5 Confronting the Anthropocene: Reflexive Repair in an Age of Global Infrastructures

Why Aren't You a Farmer?

Have you ever stopped and asked yourself, "Why am I not a farmer?" Or maybe you are a farmer, and you wonder why you do not have more colleagues. While there are still areas of the world where farming is the predominant livelihood, especially in Asia, where China and India alone account for more than half of the world's farms, the process of industrialization led to a sharp decline in the overall proportion of farmers in most Western countries through the twentieth century.[1] The numbers are extreme in the case of US agriculture, where about 90 percent of the working population was engaged in farming in 1790, just after the establishment of the new American state. Fast-forward to the twenty-first century, when fewer than 2 percent of US workers are primarily employed in farming, a downward trend with profound implications.[2]

What does it take for a nation to move from a set of sociotechnical structures where nearly everyone is growing food to another set where only a small fraction are doing that work, all in just two hundred years? Questions like these motivate this concluding chapter, where we examine the global reach of infrastructures and the repair challenges humans face after having engineered sociotechnical systems across every region of the Earth. Your identity as a farmer (or not) plays a small but important part in a larger set of trends that have important consequences for the future of human life, the role of infrastructures in that future, and the choices that we make about repairing them. If that seems overstated, consider the role of sociotechnical systems in the story of why you are not a farmer and how the methods and structures for food production and consumption connect to global challenges such as food insecurity and climate change.

Urbanization, an increasingly complex division of labor, and technological innovation are the factors most commonly cited when explaining this set of changes. But as fewer farmers produced more and more food, those remaining worked in tandem with financiers, agricultural scientists, and consumers to develop new institutions and systems that formed the backbone of industrialized agriculture. Major crops like wheat, corn, and soy were standardized and became interchangeable commodities, processed into all kinds of packaged foods found in contemporary grocery stores. Consumers, for their part, largely delegated both food production and preparation to multinational food corporations and developed new tastes and dietary practices (or at least acquiesced to the new system).[3] In line with the themes we explored in the previous chapter, the infrastructural state also cultivated the growth of expert systems of knowledge that played a critical role in developing the industrial food system. In the United States, both the Department of Agriculture and the land-grant university system were established and grew in the scope of their influence through the second half of the nineteenth century and into the twentieth. Intended to support the development of the nation's research and development capacity around agricultural production, these institutions spurred the growth of new scientific fields devoted to animal and plant breeding, agricultural engineering, and the extension and application of this knowledge to specific farm communities.[4]

In sum, industrial food systems are yet another example of a complex infrastructural system: a tangle of people, technologies, and institutions, interconnected with other critical infrastructures, such as transportation and communication networks, and embedded in deep structures of power and difference. This set of infrastructures allows US farmers to produce food on a massive scale—contributing nearly $1 trillion to the nation's gross domestic product in 2015 and based in land use that accounts for roughly half of all US land area.[5] At the same time, important trade-offs are associated with this system. First, it prioritizes foods processed from the commodity crops that are grown on the largest scales and contributes to the negative health consequences associated with the Western diet, such as heart disease and diabetes. These diseases disproportionately affect communities of color and low-income consumers, who are more likely to live in one of the 15.6 million US households that the US Department of Agriculture has designated as food insecure, or lacking "consistent, dependable access to enough food for active, healthy living."[6]

Second, in addition to the impacts on human health and inequities in who gets to eat healthy and accessible food, there are enormous environmental consequences attributable to an infrastructure that uses land and resources on this scale. Water used for agricultural purposes or running off agricultural land after storms is the largest known cause of nonpoint water pollution in the United States.[7] US agriculture also has global environmental impacts, especially through its contributions to climate change. Nine percent of all US greenhouse gas emissions come directly from the agricultural sector in the form of livestock "emissions" and crop cultivation practices. These direct sources of greenhouse gases do not include the indirect yet significant emissions due to food-related transportation, processing, preparation, and waste. In turn, farmers around the world are already facing the impacts of climate change through more variable climate and weather, especially extreme droughts and storms.[8] As climate change presents increasingly severe impacts through the twenty-first century, the future of our food production and its associated infrastructures is called into question: Will this still-young century present humanity with a new age of famine and scarcity?

This question presents a new dimension to our discussion of infrastructural repair, where the global scope and impact of our infrastructures go beyond any one system or region. In the twenty-first century, humanity confronts a kind of infrastructural reckoning: our technical systems for mastery of social and material life have transformed the world, with vast use of energy and resources, changes to global climate, and loss of countless ecosystems and species. This trend has led some scholars to claim that we are living in a new age, the Anthropocene, where our infrastructures have impacts akin to the meteor strikes or tectonic shifts that have caused global-scale environmental change in past epochs. Placing human activity on the same geological scale as asteroids and volcanoes emphasizes the pervasiveness of our influence and the ongoing ways in which infrastructural repair has had a cumulative impact on our environs. As humans have built infrastructures, solved problems with them, advanced and defended interests through them, and created our current infrastructural world, we have largely favored repair strategies that maintain and preserve the material and discursive investments and assumptions embedded in those infrastructures—a strategy of repair as maintenance. As we have emphasized in the past chapters, transformative change is a harder and more contentious mode of repair, and in some cases, it calls for entirely new infrastructures and social arrangements. If we are at a point in human history when maintaining our existing infrastructures might lead to our very extinction, we face a paradox centered on repair: *Can we repair infrastructural repair itself*?[9]

Repairing repair, or what we term *reflexive repair* and define in more detail below, typifies the dilemmas facing humanity in the Anthropocene and is the central topic we address in this concluding chapter. What are the properties of infrastructures that span and reshape the world, and how do we understand the process of repair for systems of this scope? We examine these questions in the context of international efforts to understand and mitigate climate change and movements to develop new ways of thinking about sustainability and infrastructure. Sustainability presumes that some of the same tools that created global infrastructures and their consequences can now reorient technologies, institutions, and discourses toward a greener form of modernity. Again, however, the interdependence of knowledge, practice, and global infrastructures points to the challenges of radically repairing the very systems that have created the conditions for the Anthropocene.

We also examine how repair on a global scale remains importantly connected to repair at other levels. It takes a lot of work to build and maintain infrastructures at this scale, yet this work retains a fundamentally local character. A focus on repair can therefore help us see how social and material systems connect the broadest and the most local scales of analysis. At the same time, examples such as computing networks and environmental monitoring systems show how knowledge about the world, and especially the impact of global changes in the Anthropocene, is tied to the infrastructures that help create and support these knowledge claims—such as environmental monitoring networks that keep track of climate readings around the world.[10] These connections further reinforce the paradox of repair in the Anthropocene: we cannot develop data and theories about "the world" without the very systems that are creating wide-scale change.

Repair, Reflexive Modernity, and Infrastructural Globalism

Our knowledge about the global impacts of infrastructure depends on the existence of global infrastructures, reflecting a self-referential or *reflexive* quality that is common to many sociotechnical systems. While *reflexivity* is

Locating the Anthropocene in Time and Space

Chemist Paul Crutzen and biologist Eugene Stoermer popularized the term *Anthropocene*, which has been more broadly adopted by a wide range of scholars over the past two decades.[1] Geologists propose and accept various segments of time in Earth's history by what they observe in the structure and content of sedimentation. When layers of rock and ice indicate a distinct shift in the composition of life, atmosphere, and climate on Earth, that evidence points to starting and ending dates of major events and very long-term trends in the history of the planet. These signature shifts in geological time are called "golden spikes," and the International Commission on Stratigraphy, which considers and ratifies evidence for the boundaries of geological time, places physical markers in locations around the world where a rock outcropping or ice sheet contains key evidence indicating a transition.[2] Where, either physically or metaphorically, would we drive the golden spike to mark the Anthropocene?

Crutzen, in a 2002 *Nature* article that helped to popularize the term *Anthropocene*, proposed "the late eighteenth century, when analyses of air trapped in polar ice showed the beginning of growing global concentrations of carbon dioxide and methane." Often termed "The Great Acceleration," this candidate for the golden spike emphasizes the impacts of carbon emissions since the Industrial Revolution.[3] Another argument suggests that the explosion of the first atomic bomb, in 1945, and subsequent nuclear bombings and tests, laid down a layer of radioactive fallout that will be evident in the sedimentary record for future researchers (human or otherwise).[4] A third school of thought reaches all the way back to the origins of human agricultural settlements, more than ten thousand years ago, as the time when large-scale transformation of land use and human-induced species and ecosystem loss extended the period of warming after the end of the Pleistocene.[5]

In each of these proposals, the Anthropocene was kick-started through new human sociotechnical systems. Because these systems have been developed over centuries or even millennia, and in widespread locations, debates about precisely where to locate the golden spike marking the start of the Anthropocene prove tricky. But for scientists who are focused on settling this question, one thing is clear: we cannot gather the knowledge needed to drive the Anthropocene's golden spike without more and complex infrastructures. Geographer Erle Ellis and colleagues make this point strongly in an article on the organizational and technological requirements for dating the Anthropocene: "Like the Anthropocene itself, building scientific understanding of the human role in shaping the biosphere requires both sustained effort and leveraging the most powerful social systems and technologies ever developed on this planet."[6]

Locating the Anthropocene in Time and Space (continued)

Infrastructures have helped create the conditions for the Anthropocene, but they also provide a lot of information about how, where, and when anthropogenic global change occurs, raising complex questions about the role of infrastructures and repair in both building and understanding the socio-technical context for this age.

1 Simon L. Lewis and Mark A. Maslin, *The Human Planet: How We Created the Anthropocene* (New Haven: Yale University Press, 2018); Paul J. Crutzen, "Geology of Mankind," *Nature* 415 (January 3, 2002): 23.
2 International Commission on Stratigraphy, "ICS—GSSPs," accessed December 13, 2018, at http://www.stratigraphy.org/index.php/ics-gssps; Stanley C. Finney and Asier Hilario, "GSSPs as International Geostandards and as Global Geoheritage," in *Geoheritage*, ed. Emmanuel Reynard and José Brilha (Amsterdam: Elsevier, 2018), 179–189; Lewis and Maslin, *The Human Planet*.
3 Crutzen, "Geology of Mankind," 23; Will Steffen, Wendy Broadgate, Lisa Deutsch, Owen Gaffney, and Cornelia Ludwig, "The Trajectory of the Anthropocene: The Great Acceleration," *Anthropocene Review* 2, no. 1 (2015): 81–98. Donna Haraway discusses the merits of alternative terms to *Anthropocene*, such as *Capitolocene* and *Chthulucene*. See Donna J. Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Chapel Hill, NC: Duke University Press, 2016), 47–51.
4 Jan Zalasiewicz, Colin N. Waters, Mark Williams, Anthony D. Barnosky, Alejandro Cearreta, Paul Crutzen, Erle Ellis et al., "When Did the Anthropocene Begin? A Mid-Twentieth Century Boundary Level Is Stratigraphically Optimal," *Quaternary International* 383 (2015): 196–203; Colin N. Waters, Jan Zalasiewicz, Colin Summerhayes, Anthony D. Barnosky, Clément Poirier, Agnieszka Gałuszka, Alejandro Cearreta, et al., "The Anthropocene Is Functionally and Stratigraphically Distinct from the Holocene," *Science* 351, no. 6269 (2016): 137.
5 Erle C. Ellis and Navin Ramankutty, "Putting People in the Map: Anthropogenic Biomes of the World," *Frontiers in Ecology and the Environment* 6, no. 8 (2008): 439–447.
6 Erle C. Ellis, Dorian Q. Fuller, Jed O. Kaplan, and Wayne G. Lutters, "Dating the Anthropocene: Towards an Empirical Global History of Human Transformation of the Terrestrial Biosphere," *Elementa: Science of the Anthropocene* 1 (2013): 1.

a contested term with many meanings,[11] it is relevant here in two senses. First, infrastructure systems are reflexive in a causal sense, because they often operate at scales where their impacts on the world play a major role in shaping their own operating environments. For example, they may end up depleting the very resources they need to function or changing consumer behavior in ways that create new demand for infrastructure services.

This leads to feedback loops that can stabilize or destabilize these systems. Second, this causal reflexivity requires reflexive, self-aware thinking from infrastructure engineers, operators, and policymakers: to protect against potentially destabilizing feedback loops, they need to have a well-tuned awareness of the limitations of their knowledge and the potential for unanticipated complexity in even the most carefully designed systems. The increasing need for this reflexive perspective has important implications for the design, repair, and maintenance of sociotechnical systems, and it is closely related to the "broken world thinking" that Steven Jackson sees as driving the current wave of interest in repair.[12] Historically, the emergence of these ways of thinking is tied to a broader crisis of confidence in the modern world, which calls into question many of the original ideals of modernity.

Sociologist Ulrich Beck connects this crisis of confidence with the emergence of what he calls the *risk society*, a global situation that is increasingly dominated by the problem of managing the risks of industrialization rather than its economic benefits.[13] In this new world, Beck argues, social inequalities are increasingly related to the distribution of risk exposure in the population rather than the distribution of the economic benefits of modernization. The risks of industrialization are themselves increasingly complex, difficult to define, and global in their impacts. Beck is particularly concerned with industrial accidents and pollution, using the 1986 Chernobyl nuclear accident and the consequent spread of radioactive contamination across national borders as a key example.[14] Along with sociologist Anthony Giddens and others, Beck describes this new situation, in which the modern world is increasingly focused on problems created by modernity itself, as a new phase of *reflexive modernity*.[15] Others argue that this is less a new phase of modernity than a reemergence of tensions that have always plagued human relationships with nature and technology.[16] Either way, the result has been an increasing global recognition of the limits, impacts, and fragility of modern sociotechnical systems.

Global infrastructures have arguably played a crucial role in the development of reflexive modernity, although this is not a major theme in the work of Beck, Giddens, or others who write about the risk society. Infrastructures have contributed both by creating global risks and enabling global knowledge of those risks. STS scholar Paul Edwards captures this dual impact of infrastructure through the concept of *infrastructural globalism*, the "phenomenon by which 'the world' as a whole is produced and maintained—as both object of knowledge and unified arena of human action—through global infrastructures."[17] In particular, Edwards shows how our ability to conceive of and monitor weather and climate as global phenomena depends on a huge amount of infrastructural work. It requires not just weather stations around the world and communications infrastructures to relay data, but also transnational institutions and scientific networks to work out common concepts and data standards.[18] Before this sociotechnical infrastructure existed, there was little understanding of the evolution of weather systems over time or how they moved across the globe, which made it difficult to conceive of weather or climate as posing global risks. Similar stories of sociotechnical system building can be told about almost all of the global infrastructure systems we rely on today, from the internet to food distribution systems.

Infrastructural globalism is key to understanding reflexive modernity and the risk society for several reasons. Most congruent with Beck's arguments, the development of global infrastructures is part and parcel of the process of industrialization, and infrastructure systems are responsible for many of the pollution risks Beck focuses on. However, at least two other aspects of infrastructural globalism also play a crucial role in the risk society. First, as Edwards argues, global infrastructures and their associated networks of institutions and expertise are prerequisites for any systematic notion of global risk; for example, it is only through global information systems, infrastructures, and organizations dedicated to environmental monitoring that we have any sense of the global risk posed by carbon emissions or nuclear contamination. Second, infrastructures not only create new risks; they place more humans and more complex equipment in new relationships to existing natural hazards and thus in harm's way. This creates new kinds of human vulnerabilities to weather, climate, and geological dangers, quite different from those that preindustrial societies faced. For example, an earthquake might affect a preindustrial community largely through the direct impact of landslides or tsunamis on the human body, but in a modern city, we have to worry about being injured by collapsing bridges or buildings or being cut off from infrastructure networks that connect us to distant sources of crucial supplies like food, water, and medicine. The increasing global spread of infrastructures makes these vulnerabilities a key part of the global risk society.

The hard questions reflexive modernity has raised about sociotechnical systems have led to new ways of understanding and managing those systems. Societal concern about the limits and unintended consequences of sociotechnical systems means that planning and development efforts increasingly focus on repairing existing systems to address limitations and manage unintended consequences. And when new systems are planned, more and more effort goes into anticipating how they could go wrong and building in provisions for mitigation and repair in advance.[19] As a result, concepts like sustainability and resilience are becoming increasingly important in design, planning, and engineering. Overall, these are positive developments toward developing a more productive and manageable relationship between technology and the natural world. This suggests that perhaps we should be asking some of the same potentially productive questions about repair itself.

Repair is certainly not alien to modernity. None of the vast infrastructures that characterize the modern world could have the effect they do without ongoing work to maintain them. By keeping these systems running smoothly and serving human needs, repair—particularly in the mode of repair as maintenance—may also contribute to many of the negative impacts of modernity. Even efforts to transform these systems to make them more resilient or sustainable may have unintended consequences by making them more desirable to use. This does not mean that repair is necessarily a bad thing or that its practitioners should not be recognized and rewarded. Rather, it is the reason that we need a concept of reflexive repair—that is, an approach to repair that considers and plans for the limitations and potential unintended consequences of repair itself. The analytical tools we have presented throughout this book are ultimately aimed at supporting this kind of practice and understanding.

Reflexive Repair and Sustainable Infrastructures: A University Campus Case Study

What does a sustainable infrastructure look like? Is it a contradiction in terms, given the place of infrastructural modernity in the Anthropocene? Sustainability is most often defined in the terms developed by the World Commission on Environment and Development (also commonly referred to as the Brundtland Commission) in 1987: meeting “the needs of the present without compromising the ability of future generations to meet their own needs."[20] This view of sustainability implies a form of reflexive repair, asking the current generation to engage in an honest assessment of their needs and desired quality of life, the resources and impacts associated with those needs, and how those choices affect the ability of future generations to live a comparable existence. Therefore, because infrastructures are such a core means of controlling and employing sociotechnical forces, and infrastructural globalism is centrally implicated in the challenge of the Anthropocene, sustainable infrastructures themselves must be built and repaired to ensure that the needs of the present and the future are balanced in their design and operation. Ideally, the future-oriented reflexivity of sustainability asks us to continually reflect on and repair our lives and the structures that support them and redirect our path away from practices and systems that are unsustainable and foreclose livable futures.

That is the ideal. Environmental studies scholars Kates, Parris, and Leiserowitz note that the Brundtland Commission's definition of sustainability is open to considerable "creative ambiguity" and the potential for a wide range of parties to each "project their interests, hopes, and aspirations onto the banner of sustainable development."[21] In addition, the role of those future generations is underspecified, and the definition could be taken to imply that the main inequities we should worry about are between today and tomorrow, potentially ignoring the already enormous disparities that exist in the present.[22] In the worst-case scenario, sustainability might be used as an umbrella to "greenwash" the very practices and interests that created the context for climate change and other global risks to develop and worsen.[23] However, Kates, Parris, and Leiserowitz also acknowledge that these ambiguities may open up opportunities for "diverse stakeholders and perspectives" to engage in a creative dialogue to facilitate "coordination of mutual action to achieve multiple values simultaneously and even synergistically" around the goal of sustainable development.[24]

Given these potential pitfalls and opportunities, how can we make sense of sustainability as a way of theorizing and achieving reflexive repair? In the remainder of this section, we explore a case study centered on contemporary attempts to make colleges and universities sustainable. Postsecondary education provides a useful test case for sustainable repair efforts, in large part because many universities are making substantial efforts to green their campus operations. In fact, hundreds of institutions of postsecondary education around the world (though predominantly in the United States) have made commitments to international sustainability standards, such as the Association for the Advancement of Sustainability in Higher Education (AASHE) and its Sustainability Tracking, Assessment and Rating System (STARS). STARS provides accounting tools for calculating and accrediting levels of achievement in sustainability. Practically an industry in itself now, a whole tangle of consortiums, each with its own punchy acronyms, support institutions of higher education as they make commitments to reducing carbon emissions, incorporating local and sustainable food, and other key dimensions of campus sustainability.[25]

To consider the promise and challenges of sustainable infrastructures, we share here a case study from the school where Henke works, Colgate University, which opened a new fitness center in 2012.[26] The new center was a big improvement on the old one, which was getting old and, frankly, a bit gross. In addition to its gleaming newness, the fitness center had one additional feature to brag about: it was Colgate's first campus building certified through the US Green Building Council's LEED system of sustainable building practices. LEED certification is an international standard that grades new or renovated buildings according to several metrics, including energy and water efficiency, incorporation of green building materials, and sustainable landscaping around the building.[27] The new fitness center earned a gold rating, which means it is especially green and efficient according to LEED's standards, and Colgate has since committed to seeking LEED certification for all new building projects (see figure 5.1).[28]

According to a well-regarded and widely adopted set of standards, the fitness center is an example of sustainable building. At the same time, the physical footprint of Colgate's campus expanded by fifteen thousand square feet, with a commensurate expansion in energy use and other impacts on the sustainability profile of the institution as a whole. This example is just one building from one institution, but some of the trends and associated questions about sustainability as a form of reflexive repair are well illustrated in this example, especially when we consider Colgate as one among many institutions with commitments to sustainability. As noted above, hundreds of institutions, including Colgate, have signed on to commitments through standards such as AASHE's STARS and LEED. The rapid growth of these efforts points to the potential for higher education to serve

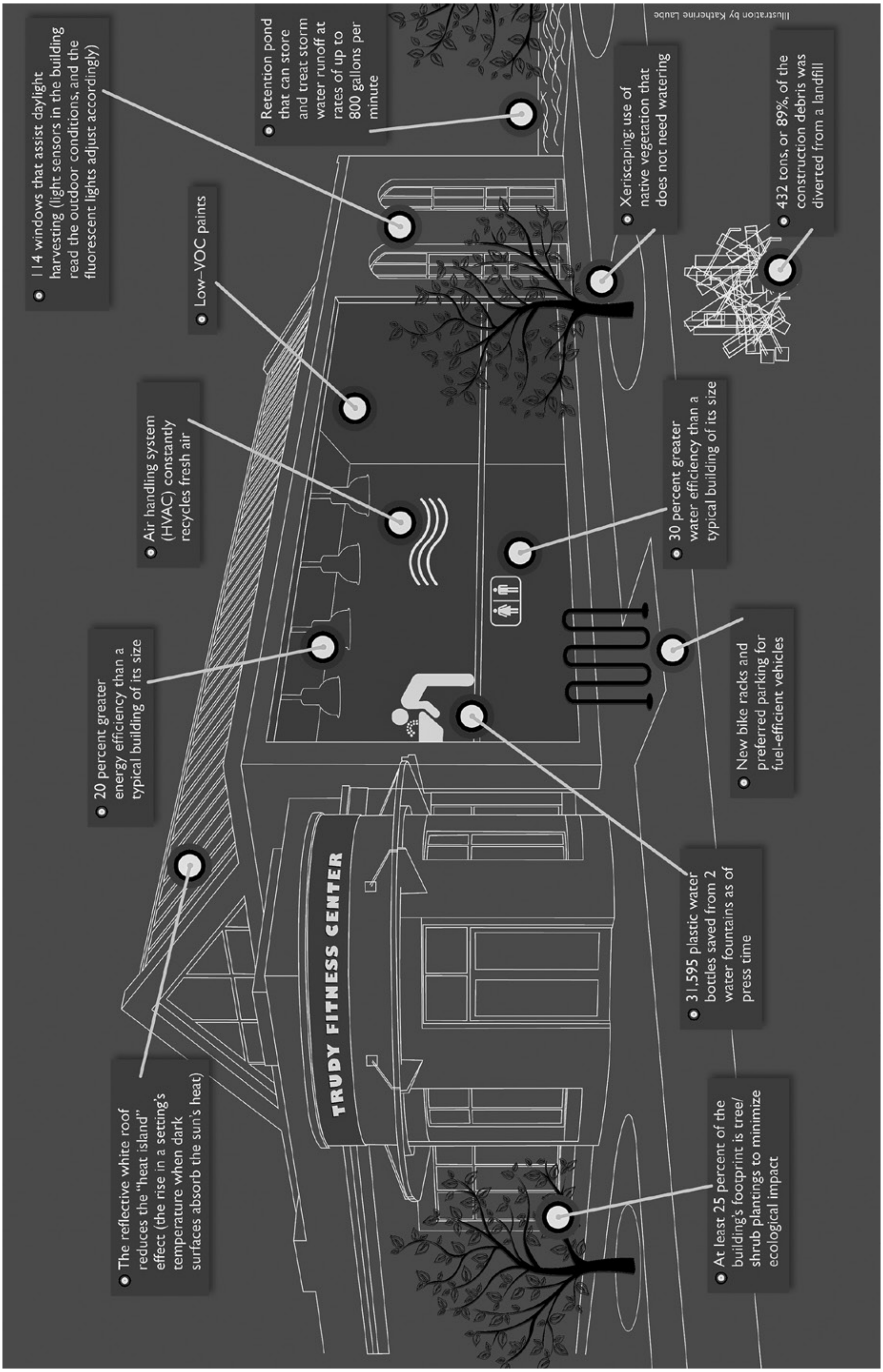

Figure 5.1
This illustration, included in a 2011 article for Colgate's alumni magazine, *Scene*, emphasizes the sustainable features of the fitness center, including elements that helped gain LEED certification for the building. Credit: Katherine Laube, Colgate University.

as a test sector for experimenting with sustainable infrastructures in relation to buildings and grounds, food procurement, travel, and other institutional features that contribute to, or are vulnerable to, climate change and other environmental impacts. While often depicted as slow and stodgy in adapting to new ideas and trends, universities can also be especially flexible institutions given their relatively diffuse administrative structure and the influence of new ideas and movements developed through research and the continual generational turnover of students. Universities must balance revenues and expenses, but the profit motive is less dominant than for corporations, especially public corporations that must answer to investors on a quarterly basis.

At the same time, it is important to consider why Colgate found it necessary to build a new fitness center. In US higher education, campus fitness centers have acquired a kind of symbolic significance in recent years as universities increasingly compete to attract more and better applicants, even while facing criticism over the growth in tuition costs as they add these lavish amenities. The new fitness center certainly is an impressive stop on a prospective student's tour of the campus, and there is a competitive pressure among similar institutions to keep up with the Joneses through new facilities. In this way, universities tend to expand. Although the number of students served might not change, the footprint of the physical campus, the number of employees, and amenities provided may all increase, requiring additional investment and growth. Andrew Ross terms universities a form of "urban growth machine" for this reason, citing the case of New York University as a prominent institutional real estate owner and developer in Manhattan.[29] Higher education is big business and, in many communities, a key source of employment, economic development, and gentrification.

If universities have the potential to be important sites for reflexive repair centered on the goal of long-term sustainability—and yet are also key centers of economic growth—how can we use them to assess the potential for change commensurate with the challenges of the Anthropocene? The distinction between repair as maintenance and repair as transformation can help us assess the scope of potential changes and to what extent those new systems or practices maintain existing structures or reorient them toward a more ambitious conception of sustainability. For example, the easiest and most cost-effective changes for a university seeking to improve its sustainability profile (and often ones that can save a lot of money) are straightforward changes, such as replacing one technology or system with another that is more energy efficient. While a good starting point and an effort that we would certainly not want to discourage, this form of sustainability work is largely repair as maintenance: modest changes to operations may occur, but the essential things that a university does, and the broader political economy of higher education, largely have not changed.

This orientation toward maintenance is embedded in the standards developed by the organizations that accredit sustainability standards. AASHE's STARS system, for example, provides a comprehensive set of sustainability standards for colleges and universities, with indicators for nearly every aspect of campus operations, including carbon emissions, waste, and social sustainability.[30] These standards now essentially define what it means for a campus to be sustainable, providing a score and a symbolic medal (bronze, silver, gold, or platinum) to summarize progress toward green goals. Although helpful for planning sustainability initiatives and tracking progress, the standards may normalize a certain level of sustainability (or lack of sustainability) as being acceptable. Moreover, by making it possible to demonstrate commitment to sustainability by constructing new buildings, green building standards like those from LEED legitimate the continued growth of more elaborate college facilities. Taken as a whole, these elements may tend to encourage modest changes that essentially maintain the status quo.

It is not hard to understand why a standardized approach to sustainability is appealing. A repair-as-maintenance approach can be effective, especially in the short term and when directed toward the lower fruit of institutional change; this work may even result in net economic and environmental savings when energy use, water consumption, and waste are reduced. In addition, STS scholars Geoff Bowker and Susan Leigh Star, whose foundational work we reference in chapter 1, note that standards are increasingly built into the design and structure of our material environments, so perhaps the standardization of repair in specific infrastructural systems, including sustainability planning, should not be surprising.[31]

The maintenance approach to sustainability embedded in some sustainability standards stems in part from a focus on individual institutions, where a boundary is drawn around a specific university and that institution's local systems and infrastructures define the scope and rate of progress. Transformative repair likely means breaking through this boundary and planning sustainability efforts with a broader range of partners, including institutions outside postsecondary education. For example, when planning a new fitness center and other projects that are important to the sustainability of the campus, a university might consider ways to develop partnerships around planning for sustainability and resilience. A project that both supports a local initiative and makes a green impact on a regional or systemic infrastructure helps erase a false line drawn around a campus and encourages sustainability partnerships with an institution's neighborhood and regional communities. In this model of sustainability, the university as growth machine becomes harder to justify, especially as the key question shifts away from, "Is the fitness center LEED certified?" toward, "How does the new fitness center increase the sustainability and resiliency of our broader community?"[32] For instance, by investing in a local reforestation effort, a campus like Colgate could mitigate its carbon footprint and at the same time provide an amenity to support a range of community needs, including ecosystem restoration, protection from flooding and erosion, and the potential to develop new jobs and recreational opportunities.[33] Working cooperatively with other local institutions may also allow colleges and universities with fewer resources to share the costs of this work and address the inequities and injustices that are built into existing infrastructural systems, ideally supporting the long-term success of sustainability efforts for a broader set of participants.[34]

50,000 Metric Tons: A Ground-Level View of Sustainability and Reflexive Repair (Christopher R. Henke)

About 50,000 metric tons: that is our best estimate of how much carbon dioxide and other greenhouse gases my small, rural village contributes annually to global climate change. Hamilton is a college town in central New York State, site of Colgate University, and my home for the past twenty years. Our impact on climate change is small, considering the vast and rapidly warming Earth. And yet in an age of infrastructural globalism, everyone gets pulled into the politics of repair through practices and decisions in everyday life, and I am no exception. I drive a car (and get the oil changed at the repair shop), use a cell phone, and pay taxes to support construction and maintenance of roads, bridges, and many other forms of infrastructure. I contribute my share (or more) of carbon to the atmosphere through my daily interactions with infrastructures, and my community does too. And the impacts of a changing climate are already being felt here, with stronger storms, more extreme flooding

50,000 Metric Tons: A Ground-Level View of Sustainability and Reflexive Repair (continued)

events, and other climate challenges for the agricultural economy at the heart of this region.

The scope of the problem often seems overwhelming. How can one community address a problem so broad in its sources and implications? Over the past decade, I have become increasingly interested in ways to support my university and community in attempts to address the problem of climate change, working with a group of colleagues to form the Hamilton Climate Preparedness Working Group in 2016. The group brings together elected officials, community members, university staff, faculty and students, and others to reduce those 50,000 tons of carbon and prepare for a changing climate and its likely impacts on our region. We never discuss this work in terms of repair and the concepts used in this book, but I often reflect on the practical and existential challenges of making positive strides at the local and systemic levels, where even repair as maintenance is daunting, let alone a more fully transformative repair.

To chip away at those 50,000 tons, our preparedness group talks a lot about infrastructures. Gas lines, light bulbs, recycling bins, charging stations for electric vehicles, and bike lanes are just some of the infrastructural elements central to our conversations and plans. Though I sometimes find all the talking a bit frustrating, I remember at moments like these that infrastructural repair is not just about fixing things but also relationships and negotiation. An approach to reflexive repair that focuses only on technical fixes and eschews conversation misses opportunities to build common discourses and identities around a complex and urgent problem; talk also allows us to listen and learn when we disagree and misunderstand. Terms that are important for our analysis in this book—such as *infrastructural elites*, *experts*, or the *disenfranchised*, highlighted in the previous chapter—become more complex yet tangible when sitting in a meeting and listening to the village mayor, the head of municipal utilities, and community representatives. Indeed, given that considerations of equity and social justice often receive short shrift in climate plans and analysis, communities that do not build these conversations across lines of economic and social difference likely leave out those who may be most vulnerable to the impacts of climate change.[1]

1 Magnus Boström, "A Missing Pillar? Challenges in Theorizing and Practicing Social Sustainability," *Sustainability: Science, Practice, and Policy* 8, no. 1 (2012): 3–14; Chandra Russo and Andrew Pattison, "The Pitfalls and Promises of Climate Action Plans: Transformative Resilience Strategy in U.S. Cities," in *Resilience, Environmental Justice and the City*, ed. Beth Schaefer Caniglia, Manuel Vallée, and Beatrice Frank (New York: Routledge, 2017).

Conclusion: Infrastructural Politics and a Tool Kit for Reflexive Repair

As we draft this final section of the book, infrastructure is a frequent topic in the news. Current US president Donald Trump made infrastructure a key part of his 2016 election campaign, with promises of a spending package to help create jobs and stimulate the economy; a recent US government shutdown was centered around a disputed wall that Trump wants to build along the US-Mexico border. On the Left, there are calls for a Green New Deal, also meant to stimulate economic growth, but eschewing carbon-centered sources of development and focusing on sustainable technology. China, with its rapidly growing economy, dedicates almost 50 percent of its investment funding to infrastructure, including a significant amount on local projects throughout the country. In addition, China's Belt and Road initiative seeks to develop transportation infrastructures connecting Asia, Africa, and Europe.[35] Despite the ideological differences between these actors and states, they agree on one thing: infrastructures and infrastructural repair are the answer to just about every problem or question.

Another set of voices, much less invested in a future centered around current structures, critiques infrastructural modernity and its basis in a material globalism ever hungry for resources and unsustainable in its current form. Advocates of "degrowth" argue that global capitalism's never-ending search for new profit centers drives unsustainable rates of production and consumption and that this growth imperative must be abandoned for smaller and less consumption-centered forms of human organization.[36] The degrowth perspective points squarely at our dependence on a carbon-based economy to build contemporary structures that facilitate growth. Economist Giorgio Kallis notes the "free bonanza of work from fossil fuels" that allowed for "a monumental transformation of environments," including, of course, the creation of infrastructural globalism.[37]

While degrowth advocates argue that humans can reorient our lives toward a smaller impact and enjoy a simpler and less stressful lifestyle in the process, other critics of human infrastructures go further. The Dark Mountain Project, for example, a collective of writers and artists based largely in the United Kingdom, emphasizes the crisis at the center of the Anthropocene and uses the imagery of a failing machine to describe the wheels metaphorically coming off current sociotechnical structures:

> The crumbling empire is the unassailable global economy, and the brave new world of consumer democracy being forged worldwide in its name. Upon the indestructibility of this edifice we have pinned the hopes of this latest phase of our civilisation. Now, its failure and fallibility exposed, the world's elites are scrabbling frantically to buoy up an economic machine which, for decades, they told us needed little restraint, for restraint would be its undoing. Uncountable sums of money are being funnelled upwards in order to prevent an uncontrolled explosion. The machine is stuttering and the engineers are in panic. They are wondering if perhaps they do not understand it as well as they imagined. They are wondering whether they are controlling it at all or whether, perhaps, it is controlling them.[38]

In this view, repair is a key part of the problem, as elites and experts "scrabble frantically" to maintain the machine. Dark Mountain Project activists call for a process of "uncivilization" to reject and replace modern ideas of progress, growth, and the methods (and perceived failures) of mainstream environmental movements.[39]

Each of these visions of infrastructural futurity presents a discourse of infrastructural repair—whether to build it up or tear it down, to use a wall to keep out an imagined and demonized other, or to break apart structures that facilitate destruction and waste. Proposals about what to do with our infrastructures are invested with political imagery and language that embed specific relations of power in those discourses—and our own analysis here is no exception, of course. In some ways, we are optimists about the potential for infrastructures to improve human lives and bring people together, but at the same time, we are very aware of how they have formed the sociotechnical backstage for some terrible events and trends in the Anthropocene. Our recognition of this tension between the positive and negative aspects of infrastructure extends to our analysis of repair. In this book, we have been critical in many cases of repair work, especially where it serves to reproduce or reinforce social inequalities or negative environmental impacts. At the same time, we appreciate the creative work of repair artists discussed earlier in the book, like Willie the mechanic, practitioners of the paper towel trick, muralists who appropriate bridge columns as their own, and other brave bricoleurs who craft materiality for their own ends, often in the face of daunting structures of power. While it is a mistake to romanticize repair,[40] we will need all the skill and creative energy that is embodied in their work to find fair and sustainable solutions to the current challenges facing humanity.

Given both the ubiquity and the challenges of repair in an age of infrastructural globalism, we follow repair scholar Steven Jackson in asking, "Is there anything inherently hopeful about acts of repair? If forms of hope practiced through repair can be quietist and conservative, can they also be critical and political?"[41] Or, put another way, and especially from the point of view of a repair practitioner: What does a critical, reflective, and ultimately hopeful vision of repair entail? We conclude the book with a set of tools for reflexively repairing infrastructures, drawing on the tool kit of concepts that we have developed and employed throughout the text.

Reflexivity

Reflexive repair is a reorientation of repair itself, toward an ethic that considers the consequences of infrastructural globalism through the complex interactions of power, scale, and time that are built into the sociotechnical structures of modernity. In this concluding section, we provide a sense of how the concepts in our repair tool kit can be put to use for a positive practice of reflexive repair. In other words, how does one actually engage in a reflexive process that considers the trade-offs and consequences of repair actions? Ideally, these tools can be used by a wide range of repair persons and might even influence professional codes of conduct and other mechanisms of codifying best (reflexive) repair practices. Reflexive repair can be employed by mechanics, plumbers, and nurses—the workers we most commonly associate with everyday repairs—but also engineers, planners, policy analysts, investors, politicians, and anyone else whose activities shape and repair our infrastructural lives. When we refer to repair persons or repair workers in this chapter, it is with this broad scope in mind.

We provide more detail on the practice of reflexive repair in the sections that follow, but at this point, it is important to emphasize that reflexivity is not a cure-all for the power imbalances, disenfranchisement, and violence that can be facilitated via infrastructures. It is easy for us to say, "Think about it," but that admonishment is not enough, as reflexive repair can just as easily be used by those who wish to exercise and preserve power as it can be used to critique those practices and structures.[42] Consider, for example, that the original builders of the Coronado Bridge seem to have been just as aware of the local configurations of power and influence around the bridge as their successors who had to retrofit the bridge (see chapter 3). There were evidently some efforts to reach out to the communities around the bridge, understand their interests, and take this into consideration in the design of the bridge. The problem is, having looked at Barrio Logan and carefully considered its place in the local power structure, the bridge builders came to the realization that Barrio Logan's interests could be safely ignored and bulldozed through the community anyway; after all, it was the path of least resistance. Their successors were no more or less reflexive in their understanding; rather, the situation had changed in ways where it was clear the retrofit could not be accomplished without extensive, self-aware engagement with the community on a basis of mutual respect.

When we advocate reflexivity, we do so with particular values in mind—things we care about, like maintaining the Earth as a viable place for all of us to live, and ensuring justice and fairness in the distribution of the costs and benefits of infrastructure systems. Those who do not share those values with us will perhaps not be moved by these arguments (or will use them for other ends). However, there is a way in which the need for repair creates a space for reflection and an opportunity for considering alternate paths. Even in the most common forms of repair, such as a quickly corrected misunderstanding in a conversation between two people or a sharp kick to a sticking door, everyday hiccups in our relationships with infrastructures raise questions about why something did not work the way we expected and how to proceed. Furthermore, and to recall our earlier discussion of reflexive modernity, we are living in a time when bigger questions about infrastructural globalism are increasingly being asked. The need for repair does not beget shared values, but it does create a moment for questions and opportunities, suggesting at least the possibility for the kind of hopeful repair we cited above. For repair persons open to those possibilities, the other concepts in our repair tool kit provide more specific details about how to pose questions about infrastructural repair.

Expertise and the Challenges of Reflexive Repair: The Soil Quick Test

Experts keep appearing throughout this book, including in this chapter, and they seem likely candidates for exercising reflexive repair, given their centrality in defining the problems and promise of infrastructural systems. Despite their influence in both creating and diagnosing infrastructural globalism, however, experts often complain that no one listens to them. How much power do experts have to define the contours of global challenges like climate change, and how much can we depend on them to act as agents of repair for transformative change?

To address this question, we return to the case of agriculture and agricultural science. Following on the work and activism of figures like Rachel Carson, who raised alarms about the impact of pesticides on birds and other wildlife in the early 1960s, a new generation of scientists in the biological sciences paid increasing attention to the ecosystem-level impacts of chemicals, including for agricultural uses.[1] In a study of University of California farm advisors who work with farmers in California's fresh produce industry, Henke reported on the use of a soil test that allowed vegetable growers to check the level of nitrates present in their soil and make decisions about the need for additional fertilizers.[2] Farm advisors urged growers to make greater use of this "quick test" as a means of controlling the use of fertilizer and reducing the runoff of nitrates into local water supplies. Some communities near the vegetable farms had high levels of nitrate contamination in their drinking water, making it unsafe to drink.

However, despite its low cost and quick results, farmers were reluctant to adopt the quick test because fertilizer was relatively cheap and was the most important input for crop growth. As one farmer explained, "Nobody's gonna skip a $40 fertilizer application and possibly lose everything they got out there. They would rather make sure they have enough or too much. And it's hard to sell that on paper."[3] The advisors were frustrated, though they were used to this kind of response, given that they had no regulatory powers and depended only on the authority of their expertise and good personal relationships with the farmers. One advisor was reflective about the calculus that farmers used when considering the promise of the quick test for reducing fertilizer runoff: "It's less compelling for a farmer to make changes in fertilizer use [with the quick test method] than if I was to tell them they could change and increase production. . . . On the other hand, if the California [Environmental Protection Agency] hauls [the vegetable industry] into court . . . then I will suddenly be their best friend."[4]

The advisors' "hard sell" in this case was a suggested repair that clashed with farmers' values and practices for fertilizer use, revealing both the economic and legal power structure of the industry. In this case, the advisors were reflective and even a bit fatalistic about the politics of agricultural and environmental repair, quite aware of the limits of their ability to promote what seems (at least from the outside) a relatively straightforward repair to fertilizing practices. The farmers, for their part, were considering the quick test through calculations of relative economic risk and projections about future conditions, including legal and regulatory actions. Experts wield considerable power, but in the end, expert discourses are only as powerful as the structures that support them.

1 Scott Frickel, *Chemical Consequences: Environmental Mutagens, Scientist Activism, and the Rise of Genetic Toxicology* (New Brunswick, NJ: Rutgers University Press, 2004); Christopher R. Henke, "Changing Ecologies: Science and Environmental Politics in Agriculture," in *The New Political Sociology of Science: Institutions, Networks, and Power*, ed. Scott Frickel and Kelly Moore (Madison: University of Wisconsin Press, 2006), 215–243.
2 Henke, "Changing Ecologies"; Christopher R. Henke, *Cultivating Science, Harvesting Power: Science and Industry in California Agriculture* (Cambridge, MA: MIT Press, 2008).
3 Henke, "Changing Ecologies," 231.
4 Henke, "Changing Ecologies," 232.

Scale

Embedded in the idea of infrastructural globalism is the sheer complexity of infrastructural scale; as infrastructures increasingly form a single, interconnected global network, repair possibilities also begin to transcend individual infrastructure systems. The concept of reflexive repair suggests a need to understand the interconnections between multiple scales of repair, though the complexity of these interconnections can at times seem overwhelming. Consider the work of the Intergovernmental Panel on Climate Change (IPCC) as just one example of the mind-bogglingly complex tradeoffs that have to be considered for repair at global scales. The 2014 IPCC report on climate mitigation runs to fourteen hundred pages, and that is just the report from one of three working groups.[43] Geared toward policymakers at the highest levels, the report includes analysis of the scale of infrastructures, from the project level to the nation, and suggests a range of regulatory, taxation, and investment strategies to reduce the carbon footprint associated with urban design and sprawl (see figure 5.2). The reality of infrastructural globalism means that a massive planetary repair manual on the scope of the IPCC reports is not just necessary, but is also, in fact, a remarkable achievement. However, from the point of view of a person or an institution facing the scope and scale of climate change, the IPCC is a very daunting resource for reflexive repair.

The connections and interdependencies of repair across scales call for a method that anticipates the way that infrastructures link together human actions and material structures. Repairs, even when they are aimed at a specific location, scale, or aspect of sociotechnical systems, tend to reverberate and have impacts at other levels because modern technologies and infrastructures are so integrated and interface with the environment in systematic ways. In fact, some repair efforts intended to promote sustainability or improve the efficiency of infrastructures, such as upgrading highways or switching to improved light bulbs, may paradoxically encourage behaviors that increase energy use and partially negate sustainability efforts, a phenomenon that environmental planners term the "rebound effect."[44]

With that understanding, we advocate two complementary approaches to help repair workers of all kinds think through the importance of scale. Each approach ties back to our discussion of infrastructural scale in prior chapters, where we detailed top-down and bottom-up approaches that

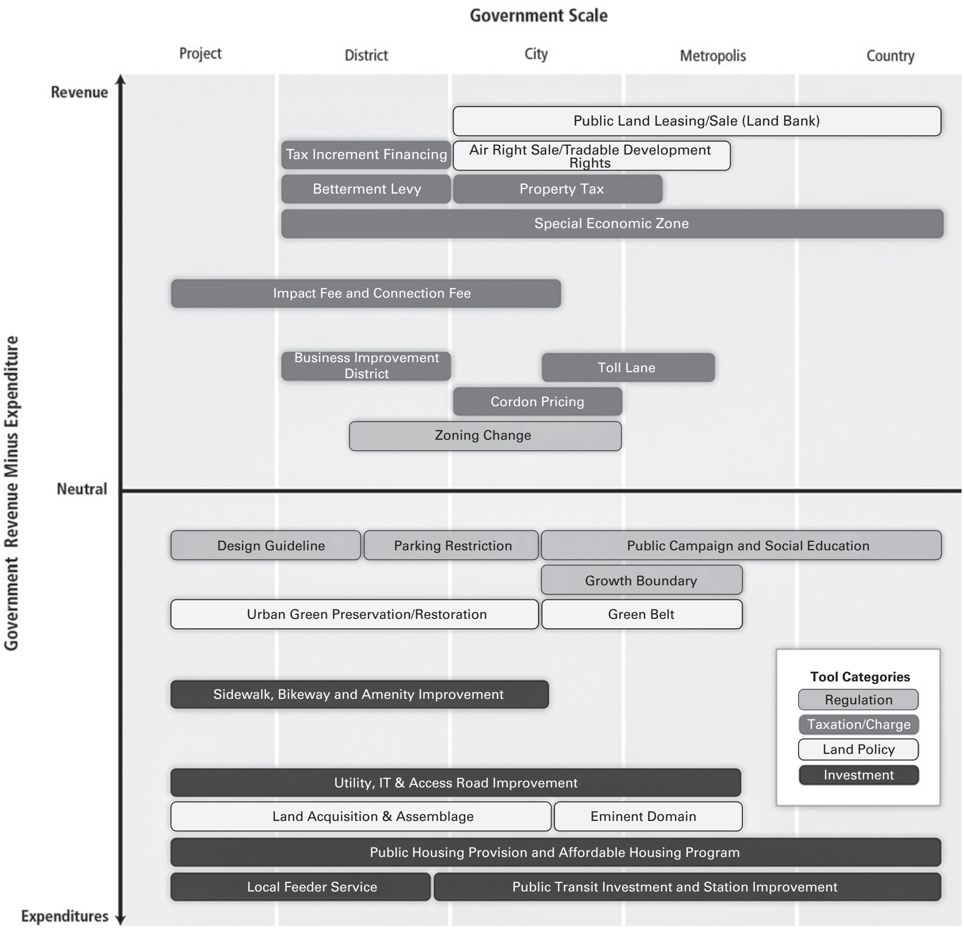

Figure 5.2

A chart from the 2014 IPCC report on climate change mitigation, graphically representing scales of government intervention (on the *x*-axis) and the resources that could fund those efforts (*y*-axis). Figure 12.20 from K. C. Seto, S. Dhakal, A. Bigio, H. Blanco, G. C. Delgado, D. Dewar, L. Huang, et al., *2014: Human Settlements, Infrastructure and Spatial Planning. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press, 2014), 970.

scholars use in seeking to understand and explain how infrastructures operate as sociotechnical systems. Top-down approaches emphasize the structural roles of ecology, culture, politics, and markets, while the bottom-up perspective highlights the importance of everyday practices and material encounters with infrastructures. Brainstorming from the level of larger structures helps a repair person think through the broader implications of a repair, its potential side effects, and how it fits into larger systems of power and control. Seeing repair from the bottom-up perspective raises questions about how repair might affect the people who have to implement it or live with it on the ground level. Will it make their jobs harder? What kinds of behaviors is it likely to encourage or discourage? Will it reduce the quality of human or nonhuman life?

While the interconnectedness of infrastructural globalism, from local to global, means that all scales and perspectives matter, this bidirectional approach to considering the role of scale is a starting point that repair persons can use in a wide range of contexts. The two approaches provide a scalar lens for thinking through the people, institutions, and infrastructures that, linked together, create the superstructure for a phenomenon or problem. For example, in the case of climate change, those linkages could include an office worker putting a wet paper towel on a thermostat, a repair technician fixing a broken thermostat, a university administrator developing a plan to reduce the carbon footprint of the institution, a utility system engineer planning for changes to a power distribution system to account for new loads, a policy committee hashing out solutions to regional power interconnect problems, a government official's efforts to develop a policy to incentivize the use of renewable energy, and an international committee's recommendations on the comprehensive changes in technology and behavior needed to keep global warming below 2 degrees Celsius within the next century.

Delegates negotiating international climate accords are likely to focus first on this latter set of state and global scales and therefore may start by considering top-down views of repair. A committee facing up to the sustainability challenges of a university or other local or regional institution might consider how their work meshes (or not) with other institutions' practices and goals. Ideally, by alternating between top-down and bottom-up perspectives, repair persons can knit together multiple levels and begin to grasp the scalar complexity of repair.

Power and Invisibility, Discourse and Materiality

Infrastructures are incredibly powerful tools that enable many different human activities, especially through control of environmental conditions and forces, by reducing constraints on the human body and facilitating the compression of time and space. These properties of infrastructures allow humans to do some amazing things, and when those benefits and opportunities are widely available to most or all, infrastructures might be celebrated as an emancipatory force, a product of human ingenuity and labor that allows us to fulfill the dreams of the Enlightenment and its vision of steady human progress. However, we have shared many examples that highlight inequities in the benefits and capital that may accrue from infrastructures, and how repair is deployed to maintain those structures of inequality. Furthermore, with increasing recognition of the stark challenges presented by the Anthropocene, the impacts and externalities of infrastructural repair call into question the progressive connotations we might attach to the onset of infrastructural globalism and the possibilities it opens up for some portion of humanity.

The fact that infrastructures serve as global interfaces between human culture and nature means that their characteristics and impacts, whether we deem them good or bad, can sometimes be hard to see: the sociotechnical character of infrastructures naturalizes their structures, including imbalances in their power and effects. The expertise required to build and repair infrastructures is also difficult to attain and practice, and may seem almost like magic to those who do not have access to those skills and tools. Infrastructures are never truly invisible, but their salience to us, including their role in shaping power and privilege, shifts in and out of our consciousness based on their operation and to what extent we depend on or are oppressed by them. In addition, the discursive frames and meanings we attach to infrastructural forms provide the cultural context to understand and debate the shape and repair of infrastructures. This discursive work takes place alongside material forms of repair. Repair is not just a material, technological process, but rather a process that engages our core beliefs, assumptions, and ways of understanding each other and the world.

Reflexive repair in the context of infrastructural power, then, means asking questions that bring the sometimes obscure but always present properties of infrastructures to the surface, critically appraising the embedded dynamics of power, discourse, and materiality that are built into these sociotechnical structures. The distinction between repair as maintenance and as transformation is a key concern in the formation of such questions, especially: If repair is maintaining something, what exactly is being maintained? That broader question about maintenance can be broken down into a more targeted set of three questions, based in concepts from the repair tool kit. First, does a proposed repair largely reproduce existing power structures, or does it seek to remedy inequalities or injustices built into existing infrastructures? Second, does a proposed repair account for the people, communities, and ecologies most centrally affected by the material and discursive shape of an infrastructure? Who has a stake, and are they given a voice? Third, does a proposed repair solution restrict or close off possible futures, especially those we can imagine wanting for ourselves and future generations?

Good repair starts with questions that hypothesize about trouble and point toward solutions. By reflectively asking these questions about the practice of repair itself, we may develop better methods and tools to face the challenges of our infrastructural future.

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Repairing Infrastructures

The Maintenance of Materiality and Power

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