard soon followed in 1986 with the

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1 For a seminal study, analyzing the interrelationships of these various pressures, see Cummings *et al*. 1992.
2 Marcum and Friedlander 2003.
3 See, for example, Tanselle 1989 and 1992, and Baker 2001.
4 See, for example, Reilly, Nishimura, and Zinn1995.

opening of a high-capacity, environmentally controlled off-campus warehouse for shelving books, journals, and archival materials from its overflowing library collections. The efficiencies of its modular design and the preservation benefits of its temperature and humidity control had great appeal, and the so-called Harvard model soon became the envy of cost-conscious university administrators around the country. However, the idea of moving collections off campus also sparked opposition and debate, especially among those faculty members whose teaching and research depended on ready access to physical collections.[5]

Wider adoption of off-campus shelving depended on the ability of faculty and students to find and promptly retrieve needed items from these facilities. By the turn of the twenty-first century, online catalogs had markedly improved their user-friendliness and retrieval capabilities. Following the examples of Google and other web-based information services, they began incorporating simple search-box interfaces. The option of browsing titles in online catalogs also became more effective, though far from perfect, and improved the ability of researchers to identify and locate needed library materials that were related by subject and classification. In addition, to address the retrieval issue, libraries began offering next-day delivery services, like those that had emerged and improved with the growth of Amazon and other online retailers.

With these two critical mechanisms—improved search and delivery—libraries demonstrated that they could respond positively to faculty criticisms about their reliance on remote shelving. These solutions did not satisfy all the faculty, but they built enough confidence that universities across the country began constructing their own versions of the Harvard model.[6] Moreover, the response of research libraries and the subsequent spread of off-campus shelving had much broader implications. They effectively put library collections shelved both on and off campus in a large and growing universe of networked information, which led in turn to major changes in the service orientation of the library as an organization of information resource specialists.

The changing roles of information resource specialists

Lorcan Dempsey, one of the most astute observers of changes in research libraries over the last three decades, has referred to the large, diverse, and emergent body of networked information as a "facilitated collection." This body of material of course includes the "owned collection" that research libraries have traditionally built and shelved on campus. However, by virtue of the deployment and use of networked catalogs in combination with both online and physical delivery services, it also comprises locally owned materials shelved off-campus, as well online books, journals, archives, and databases that are either freely available or to which the library has paid to

5 For one of the most articulate cases against off-site shelving, see Abbott 2006.
6 See, for example, Nitecki and Kendrick, eds., 2001 and Weeks and Chepesiuk 2003.

acquire rights. It even includes materials held physically or virtually at other libraries. In this new, networked information space, the traditional skills of selection, acquisition, cataloging, circulation, and reference, which a library needed to assemble a large, local collection, would no longer be sufficient to meet the information needs of the research university. A broader range of expertise would be required to "facilitate" faculty and students in gathering and using from the network whatever physical and digital materials they need for research and instruction as they need them.[7]

Consider how research libraries around the country have reconfigured their services in relation to the changing use of collections and library spaces. Giving special priority to changing research and learning practices, they have closely monitored the use of collections, shifted little used materials offsite, and created over time new and redesigned spaces for technically sophisticated classrooms and areas for individual and collaborative study and research. In these areas, librarians, often in collaboration with academic computing specialists, now host and provide support for instructional methods and for faculty and student work in the digital humanities and, more broadly, digital scholarship.[8]

According to one study, "the overarching framework" for these changes has been "an increasing focus on what users do (research, teaching, and learning) rather than on what librarians do (collections, reference, library instruction)."[9] This shift in emphasis has occurred not only within the walls of the library, but also outside on campus, mainly in the responsibilities of so-called "liaison" librarians. Traditionally comprised of bibliographers and instructional librarians, these liaisons would consult with faculty to identify materials to add to the collections and assist them in teaching students how to use the collections. With changing technology and the rise of the "facilitated" collection, the role of the liaison has come to require a very different mix of technical and disciplinary expertise for engaging with faculty in their research and teaching.

In 2005, Barbara Dewey was among the first university librarians to outline the changing requirements for faculty liaisons. She called for these specialists to become "embedded" with the faculty.[10] Since then, through retraining and recruitment, research libraries have made concerted efforts to build cadres of liaisons with a variety of technical skills, such as text mining, statistical analysis, imaging, visualization, mapping and geolocation, data management, and publishing, as well as sufficient disciplinary knowledge to be able to help faculty apply these technical skills in achieving their research and teaching priorities. Libraries, of course, vary in the number of liaisons they are able

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7 Dempsey 2017. See also Dempsey, Malpas, and Lavoie 2014.

8 For a recent and comprehensive overview of how research libraries are redesigning space and services, see Hickerson, Lippincott, and Crema 2022 and Lippincott 2023.

9 Jaguszewski and Williams 2013:4, quoted in Dempsey (2017) who has characterized this change as a shift from the "outside-in" to the "inside-out" library.

10 Dewey 2005: 6.

deploy and in the mix of technical and disciplinary expertise that these liaison teams offer.[11] However, even though Dewey suggested early on that libraries also embed them in research centers and institutes, most have aimed their liaisons at academic departments, thereby missing the opportunity to help advance climate change and other wicked problem research occurring in the centers. Why?

Academic departments and research centers

According to the sociologist, Andrew Abbott, departments are the "essential and irreplaceable building blocks of American universities" because they provide an enduring social structure for several key, interlocking university functions.[12] First, departments provide disciplinary homes for faculty. Second, departments control course assignments and degree requirements, which serves to train new generations of scholars. Third, departments are the main loci of hiring faculty as well as advancing their careers through the promotion and tenure processes.

Although the subject matter of each discipline has changed considerably over the last century, this department-based structure of disciplinary affiliation, student credentialing, and faculty career management has remained remarkably stable. Even the relatively recent exceptions—the expansion and reorganization of the biological subfields; the emergence of data science programs, the formation of area, ethnic, and gender studies; and the disappearance of geography departments—prove Abbott's building-block rule. To persist in U. S. research universities, disciplinary innovations must find expression in the departmental structure of these institutions. It is entirely natural then that university librarians would aim their liaisons at the departments as a first line of support for faculty teaching and research.

And yet, for the library and other information specialists to support faculty research, it is plainly insufficient for them to concentrate solely on the departments. Certainly, many faculty members do manage their research agendas within the disciplinary and resource confines of their departments. However, contemporary university research—and the social benefits and intellectual breakthroughs that it produces—also relies on a social structure that extends beyond the departments and includes research centers and institutes, or what some observers have broadly described as "organized research units" (ORUs).[13]

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11 The literature on the evolution of the liaison librarian is voluminous. For especially useful analyses, see: Kesselman and Watstein 2009; Jaguszewski and Williams 2013; Vinopal and McCormick 2013; Cooper and Schonfeld 2017; Brown, Alvey, *et al.* 2018; and Frenkel, Moxham, *et al.* For a selected bibliography on the topic, see Vine 2018. While academic libraries embarked on a process of evaluating and redefining the liaison role, medical libraries took a notable and slightly different tack by exploring the feasibility of establishing a role for what Davidoff and Florance (2000) called an "informationist." See also Federer 2013; and Hashemian, Zare-Farashbandi, *et al.* 2021

12 Abbott 2001: 128.

13 See, for example, Geiger 2004: 9.

Historians of American higher education generally identify the Harvard Observatory, founded in 1839 to provide equipment for astronomical research, as one of the first ORUs. Natural history and other museums with collections of objects of scholarly value and agricultural extension stations in land-grant universities are two other early examples of the formation of extra-departmental research centers.[14] These early examples illustrate the potential advantages of the ORU structure and how it can effectively complement the core structure of academic departments and expand the research capabilities of the university.

First, compared to the multipurpose nature of departments, centers and institutes concentrate on a single function: research.[15] This focus makes them administratively easier to create than departments and, like the agricultural research stations, gives the university and its researchers an agile mechanism to respond quickly to social needs and intellectual opportunities. Second, in the ways that museums do, the structure of centers and institutes can give faculty the freedom and opportunity to interact with other researchers outside their departments (and, in some cases, outside their universities) on topics and with sources and methods that may reach beyond their disciplinary paradigms. In addition, ORU's can, like the Harvard Observatory, give faculty members access to staff and equipment that can increase the scale and duration of their research in ways that academic departments simply cannot afford.[16]

Seeking these advantages of agility, interdisciplinarity, and added resources, and given considerable encouragement and investments from government agencies and private foundations, research universities have greatly expanded the number and variety of ORUs throughout the twentieth and into the twenty-first centuries. Data compiled by the Gale research group indicates that there were more than 10,000 research centers at colleges and universities in the United States in 2012, and that the 25 leading research universities accounted for nearly 3,000 of them, for an average of 120 per institution.[17] The sheer number of ORU's has prompted observers to characterize their structure variously as enigmatic, complicated, and poorly integrated into the overall administration of the institution.[18] It is no wonder then that libraries and their faculty liaisons have been reluctant to allocate their time and skill to help advance faculty research in centers and institutes. If there is an underlying order that could give libraries confidence in their choices about which research ORUs to support, then what is it?

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14 Geiger 1990: 5; stahler and Tash 1994: 542.
15 Stahler and Tash 1994: 541.
16 Geiger 1990: 4-5; Hays 1991: 3; Sá 2008: 33-34.
17 Jacobs 2014: 97-98.
18 Hays 1991: 1-2, 5.

Criteria for Identifying High-Priority Research Centers

A useful taxonomy of research centers and institutes distinguishes three types: shadow, adaptive, and standard organizations.[19] "Shadow" and "adaptive" centers and institutes are faculty oriented. Because they are by far the most numerous types, they can overshadow and obscure the institutional value and significance of the "standard" type of research centers, which are oriented to institutional mission and appear much less frequently than the others.

Shadow and adaptive centers have very little formal organization. Projecting the research interests of individual faculty members rather than those of the institution, shadow centers and institutes designate little more than the labs of faculty members or the websites documenting their research activities. Adaptive centers have a slightly more formal organization, which is typically needed because they serve to help faculty members "adapt" quickly to the needs of administering the funds, and perhaps the temporary staff, associated with a research grant or contract. The president of a prominent research university was speaking in the early 2000s about shadow and adaptive centers when he addressed the staff of the Mellon Foundation, where I served as a program officer, and said wryly that every faculty member in his institution seems to want at least one to call their own.

Research universities typically give faculty wide latitude to create and participate in shadow and adaptive research centers. However, they exercise a mix of incentives and administrative controls as leverage to ensure that the missions of so-called "standard" centers are aligned with institutional research priorities, including emphasis on climate change and other wicked problem or grand challenge research. This leverage produces a set of organizational features that can help research libraries and their faculty liaisons clearly distinguish standard research centers from the other types as a possible focus for research support.[20]

- **Articulate mission**

First, the missions of standard research centers are typically well-articulated and aligned with university priorities. It is often stated in the form of a strategic plan that the center regularly updates. The plan will clearly identify the set of research problems that the center seeks to address, the objectives it will pursue during a specific period, the interdisciplinary and other resources it needs, and the measures it will use to gauge success.

- **Institutional Leader**

Second, rather than being self-appointed, the leaders of standard centers generally draw their authority from the institution. The university administration selects directors based on their individual accomplishments in the relevant field of research as well as their leadership talents. Given these qualities and the importance of the center's mission to the institution, the director generally reports to a senior administrator, such as the provost or vice president for research.

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[19] Hays 1991: 5. For a different typology, see Sá 2008: 33-34.
[20] Stahler and Tash 1994: 541; Sá 2008: 34-37

- **Stable Budget**

Third, a standard center operates under a stable, core budget. Universities generally expect the center's researchers to apply for and receive substantial grant funding for individual projects. However, they will typically set aside institutional funding for key administrative costs, such as support for the director and a small set of staff members who may also help the center with fund-raising and grant management. The university funds may also support programmatic activities, such as an annual competition for seed funding designed to spark interest in the center, promote collaborations, and test and refine faculty research plans. In addition, universities may go even further and obtain multi-year funding from government agencies, such as the National Science Foundation, NASA or the U. S. Geological Survey, or one or more private foundations. These funding arrangements may cover the administrative as well as the project costs of a standard center.

- **Defined Procedures**

Finally, standard centers generally establish a defined set of procedures for key functions. They need to create a regular schedule for meetings of center leadership and participants, obligations for participants to present and discuss the results of their work with other center researchers, and mechanisms to award internal seed funding. In addition, they must address the particularly sensitive issue of faculty qualifications for participation. The rights and duties of research center membership can often conflict with the teaching and research requirements that university departments set for a faculty member's promotion and tenure.[21] As a result, standard centers typically restrict full membership to tenured faculty only. To help ensure that research at the center does not obstruct the path to tenure, they will often limit the participation of junior faculty to a partial or affiliate status.

Another key procedural issue for standard centers is to define conditions for them to affiliate and collaborate with other research centers. Some universities deal with the proliferation of shadow and adaptive centers by encouraging those with shared research interests to affiliate with each other under the umbrella of designated standard center.[22] Yale University's Planetary Solutions is an example of such an umbrella organization for climate change research.[23] Other standard university centers encourage cross-institutional collaborations. For example, in partnership with the United States Geological Survey, North Carolina State University and the University of Alaska, Fairbanks each host Climate Adaptation Science Centers (CASCs), which are part of a national network of such centers designed to foster inter-university research collaborations on climate change in different regions of the nation.[24]

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[21] These tensions and ways to mitigate them have received considerable attention in the literature on higher education administration. See, for example, Geiger 1990: 17, Stahler and Tash 1994: 545, Sá 2008: 36-37, and especially Boardman and Bozeman 2007.

[22] Hays 1991:9-14.

[23] Yale University n.d.

[24] North Carolina State University n.d., and University of Alaska Fairbanks n.d. For an overview of the national CASC program, see United States Geological Survey n.d.

An influential 2017 study of 18 environmental and sustainability centers and institutes at U.S. universities confirmed these features—articulate mission, institutional leadership, stable funding, and defined procedures— as among the "best practices" for ORUs in general, but especially for those focused on the wicked problem of climate change.[25] Paying close attention to these features can help libraries and their faculty liaisons identify those research centers and institutes at their universities where their support could be most effective in advancing institutional priorities. For libraries seeking to support climate change research but lacking a center or institute at their own institution that meets these qualifications, it may be appropriate for their faculty liaisons to reach out to an inter-institutional center, such as one of those sponsored by the U.S. Geological Survey. In any case, the choice to allocate library support to a climate change research center or institute requires further decisions on a related policy question: to what aspects of wicked problem research can faculty liaisons most effectively contribute and what expertise would be required? I turn to this key question in the next chapter.

[25] Hoffman and Axson 2017.

SUPPORT FOR INTERDISCIPLINARITY, PUBLIC ENGAGEMENT, AND DATA ANALYSIS IN CLIMATE CHANGE RESEARCH

The scope of climate change as a "wicked" challenge requires all hands on deck. In the physical and natural sciences, researchers are seeking to measure and predict ever more precisely the effects of carbon and other emissions. At both global and local scales and in both long- and short-term time frames, they are focused on expanding our understanding of the physics and chemistry of atmospheric and oceanic climate cycles. They are also studying how these cycles affect—and are affected by—the biologically diverse flora and fauna of the planet, including especially human societies.

In the social sciences, researchers study closely the effectiveness of large and small efforts within those societies to mitigate and adapt to climate changes. Economists have sought to calculate the value of resources and processes that societies need to bring to bear in decisions about specific kinds of mitigations and adaptations. In addition, the work of political scientists, sociologists, psychologists, and other social science researchers help us grasp the variety of other factors at play in these decisions, including social organization, individual roles, differential power structures, and the dynamics of collective action and risk management.

Specialists in the humanities, or what one might aptly call in this context the "imaginary disciplines," concentrate on still other, mainly cultural, dimensions of climate change. Contributions from philosophy, religious and literary studies, history, anthropology, the arts and related fields impel us to *imagine* alternative ways of confronting the "wild beasts of the earth." What would be possible if we consider our climate predicament in relation to justice and the good life, our gods, our fictions, our pasts, other cultures, and our creativity? Without such *imaginaries* in climate change research, it will be difficult to accommodate to, much less to mitigate, the grim realities that that face the planet.[1]

As one gauge of the work scholars are conducting in and across all of these areas, Clarke & Esposito recently reported on the growth of research publications addressing climate change and sustainability topics. Citing the appearance in 2022 of major new journals from Cambridge and Oxford

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1 For a brief but useful overview of disciplinary interests in climate change research, see Alexander 2023: 59-86. My usage of "the imaginary" builds on the concept as articulated by the philosopher, Charles Taylor, who wrote: "I adopt the term imaginary..because my focus is on the way ordinary people 'imagine' their social surroundings, and this is often not expressed in theoretical terms, but is carried in images, stories, and legends" (2004: 23). For more general treatments of the concept, see Strauss 2006 and James 2019.

University Presses, Nature, and the Public Library of Science (PLOS) and the publication during that year of more than 30,000 articles in two MDPI journals, they observed that publishers have embraced these critical issues "like never before."[2] Given this enormous and growing volume, one might reasonably wonder why more librarians are not actively involved in climate change centers and institutes simply to help researchers navigate the flood of published output from the various disciplines seeking to address this wicked problem. Some researchers whom I interviewed in this project did say that they would welcome specialized help in finding the publications most relevant to their work when preparing literature reviews for grant applications.

However, most of these researchers expressed comfort with the search and discovery tools available to them and went on to identify other kinds of specialized support that they would appreciate. The most frequently mentioned areas were need for help in (a) broadening the disciplinary range, (b) deepening their engagement with the public, and (c) extending the data analysis capabilities of their centers or institutes. By focusing on these three dimensions of climate change research, there is an opportunity for research libraries to take advantage of the concentration of activity in research centers and institutes. There, they could readily—and more efficiently than working with individuals in their departments—apply and refine the research support skills and services that they have been developing over the last several decades, and do so in ways that could measurably help their research colleagues and their universities to accelerate work on what has become a grave public emergency. In this chapter, I offer considerations for how research libraries could best seize this opportunity in each of those three areas: interdisciplinarity, public engagement, and data analysis.

Interdisciplinarity

As I have already noted, knowledge regularly advances when researchers work fruitfully together at or across the edges of their areas of expertise. One of the primary purposes of research centers and institutes is to foster such working relationships. However, scholarly collaborations are difficult both to foster and to maintain. Personalities can clash; power struggles can emerge; organizational design can hamper interaction; and conceptual differences can interfere with communication.[3] These and other difficulties have prompted philosophers, historians of science, and sociologists to focus study on collaboration itself, producing handbooks on interdisciplinarity and its practice and creating a field that some call the Science of Team Science.[4]

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2 Clarke & Esposito 2022.
3 See, for example, Hackett 2005 and Parker and Hackett 2012
4 See Frodeman, ed. 2017; Bozeman 2017; Hall, Vogel, and Croyle, eds. 2019.

From this work have emerged various typologies of interdisciplinarity.[5] For purposes of this discussion, I rely on a common, three-part classification that distinguishes interdisciplinarity from multidisciplinarity and transdisciplinarity. The key factor separating these categories is the degree to which participating researchers from two or more disciplines seek to integrate their work. In interdisciplinary research, researchers from two or more separate fields of study address a common problem by integrating data, tools, and/or conceptual approaches to accomplish results that they could not achieve working separately.

In multidisciplinary work, according to this three-part classification, researchers do not seek such a level of integration. Instead, they coordinate their work on different aspects of a common research problem and merely juxtapose their theoretical and methodological approaches as well as their results. Researchers engaged in transdisciplinary research surpass the kind of integration achieved in interdisciplinary collaborations, achieving new conceptions and approaches that transcend their disciplinary origins.

It is tempting to array these types of interdisciplinarity in stages as an evolutionary or developmental model. In the early 1970s, Jean Piaget, the famed child psychologist, was among the first to take this position. He argued that the juxtaposition of concepts in multidisciplinary work is a prerequisite to attempts at integration in interdisciplinarity, which in turn is required for the kinds of syntheses achieved in transdisciplinarity.[6] Despite the apparent logic of this developmental model, the ability of researchers to achieve different levels of conceptual and methodological integration and synthesis across disciplines appears to rely less on a staged progression from one type of interdisciplinarity to another than to the interplay of a variety of other factors. [7]

Not the least of these other variables is the intellectual proximity of the fields of study in a research collaboration. The closer their fields are conceptually and methodologically to one another, the more likely it is that researchers will achieve the integration and synthesis needed to establish new fields and approaches.[8] Notable recent examples include advances in closely related subfields of biology and chemistry. Similarly, the emergence of American studies and foreign area studies resulted from work among scholars in closely related subfields of language, literature, and history.

But consider some of the thorniest problems in climate research. For example, what is the best way for a particular community to work with a local employer to stop spewing polluting gases into the air? Or what can the states

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5 Klein 2017. See also See Hall, Vogel, Stipelman, *et al.* 2012; Boix Mansilla 2017; and O'Rouke, Crowley, *et al.* 2019.
6 Piaget 1972.
7 Pohl, Truffer, and Hirsch-Hadorn 2017
8 See, for example, Thorén and Persson 2013: 341-342; Andersen 2016; and Pederson 2016.

in a region that is regularly plagued year after year by disastrous wildfires or hurricanes do together to adapt most effectively to the threat of further catastrophes? Given the urgency of these problems, researchers with the scientific, social, and cultural expertise to address these aspects of climate change must find ways to work together. However, these disciplines span a considerable conceptual and methodological distance. Expecting specialists in these fields to achieve the levels of integration that define transdisciplinarity is almost certainly to prove both ineffective and counterproductive.

Indeed, a common complaint of researchers focused on complex problems is that they feel considerable pressure to achieve transdisciplinary syntheses and are, as a result, regularly subject to disciplinary imperialism and capture.[9] Because the negotiations required to achieve shared conceptions and methods are so difficult and time-consuming, one member of the team—often the STEM party with the most funding—almost invariably tries to insist that "we will collaborate just fine if you all simply abandon your approaches to the critical problem at hand and adopt mine." The frequency of this kind of negative outcome has led some observers to conclude that the emphasis on transdisciplinary integration, especially in climate change research, sets expectations far too high.

Among these critics are the Swedish philosopher of science, Henrik Thorén, and his colleagues, who start their analysis of interdisciplinary collaborations with the recognition that "the conceptual or theoretical integration of distant or rigid disciplines is unlikely."[10] They go on to argue that researchers—and their universities and funders--need to be much more pluralistic in the forms of interdisciplinarity that they seek and support. Especially in wicked problem research, they should not overlook the critical importance of multi- and inter-disciplinarity.

According to Thorén and his colleagues, the key driver in any form of interaction across disciplinary boundaries is the extent to which researchers succeed in "problem feeding."[11] That is, fruitful collaborations depend on the ability of researchers to take a problem that they cannot fully address in their own discipline and formulate it so that collaborators in other disciplines recognize and accept it as addressable within the scope of their fields. The levels of conceptual and methodological integration that collaborators actually achieve depends, in turn, on disciplinary proximity as well as still other factors such as the personal compatibility and relative status of the researchers as well as the design of other aspects of their working environment including the information infrastructure.

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9 See Brister 2016, Persson, Hornborg, *et al.* 2018, Green and Anderson 2019: 733-736; Schipper, Dubash, and Mulugetta 2021: 3-5

10 Thorén and Persson 2013: 342. See also Pederson 2016:3

11 Thorén and Persson 2011, 2013; Thorén, Persson, and Olsson 2021.

In university centers and institutes devoted to climate change research, there are at least two ways that liaison librarians and other university information experts could enhance the information infrastructure of centers and institutes and thereby accelerate wicked problem research across the disciplines in the sciences, social sciences, and humanities. First, with help from library metadata specialists, library liaisons could assist researchers in the conceptual translations needed to facilitate problem-feeding.[12] Metadata experts specialize in developing and applying controlled vocabularies to describe the subject matter of specific fields of study. Drawing on these structures, they can help climate change researchers to create bridges or crosswalks—the lingua francas—needed for researchers to share how they formulate and address problems in disciplines that are both close to and distant from one another. In this process, librarians may also learn how to refine, repair, and perhaps even reimagine their metadata structures.

Second, as we have seen, librarians have developed considerable technical skills in the emerging networked environment. These skills apply to the full range of data types—textual, audiovisual, spatial, and numerical—on which researchers rely, and include text mining, imaging, visualization, mapping and geolocation, and statistical methods. By bringing these kinds of information expertise to university centers and institutes focused on climate change, they can further help researchers from a variety of different disciplines to understand and feed problems to one another and learn how best to integrate the methodological approaches they each take in grappling together with aspects of this wicked problem.

Public engagement

In 1995, Ernest Boyer, then president of the Carnegie Foundation for the Advancement of Teaching, addressed the American Academy of Arts and Sciences. He called on the Academy to support a "scholarship of engagement" that would "connect the rich resources of the university to our most pressing social, civic, ethical problems."[13] Boyer does not specifically mention wicked problems like climate change. However, his call is consistent with the recognition that such problems require research collaborations that span the sciences, social sciences, and humanities, and extend beyond to engage the modes of knowledge embedded in communities outside the academy.

Boyer understood that asking universities to support engagement would challenge their traditional three-part mission of research, teaching, and civic service. He thought of public engagement as an extension of—and on par with—research and teaching, but worried that universities would treat this category of scholarly work rather dismissively as a kind of service, especially for purposes of promotion and tenure. Too often, he wrote in an earlier

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[12] See, for example, Carlson and Kneale 2011: 169; Knapp 2012: 208-209; and Brown and Tucker 2013: 206.
[13] Boyer 1996:32.

essay entitled *Scholarship Reconsidered*, "service means not doing scholarship but doing good," like serving on committees, advising student clubs, or participating in town councils. However, engaging the public in advancing knowledge deserves recognition as "serious, demanding work, requiring the rigor—and the accountability—traditionally associated with research."[14]

In the decades since Boyer's call, many universities have recognized the need for greater public engagement and taken steps to encourage various kinds of collaborations between researchers and members of local communities. The Association of Public & Land Grant Universities has been especially attentive to this topic, issuing a series of reports on how its members could more effectively support what it calls "public impact research."[15] Some institutions, like Columbia University, have gone so far as to contemplate community-engaged scholarship as a "fourth purpose" that "expands and strengthens," but does not supplant, the commitment of higher education to its traditional three goals of research, teaching, and civic service.[16]

However, the support efforts at both public and private research universities have generally fallen short, consigning engagement to the category of service rather than giving it the credit in promotion and tenure reviews that Boyer thought it deserved. According to a 2021 study sponsored by the Academy of Community Engagement Scholarship (ACES), one of the culprits in this failure has been the "definitional anarchy" surrounding the term "engagement." Since Boyer first called for increased emphasis, the relationships between researchers and external partners and stakeholders have varied "along a continuum of engagement from doing 'to' and 'for' communities to engaging 'in' and 'with' communities."[17]

The value of the ACES' study is that its authors weighed in on the definitional debate and tried to pinpoint the form of scholarly engagement most deserving of institutional recognition and credit. After evaluating the alternative definitions, they concluded that:

> engagement, in its strongest and most authentic form, is built on reciprocal, mutually beneficial relationships between members within and outside of the academy. In this form of engagement, there is shared authority and a co-creation of goals and outcomes.[18]

When properly "engaged," researchers recognize the value of different, usually practical or indigenous, modes of knowledge, and they treat the individuals in the communities bearing such knowledge, not as objects of

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[14] Boyer 1990:22.

[15] Association of Public & Land Grant Universities 2019; see also Aurbach, Kennedy, *et al.* 2023.

[16] Katznelson 2020: 21.

[17] Blanchard and Furco 2021: 19

[18] *Ibid.*

study or consultation, but as participants who help determine what to study and how.

For climate change research, the scholars whom I consulted in this project identified the following types of publics with whom they and others were actively engaged:

- Local residents in urban or suburban neighborhoods, rural areas, or tribal reservations with deep understanding of the local history of climate change, its effects, and efforts to address it;
- Underrepresented communities directly harmed by climate change or the emissions or pollutants that contribute to it;
- Owners or custodians of monuments, museums, records, and other cultural heritage endangered by the effects of climate change;
- Government agencies charged with regulating the causes of climate change or promoting efforts to mitigate it; and
- Industry partners seeking to control emissions or otherwise address climate change;

The serious, demanding nature of respectful, mutually beneficial engagements with these kinds of communities deserves not just credit, but other kinds of support from research universities. Research libraries have recognized that they can and should be helpful in the engagement process, especially in providing information expertise.[19] But how?

For researchers in climate change centers and institutes, engaging productively with local, practical, and indigenous modes of knowledge is a kind of interdisciplinarity. The information requirements for conceptual translation and methodological integration that the library liaison can help meet for public engagement are correspondingly similar. However, the conflicts in conceptual definitions and methodological approaches that need to be bridged across a variety of academic disciplines and community-based modes of knowledge may be even more complicated, and time-consuming to resolve than those across academic disciplines.

The differences typically turn on how members of local communities experience the climate problem. These experiences can vary widely depending on individual and shared knowledge of local ecologies, the cultural meanings they attach to natural phenomena, and the racial and gender inequities as well as the power and economic differentials that make communities more or less vulnerable to climate changes.[20] As the Nobel Prize-winning political economist, Elinor Ostrom, and her colleagues proved

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19 Ruttenberg, Taylor, *et al.* 2022.

20 Some useful entry points to the large and growing literature on this set of issues include: Whyte, Brewer, and Johnson 2016; Beaulieu, Breton, and Brousselle 2018; Goldman, Turner, and Daly 2018; Nightingale, Eriksen, *et al.* 2020; Kashwan, Mudaliar, *et al.* 2021; and Schipper, Dubash, and Mulugetta 2021;

time and again in their rigorous engagements with local communities around the world, these variations expose many academic models of human interactions with the biosphere as too simplistic and therefore untrustworthy to local publics.[21]

To help build trust between researchers in climate change centers and institutes and collaborators in local communities, library liaisons can bring expertise in visualization and other forms of data representation to make academic models of climate change more easily accessible to local communities.[22] Liaisons can also bring to bear the growing expertise of librarians and archivists with community-based archives to help local communities create, manage, and preserve their own repositories of climate related-knowledge.[23] But these kinds of support for publicly engaged scholarship, may not be enough.

The ambiguity in the meaning of publicly engaged scholarship means that not all scholars adhere to the principles of reciprocity and mutual respect in the process of engagement. In the interviews I conducted, I heard numerous examples of "carpetbagging" scholars who swoop in on a hard-won relationship, take what they need to check the box of "engagement" from a meeting or two, leaving members of the local community to question the trust they thought they had previously established with academic researchers. Information experts must be invested in the relationships between researchers and local communities and help guard carefully against these and other abuses of trust.

Data Analysis

Over more than a century and a half, researchers have constructed what science historian Paul Edwards has described as a "vast machine" of data and interpretive models to help us understand the interactions between climatic systems and human and other biological systems. The data on which these models are based are typically well-structured, numeric observations gathered from an increasingly sophisticated combination of sensors deployed in the atmosphere, in oceans, rivers, and lakes, and on land, including in local neighborhoods.[24] However, as we have seen, the wickedness of climate change means that models relying on these kinds of data tell only part of the story.

Interdisciplinary collaborations and community engagements in climate and other kinds of complex investigations have forced researchers, often reluctantly, to extend the meaning of "data" to include other kinds of relevant sources, many of which are heterogenous, unstructured, and require

21 See, for example, Ostrom, Janssen, and Anderies 2007.
22 Examples from which librarians might draw inspiration include Euskirchen, Timm, *et al.* 2020 and Kibria, Seekamp, *et al.* 2024
23 See, for example, Caswell, Harter and Jules 2017; Welland and Cossham 2019; O'Quinn 2022
24 Edwards 2010; See also Lin, Quian, Bluestein, *et al.* 2022.

specialized methods to collect, represent, analyze, and interpret. Among these other sources are texts and other written records; interviews, oral histories, and other audio formats; as well as maps and still and moving images.[25] For purposes of this discussion, I will use data in its wider sense to cover the broad variety of evidentiary sources.

The information infrastructure in universities to support climate researchers in their collection and use of these data is still emergent, with some areas more developed than others. Campus-wide, the beginning and end of the research workflow are perhaps the most well supported. Researchers in climate centers and institutes can readily avail themselves of this support. Librarians, usually working with specialists in campus computing organizations and university research offices, have become increasingly adept in helping investigators at the start of the research process to develop data management plans as required by funders in grant applications. At the other end, once a project is complete, they also assist researchers in depositing data in institutional, disciplinary-based, or community-based repositories as appropriate.[26] Sophisticated regional, national, and international networks of information specialists, such as the Research Data Alliance and the Data Curation Network, have arisen to provide further support in both data planning and ensuring that deposited data meet certain standards, such as those that embody the principles of **F**indability, **A**ccessibility, **I**nteroperability, and **R**eusability, or **FAIR**.[27]

University information infrastructure is much less mature in support of the other parts of the research process. Demand is high and growing among researchers across disciplines for support in data collection, including digitization of written, printed, and other analog materials; data cleaning and normalization; the use of natural language processing, statistical algorithms, visualization tools, and other analytical techniques; and storage and computational resources to undertake these processes. In response, many universities are either relying on libraries and campus computing organizations or standing up separate data support services.

These providers have begun to introduce training programs, often partnering with the data carpentries and similar external services. They are also experimenting with ways to offer one-on-one consultations with those who have complicated or highly specialized research data needs. However, as with many early-stage startups, these efforts tend to be poorly coordinated

[25] Gandomi and Haider 2015 assert that 95 percent of so-called "big data" are sources in unstructured formats. Scholars in the humanities disciplines have centuries of experience in analyzing and interpreting these kinds of sources but are especially reluctant to characterize them as "data." Some see such a classification as reductionist and a form of disciplinary imperialism from the sciences. See, for example, Posner 2015, Thoegersen 2018, and Ruediger and MacDougall 2023.

[26] Tenopir, Kaufman, *et al*. 2019. See also Borgman and Bourne 2022.

[27] Berman and Crosas 2020; Johnston, Carlson, *et al*. 2018; Nitecki and Alter 2021; and FAIRsharing.org n.d.

and difficult for researchers to find and use. The providers are still learning how to organize among themselves and implement more efficient, tiered models of support. Standard, best practice for customer service, these models would provide a single point of contact that immediately offers help for those researchers with relatively simple and frequently asked questions while referring those with more complicated requests to a pool of dedicated information specialists.[28]

Frustrated in this emergent environment, researchers are generally on their own to navigate data management and use issues, or they rely on their graduate students for help. Many of the climate researchers that I interviewed in this project complained that the lack of professional help weakened their research and led to reproducibility problems. One even admitted that he had difficulty reproducing the results reported in his own Ph.D. dissertation.

For climate researchers, participation in standard, university-supported centers and institutes does not necessarily help. Some centers and institutes may have obtained grant support to hire a data specialist or two, and a few, like Columbia's Center for International Earth Science Information Network (CIESIN), are focused entirely on data issues.[29] However, my interviews indicate that climate research centers and institutes are generally unable to offer support for the research process of individual researchers. Rather than a liability, could this lack of support represent an institutional opportunity?

Climate change centers and institutes concentrate researchers across disciplines around a complex, wicked problem. As discussed earlier in this chapter, information specialists could offer researchers in these centers and institutes much needed help in dealing with the issues of conceptual translation, methodological integration, and value alignment, which are associated with interdisciplinarity and community engagement. How researchers resolve these issues is also fundamental to how they collect, represent, and use data, and to whether those data are findable, accessible, interoperable, and reusable (or FAIR) to other researchers.

Because a problem-oriented concentration of researchers in a center or institute suggests that they likely share interests in certain data types (text, numerical, spatial, audio, and visual) and in methods for analysis, there is a corresponding opportunity for librarians and other information specialists to concentrate their expertise in such a place. With a concentration of both

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[28] The ACCESS program, which is funded by the National Science Foundation, seeks to connect researchers to network-based high performance computing (HPC) and related advisory services. It provides a good example of a tiered model of support. See National Science Foundation, n.d. For more information on the data carpentries, see The Carpentries, n.d. For recent overviews of data support services in research universities, see Radecki and Springer 2020; Ruedeger, Atwood, *et al.* 2021; and Oliver, Rios, *et al.* 2024.

[29] Columbia Climate School n.d.

research demand and information expertise, these specialists could help their universities avoid costly, one-off data management support structures. Instead, while contributing to research on the wicked problem of climate change, they can use the center or institute to build, test, and harden an efficient and cost effective local infrastructure of tools, methods, and support for researchers and their data management needs, more generally. In addition, they can use the center or institute as a platform for introducing and learning how to support new technologies, such as generative artificial intelligence, in places that, unlike departments, reach across researchers in multiple fields and publics.

CONCLUSION

In *Steps to an Ecology of Mind*, the philosopher and anthropologist, Gregory Bateson explored the multiple dimensions of the relationship between human society and culture and the environment. He recognized the centrality of the physical and biological laws established by the "hard sciences." However, he insisted that these "fundamentals" are not enough to fully comprehend the relationship. He envisioned and tried to embody in his own work a different, more wholistic kind of research practice with the capacity to embrace, simultaneously, the significance of both entropy—the fundamentals like the laws of thermodynamics—and sacrament—the human context of social organization and cultural meaning attached to those laws.[1]

In this report, I began by outlining, mainly from the perspective of the hard sciences, the human causes that are making the world hotter, disrupting the earth's atmosphere and oceans, and creating an increasingly alarming climate emergency that will dominate this, the environmental century. Human society may be able to mitigate the impending dangers that these climate changes portend, but it will certainly need to adapt to a world that is physically, politically, and culturally more uncertain. This array of interrelated uncertainties makes climate change not a simple problem to solve, but a "wicked" one that can only be addressed with a capacious ability to range, as Bateson observed, from a grasp of entropy to an understanding of sacrament.

With their faculties in a wide array of disciplines, and their sensitivity to the public interest in problems like climate change, research universities have this much-needed capacity built into their very structure. They are knowledge factories with the range of scientific, social, and cultural expertise to understand and address climate change. However, as we have seen, their abilities to deploy these resources to address the full complexity of wicked problems is imperfect and in need of reforms, which some institutions have already begun to undertake.

Many other observers of higher education have also called for substantial change in the ways that universities address climate change and other pressing wicked problems. Earlier, for example, I referred to the work of Michael Crow, the president of Arizona State University, who called for a "Fifth Wave" of universities. Another is Philip Lewis, former dean of the Cornell University College of Arts and Sciences, and a former vice president of the Andrew W. Mellon Foundation. In his closely argued and eloquent case for change, Lewis calls on "the Public Humanities—a coalition of the arts, traditional humanities, and social sciences—[to] press the University

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1 Bateson 1972: xv-xxvi.

toward what I choose to term a reformation"[2] Here, in this report, I have identified yet another, but complementary, locus of reform in the organizational and informational dimensions of the university research infrastructure.

Over the last several decades, digitization and digital networks have deeply penetrated and substantially altered the information environment for academic researchers. To meet the demands of this new and evolving world and thereby provide more effective support for faculty research, libraries have been cultivating new forms of staff expertise and reorganizing their service offerings. In ways that are often not fully recognized in their own institutions, libraries have shifted their primary focus from building local collections to helping faculty and students gather from the network and use whatever physical and digital materials they need for research and learning as they need them. One limitation of these developments is that research libraries and other information experts on campus have aimed their skills and services primarily at faculty in their departments.

Universities can concentrate the attention of their researchers on wicked problems like climate change by sponsoring what I have called "standard" research centers and institutes. My thesis in this report is that research librarians and other information specialists could meaningfully advance climate change research by focusing their expertise on the activities in these centers and institutes. I have further suggested that libraries should especially consider supporting the information needs of climate researchers in ways that would (a) broaden the disciplinary range, (b) deepen the public engagement, and (c) extend the data analysis capabilities in these centers and institutes.

Would these organizational and service changes that I have proposed deep in the information infrastructure of the research university achieve the broader reforms for which Lewis and others have called and help meet the climate emergency that the nation and the world face? To this critical question, I can think of no better response than to quote what Lewis writes in his own closing argument:

> [T]he possibilities for stimulating resilience in the face of harmful [climate] change are real and lie clearly within the purview of the institution's research mission. In the same vein, the possibility of lessening the intensity and extent of suffering by humans and other living beings is a worthy motive for research and reflection in essentially all academic fields. Accordingly, even if a full-blown project with global reach is not feasible, I submit that the University should still heed the urgent call and move as far and as fast as it can.[3]

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[2] Lewis 2024: 204.
[3] *Ibid.*: 206-207.

APPENDIX A: INTERVIEWS

Maggie Allan, Collaborative Research Manager, Graham Sustainability Institute, University of Michigan, August 10, 2023

Elyse L. Aurbach, APLU Civic Science Fellow; Director, Public Engagement and Research Impacts, Office for the Vice President for Research, University of Michigan, December 6, 2023

Brad Bottoms, Data Scientist, Center for Social Solutions, University of Michigan, August 31, 2023

Lisa Carter, University Librarian and Dean of Libraries, University of Michigan Library; Professor of Information, School of Information, University of Michigan, October 4, 2023

Robert S. Chen, Director and Senior Research Scientist, Center for International Earth Science Information Network, Columbia University, October 5, 2023

Steven Allen Cohen, Senior Vice Dean of Columbia's School of Professional Studies; Professor in the Practice of Public Affairs; Principle Investigator of the Research Program on Sustainability Policy and Management, Columbia University, August 7, 2023

Andrew Creamer, Science Data Specialist, University Library, Brown University, March 31, 2023

Bruce Crevensten, Technical Lead, International Artic Research Center, University of Alaska Fairbanks, November 8, 2023

Alexander M. de Sherbinin, Deputy Director and Senior Research Scientist, Center for International Earth Science Information Network, Columbia University, September 21, 2023

Neil Donahue, Thomas Lord Professor, Chemical Engineering, Chemistry, Engineering and Public Policy; Director, Steinbrenner Institute for Environmental Education and Research, Carnegie Mellon University, November, 2023, November 28, 2023

Robert Dunn, Senior Vice Provost for University Interdisciplinary Programs; William Neal Reynolds Distinguished Professorship, Department of Applied Ecology, North Carolina State University, August 28, 2023

Emily Ferrier, Social Sciences and Entrepreneurship Librarian, University Library, Brown University, March 31, 2023

Liam Forbes, Manager, Research Computing Systems, Geophysical Institute, University of Alaska Fairbanks, November 8, 2023

Sheila R. Foster, Visiting Professor of Climate, Climate School, Columbia University, October 26, 2023

Scott Frickel, Professor of Environment and Society & Sociology, Brown University, March 23, 2023

Cari Furiness, Assistant University Director, Southeast Climate Adaptation Science Center; Research Associate, Department of Applied Ecology, North Carolina State University, September 26, 2023

Kelly Sims Gallagher, Professor of Energy and Environmental Policy, Director, Center for International Environmental & Resource Policy, Tufts University, March 6, 2023

Dr. Emily Griffith, Associate Professor of the Practice, Statistics; Director of Consulting, Data Science Academy, North Carolina State University, September 12, 2023

Alex N. Halliday, Founding Dean, Climate School; Director, Earth Institute, Columbia University, September 13, 2023

Dianne Harris, Professor of History; Dean of the College of Arts & Sciences, University of Washington, January 20, 2023

Meredith Hastings, Professor of Environment and Society & Earth, Environmental and Planetary Sciences; Deputy Director, Institute at Brown for Environment and Society, Brown University, March 2, 2023

Jennifer Haverkamp, Director, Graham Sustainability Institute, University of Michigan, August 2, 2023

Drew Horning, Managing Director, Graham Sustainability Institute, University of Michigan, August 7, 2023

Susan Ivey, Director, Research Facilitation Service, North Carolina State University, August 23, 2023

Kerstin A. Lehnert, Doherty Senior Research Scientist, Lamont-Doherty Earth Observatory, Columbia University, September 22, 2023

Earl Lewis, Thomas C. Holt Distinguished University Professor, History, Afroamerican and African Studies, and Public Policy; Director and Founder, Center for Social Solutions; •University of Michigan, August 23, 2023

Dr. Amy Lauren Lovecraft, Professor, Political Science; Director, Center for Arctic Policy Studies, University of Alaska Fairbanks, November 16, 2023

Joseph Meisel, Joukowsky Family University Librarian and Adjunct Associate Professor, University Library, Brown University, March 30, 2023

Matthew Margetta, Managing Director, the Institute at Brown for Environment and Society (IBES), Brown University, March 2, 2023

Sarah Mills, Senior Research Area Specialist and Intermittent Lecturer in Program for the Environment, School for Environment and Sustainability; Director, Center for EmPowering Communities, Graham Sustainability Institute, University of Michigan, August 16, 2023

Heidi Nicholls, Mellon Black Beyond Data Postdoctoral Fellow, Hohns Hopkins University, April 17, 2017

Robert O'Connor, Program Director, Decision, Risk and Management Sciences, National Science Foundation, February 8, 2023

James O'Donnell, University Librarian, Arizona State University, March 10, 2023

Alexa L. Pearce, Associate University Librarian for Research, University Library, University of Michigan, October 16, 2023

Casey Pickett, Project Director, Yale Planetary Solutions Project, Yale University, February 22 and March 10, 2023

Greg Raschke, Senior Vice Provost and Director, University Libraries, University of North Carolina, August 10, 2023

T. Scott Rupp, Professor, Forestry; Deputy Director, International Arctic Research Center; University Director, Alaska Climate Adaptation Science Center; University Alaska Fairbanks, October 26, 2023

Erin Seekamp, Goodnight Distinguished Professor, College of Natural Resources; Director, Coastal Resilience and Sustainability Initiative, North Carolina State University, August 25, 2023

Rachel Sperling, Librarian for Environmental Studies, Yale University, June 1, 2023

Ann Thornton, Vice Provost and University Librarian, University Libraries, Columbia University June 21 and October 13, 2023

Parth Vaishnav, Assistant Professor, School for Environment and Sustainability, University of Michigan, August 16, 2023

Keith Webster, Dean, University Libraries, Carnegie Mellon University, April 3, 2023

Dave White, Director, Global Institute of Sustainability and Innovation, Arizona State University, March 7, 2023

Professor Daniel A. Zarrilli, Special Advisor for Climate and Sustainability, Climate School; Adjunct Professor, International and Public Affairs, Columbia University, November 10, 2023

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