2. Speculative Citizens: How to Evidence Harm

Chapter 2

SPECULATIVE CITIZENS

How to Evidence Harm

In the Endless Mountains of northeastern Pennsylvania, residents and community groups are monitoring the growth and impact of a relatively new industry, hydraulic fracturing. Also known as "unconventional shale gas extraction," or simply "fracking," this industry increasingly crisscrosses and carves up Pennsylvanian landscapes, as well as many other sites around the world, from Oklahoma to Siberia. Fracking involves extracting natural gas through first drilling vertically thousands of feet underground, then drilling laterally up to a mile and a half beneath shale rock formations, and finally injecting vast amounts of water, sand, and chemicals to fracture shale deposits and release bubbles of gas trapped in the porous rock. The extensive infrastructures of fracking span well development and drilling, well completion and production, on-site and off-site processing, distribution and storage of gas.

At every point in this infrastructure, pollution potentially occurs to air, water, and soil. The wells drilled at initial points of extraction generate greenhouse gases primarily in the form of methane, along with air pollutants including particulate matter and volatile organic compounds (VOCs). The water and chemicals used to exert pressure to remove shale gas can contaminate drinking water and surface water through wastewater ponds of "flowback" drilling fluid left to be trucked away or evaporate into the air and settle into the soil. The compressor sites where gas is pressurized, refined, and pumped into pipelines generate additional methane, diesel, and VOC emissions in the form of benzene, toluene, ethylbenzene, and xylene (BTEX compounds), some of which are known carcinogens at even minute levels of exposure.[1] And the extensive truck traffic that hauls materials for initial well development to waste removal contributes to ultrafine particulate matter and diesel emissions recognized as carcinogens by the World Health Organization.[2]

Figure 2.1. Fracking well pad undergoing active drilling; oversized truck transporting fracking equipment in northeastern Pennsylvania. Photographs by Citizen Sense.

Across these infrastructures of energy extraction, established, new and uncertain formations of pollution occur that are yet to be studied both for their distribution and type and for their possible future accumulations and effects. The rise of fracking has forced multiple questions about how this mode of energy production could damage environments and health. In the United States, shale gas has been referred to as a "bridge" technology. Widely considered cleaner than coal, it has been promoted as an interim solution on the way to more renewable and sustainable energy sources while also reducing dependence on imported energy sources. Yet the extraction, distribution, and use of these fossil fuels cause concern about how to evidence bodily stress and environmental pollution from these industries.

In Pennsylvania, residents take up assorted instruments to monitor and document fracking-related pollutants in the air, water, and soil. People use a battery of equipment, from badges to sensors and video, to detect and track pollution. Some of these devices are analog and low-tech, while others are digital and more complex to operate. They also share their techniques and findings with other community groups, state and federal regulators, and environmental and health NGOs. By using monitoring devices, residents seek to evidence harm. They express care for environments and health by documenting pollutants in situ and attempting to link these ill effects to health and environments. In a different but resonant register to the NoDAPL drone video monitoring in the Introduction to this book, fossil fuels that crisscross landscapes produce ongoing pollution and contamination, which further generates an array of citizen-sensing practices that track pollution to hold polluters to account.

One such digital technique involves using forward-looking infrared (FLIR) video documentation. When the FLIR camera operates in non-infrared mode, emissions from gas infrastructure are not visible. However, when in full operation the FLIR thermographic camera exposes significant drifts of methane, VOCs, benzene, and other gases that are often leaking from gas infrastructure.[3] In black-and-white or magenta-and-orange scenes framed by the FLIR menu and time stamp, leaking emissions that are otherwise not detectable become evident. FLIR thermal imaging is typically used for safety checks and monitoring hot spots. Here, citizens put this technology to work to observe the emissions from a compressor station as one point in the more extensive sprawling infrastructure of the natural gas industry.

People post FLIR videos on YouTube that document emissions from fracking infrastructure in Pennsylvania and farther afield. In a video recorded by Frank Finan at a compressor station in Dimock near the Tennessee Pipeline, vertical and L-shaped exhaust pipes discharge emissions at high velocity.[4] Slower vaporous

Figure 2.2. Frank Finan monitoring emissions at a compressor station using a FLIR camera. Photographs by Citizen Sense.

clouds surround more rapid jets of emissions, with some plumes billowing and trailing wistfully and others carving stark vertical lines. The camera pans and fixes on numerous outlets, although it is often difficult to determine the precise location of leaking emissions. The image is framed with the markers of the FLIR camera details. The time stamp, 5/21/14 at 3.35.45 pm, advances for 2 minutes and 2 seconds of footage. The battery indicates that it is partially charged. The FLIR menu functions mark the top edge of the frame: HI OFF, AUTO, HIST, BL. Soundless and silhouetted infrastructure pumps and heaves fumes skyward. Gas deep underground hurtles and shuttles upward to wellheads, then on to pipelines, which channel gas to this point to compress and equalize it to be sent farther along pipelines and to additional compressor stations. Impurities are removed, and explosions are meant to be prevented, so periodic "blowdowns" are staged to release excess pressure from the compressor site.[5]

Frank began using the FLIR camera to document the undocumented and often poorly understood effects of fracking. With footage dating back to 2011, his videos, along with records from many other residents in the area, form an archive of citizen environmental monitoring.[6] They track the changing landscapes of the Endless Mountains and many other shale plays across the United States. At the time of this writing, Frank had uploaded nearly one hundred videos that document emissions at compressor stations and pipelines, in wooded settings and farmlands. The FLIR documents this infrastructure as it undertakes the work of fossil-to-fuel conversion, where once-ancient plant matter surfaces to the atmosphere in particles and gaseous compounds: methane, VOCs, carbon dioxide, nitrogen oxides, particulate matter, and more. The citizen videos record emissions as they surge and leak from vents and release valves, altering atmospheres, affecting bodies, and transforming environments.

As *Citizens of Worlds* documents, air pollution is a problem that causes significant harm to health and environments. The WHO has established that air pollution is one of the leading causes of disease and death worldwide.[7] Air pollution also connects to environmental struggles. It is an indicator of resource extraction, rampant development, fossil-fuel consumption, traffic gridlock, and contentious infrastructure projects. Air pollution can be evident at distinct sites of spatial segregation, as environmental justice research has demonstrated,[8] and it can also be much more pervasive within congested urban environments. As will be discussed in the next chapter, nearly all Londoners experience harmful levels of particulate matter. Air pollution can be omnipresent and yet unevenly distributed in the harm it causes. Breathing and "breathtaking spaces," as described by Christina Sharpe,[9] are particular practices and sites worthy of study to understand how people experience environmental and social injustices, how

they cultivate practices of combat breathing, and how they work toward more breathable worlds.

Air-quality monitoring ordinarily takes place through distributed infrastructures meant to protect public health by lessening the effects of air pollution. From health research to policy guidelines to official monitoring stations and labs that analyze data, these monitoring infrastructures can inform corrective action, typically through policy measures, if levels of pollutants exceed guidelines. Air-pollution monitoring could be approached as a material expression of governmental care for public and environmental health. Yet care can as likely turn to neglect and harm, since instantiations of care may be incomplete and even lead to forms of oversight and inertia, where worlds become more or less breathable for some and not others.

In rural environments where most fracking occurs, there is a relative absence of air-quality monitoring networks, because air pollution is generally seen as a problem of urban environments and higher population densities. At the same time, in the United States, fracking is relatively exempt from federal-level clean air and water regulations (in the "Halliburton loophole" of the US Energy Policy Act of 2005). As an industry, it is not subject to the same national safeguards that might prevent pollution to air and water, since these regulations are mainly devolved to states.[10] In this sense, there are many ways in which exposure to harm might not be monitored or prevented, whether through lack of policy or regulation of pollutants and industrial processes or because individuals experience distinct and situated exposures to pollution that the typically fixed and sporadic monitoring stations cannot document. Government-run environmental monitoring infrastructures then materialize as uneven distributions and enactments of care.

Multiple citizen-based and scientific monitoring practices have taken place in the Marcellus Shale region to address the relative lack of data about air pollution from fracking. These practices create alternative monitoring infrastructures to document harm and address the relative lack of care for environments and health. This chapter investigates how residents, activists, and community groups deployed multiple monitoring technologies to document fracking-related environmental pollution and address gaps in regulatory approaches to pollution. In the course of this chapter, I consider how citizen-sensing practices support different ways of evidencing harm and materializing care as expressions of citizenship. Environmental monitoring with environmental sensors could both facilitate and limit this process. In this way, practices for sensing pollution give rise to speculative citizenships and struggles that work toward more breathable worlds.

While a certain amount of attention has been directed toward citizens' monitoring of water quality contaminated by fracking because of the spectacular and

Figure 2.3. Participant contributions to logbook documenting fracking infrastructure and pollution, including flaring at a wellhead, and construction activity at a drilling site. Photographs by anonymous Citizen Sense participants; courtesy of Citizen Sense.

alarming phenomenon of residents in fracking sites being able to light their water taps on fire due to high levels of methane migrating from potentially faulty well casings,[11] this research focuses on the relatively under-examined topic of citizen sensing of air pollution at fracking sites.[12] Whether in the form of ultrafine particles and particulate matter, nitrogen oxides, climate-change-accelerating methane, VOCs, ozone, and more, an array of compounds generated and following on from fracking processes are known to be accumulating in the air and suspected of affecting bodies and environments.

Following on from the last chapter, which investigated how to retool action through the instrumental citizen, this chapter looks more closely at the speculative citizen. I address practices of citizen-based monitoring of air pollution near fracking sites as speculative attempts to evidence and address harm to environments and health. Citizen sensing of environmental pollution can unfold through speculative registers, because it seeks to generate alternative or supplementary forms of evidence while transforming political engagements for addressing environmental harm. Speculative forms of citizenship potentially materialize through environmental sensing practices as they search for prospective forms of political assembly, engagement, and effectiveness that have yet to be realized.

This chapter attends to how residents' experiences and anticipations of harm have contributed to practices of monitoring environments. The Citizen Sense research group documented and reviewed these monitoring practices, while at the same time working with residents to develop and install citizen-sensing toolkits throughout a three-county area in northeastern Pennsylvania. In this context, I investigate toolkits as they are developed, installed, put to work, broken, and queried in the open air. This practice-based and collaborative approach expands the discussion of the how-to and open-air instrumentalisms from the previous chapter to consider what unexpected uses, committed engagements, and heated struggles unfold through the use of citizen-sensing technologies.

Multiple modes of how-to engagement surface here, including how to establish the "facts" of pollution, how to sense pollution, how to activate collective practices of open-air inquiry, how to transform data into evidence, how to evidence harm, and by extension, how to mobilize speculative monitoring practices toward transformative political engagements.[13] This chapter next considers how speculative practices for evidencing harm and expressing care generate practices of speculative citizenship. I then describe in more detail how people have monitored environments to document air pollution, and the collaborations we undertook to develop a citizen-sensing infrastructure for tracking industry emissions. "How-to" unfolds here as a process of collective anticipation and inquiry. Such

inquiry attempts to document harm and generate speculative practices and infrastructures of care that contribute to more breathable worlds.

SPECULATIVE PRACTICES FOR CARING ABOUT AIR

Citizen-sensing practices for monitoring air pollution are often described as a way to "care about your air."[14] Such practices can seem to offer a straightforward strategy for protecting one's health by avoiding exposure to air pollution. Yet in the absence or inaction of governmental air pollution infrastructures, such practices do not readily generate direct solutions to the problem of air pollution, since they do not reduce overall levels of air-pollution emissions. Instead, caring about air becomes entangled with speculative practices for evidencing and addressing harm. Neither care nor the subjects and actions that would constitute care are so clearly identified, since the forms and forums needed for citizen data to have an effect are in the making, and forms of harm are accumulating and often not fully known. Moreover, the conditions in which these monitoring practices could gain a foothold and demonstrate environmental and bodily harm as experienced and yet to come are in process, forming in relation to lived conditions.

Citizen-sensing practices for monitoring air pollution are ways of expressing care about breathable worlds by attending to exchanges across environments, entities, communities, and health. Practices of collecting air-pollution data are speculative attempts to document harm and demonstrate the need for care. Operating outside of the more official infrastructures of care, citizen-sensing practices indicate that more attention should be given to air pollution. They attempt to instigate corrective actions. Yet the exact contours of these political engagements can be somewhat open-ended, and they do not immediately translate into regulation, policy, or even agreement about common environmental problems.

Proposals and practices of care are not straightforward. Moreover, citizen monitoring of air pollution could be generative of what Lauren Berlant calls "cruel optimism,"[15] a concept that addresses how political hopes can generate self-defeating or threatening conditions rather than the liberation they would promise. Here, technologies seem to generate the care lacking in governmental practices and infrastructures. Yet these same devices could as easily produce overlooked data, failed inquiries, and half-hearted engagements. With these cautionary tales in mind, I shift the focus from making normative proposals for care to addressing the complex and speculative practices of evidencing harm as contingent precursors or entreaties to care in the making. Such an approach is more propositional. It resonates with Puig de la Bellacasa's suggestion that "engaging

with care requires a speculative commitment to neglected things."[16] Speculative commitments could refer to practices for expanding potential within present political engagements as well as practices for generating citizens and worlds where other ways of addressing air pollution become possible.

While monitoring ostensibly focuses on gathering the "facts" of pollution, a speculative approach to monitoring involves the co-constitution of facts and worlds where those facts make sense.[17] Rather than accumulating facts as self-evident demonstrations of environmental pollution, a more speculative approach to citizen sensing shifts the conditions in which observation, evidence, and care might materialize. Speculative propositions do not articulate in advance the conditions in which they will have relevance; instead, they bring into existence movements of thought and thinkers, citizen and data, where different inhabitations could be possible.[18] In this way, citizen sensing is a proposition for how to document experience, generate facts, and build worlds in which those experiences and facts are relevant. Here are practices whereby speculative citizens might constitute breathable worlds as exchanges and evidence in the making.

But these speculative capacities extend to more-than-humans; they are not merely an attribute of human citizens as usually understood.[19] Experiences are distributed, and speculation is a practice undertaken collectively. Speculation can be distributed through things, which are propositions and potentialities for feelings and encounters: they lure entities into ways of being. In this sense, any account of "the social" would necessarily need to attend to the multiple entities that are continually sparking speculative encounters. When monitoring for pollution at fracking sites, these entities include sensors and chemical compounds, data platforms and wellheads, truck traffic and meeting halls, bodily afflictions and noxious smells, as well as ancient rock and energy markets. Speculative practices for evidencing harm unfold with and through environmental sensors and these extended milieus. This is where speculation meets open-air instrumentalisms, where the practices of evidencing harm are not simple actions leading to outcomes but involve distributed practices of making citizens and worlds. What might begin as a seemingly straightforward sensor toolkit opens into distributed practices for making more breathable worlds.

Speculation can occur in yet another register, since rather than simply resolve or clearly evidence the probability and effects of pollution, monitoring practices can at times also amplify uncertainty, give rise to speculation, and cause people to wonder, if not worry, about ongoing exposure to pollutants. Some of this uncertainty can proliferate through increased collection of evidence, where the documentation of pollutants can give rise to concerns and questions about effects of pollutants over time, how they will travel through environments and

bodies, and whether individuals will find themselves with health issues linked to fracking-related pollutants. Pollution monitoring can activate speculative practices for evidencing harm. These practices could be a way to direct attention to exposed communities. At the same time, speculative practices for evidencing harm could provoke conjecture about future environmental effects, as possible forms of harm-in-waiting that are difficult if not impossible to substantiate. Speculation, here, could be a cause for concern and even dread.

However, speculation neither signals a sort of "relativism" nor forms the basis for dismissing citizen data as speculative conjecture. Instead, it designates how propositions for making worlds come to matter. To dismiss the experience of citizens living on the gas fields would be to fix the environments, experiences, and concerns of fracking as already settled and addressed through a singular reference point of industry, government, or scientific expertise. Yet as with any technology that unfolds in unpredictable ways, new practices for making sense of and attending to this industrial process can also form new collective worlds. Indeed, speculation could be less about resolving uncertainties and more about constituting environments, worlds, and subjects that can register pluralistic evidence and experiences.

Speculative Citizens

By monitoring environments, citizens develop speculative modes of engagement with their lived environments. The instrumental citizen here shifts to the speculative citizen. The "speculative citizen" is a concept that describes how different ways of experiencing environments and pollution assemble as propositions for how to sense and build more breathable worlds. As it turns out, the instrumental might have been speculative all along. Returning to the instrumental experimentalism discussed by John Dewey and influenced by William James, we could say that environmental sensing for evidencing harm is a way of putting propositions to work in the world, in concrete situations. Speculation is not, in this sense, a fictional condition but rather a testing, shaping, honing, and transforming of conditions through open-ended practices of inquiry. Open-air instrumentalisms are both speculative and practical. Their doing and unfolding contribute to the making of subjects, communities, and worlds, as well as political possibilities. These open-air instrumentalisms are not the exclusive work of human makers but are part of a field of influence. This is how worlds and propositions for breathability can take hold.

Speculative citizens are not just articulations of propositional citizenship and political engagement. They are also more ecological and distributed formations of what a citizen is or could become, both as a relational entity and subject

informed by exchanges with worlds. Political subjects and worlds materialize through these collective and distributed processes of inquiry. What a citizen or citizenship is or could become is less a matter of definitions and more a question of the propositions, inquiries, practices, and political engagements that might be staged—here through environmental sensing. Yet this operationalization of speculative citizens is not equally available to all who monitor environments or create alternative forms of evidence. Harm might inform what counts as a citizenry worthy of protection or care. Yet it might also exclude some people from making a case for harm, or perpetuate the trials of demonstrating ongoing harm so that people become worn down or exhausted by monitoring efforts.

It is these registers of environmental monitoring that I next discuss through the development and distribution of a citizen-sensing toolkit for monitoring air pollution with residents in Pennsylvania. I document how practices of evidencing harm involve speculative encounters with environments, atmospheres, pollutants, data, regulators, industry, and communities. These practices could be oriented toward attempts to "empower" citizens by shifting the infrastructures, technologies, and monitoring practices to less institutionalized arrangements. At the same time, such practices do not easily or readily mitigate harm. Instead, they require new forms of collective attachment and individuation to activate political engagement and effect. How citizen sensing becomes relevant (or not) then materializes through speculative encounters and commitments to evidencing harm, where the instigation of new relations could be characterized through less normative—and even "complicated"—forms of care.[20] By focusing on the speculative dimensions of evidencing harm, I suggest the processual and collaborative practices of care could be more fully considered.[21] Such an approach focuses on how to generate atmospheric forms of care and environmental policy that are more responsive to multiple experiences and evidence of the harm caused by air pollution, as documented through citizen-sensing practices.

MONITORING FRACKED ENVIRONMENTS

In the fall of 2013, the Citizen Sense project began research on citizen-led monitoring of air pollution on the Marcellus Shale in northeastern Pennsylvania, where there has been a high concentration of active drill sites. The Marcellus Shale is a sedimentary rock formation that spans the Appalachian Mountains and extends across New York, Pennsylvania, West Virginia, and Ohio. The formation is around 350 million years old. An ancient inland sea once settled here, where rock layers and gas from decomposing organic material are now compressed together underground.[22] One of the first shale plays to be drilled in the United

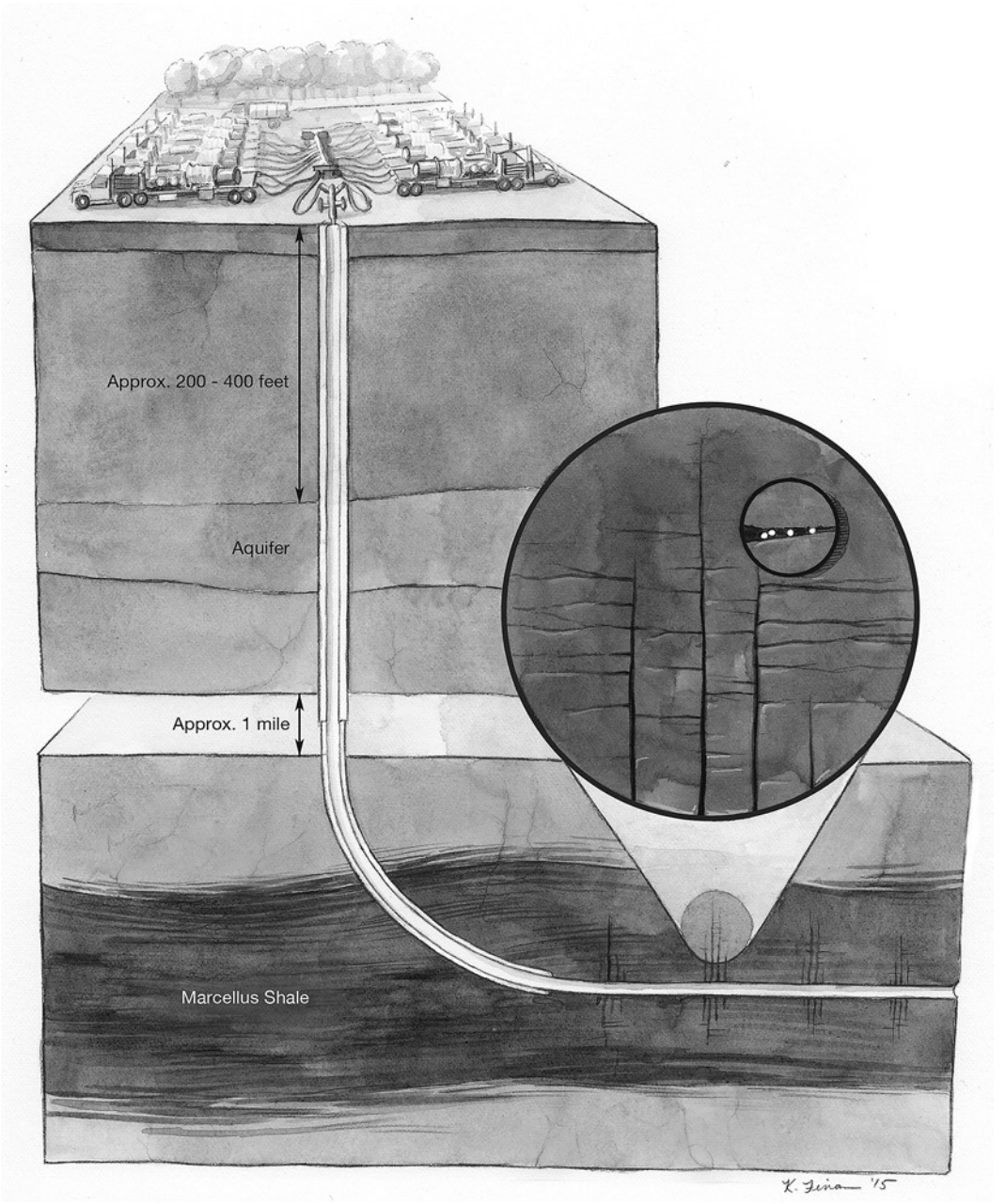


Figure 2.4. Diagram of Marcellus Shale and fracking. Illustration by Kelly Finan; courtesy of Citizen Sense.

States, the Marcellus Shale has undergone its most active stages of development since 2008. As of 2020 in Pennsylvania, this highly productive zone of unconventional gas extraction had nearly 12,450 active unconventional wells in operation, along with 14,666 recorded environmental violations at well sites.[23] Moreover, wells and fracking infrastructure sites continue to multiply. Some estimates suggest the total number of wells will expand to 100,000 over the next several decades in Pennsylvania alone.[24] Environmental violations have included everything from failing to dispose of residual waste correctly, to wastewater discharge, poor construction of pits and tanks, and not adopting Pennsylvania Department of Environmental Protection (DEP) pollution-prevention measures.[25]

Most fracking developments and the leasing of extraction rights are taking place in rural communities with few sources of revenue. Shale gas can boost rural economies by increasing the incomes of retirees and farmers, teachers and local governments. However, at the same time, the rural idyll that may have attracted people to settle here, and the long-standing relationships residents have established with the area, has changed due to shale-gas production and its

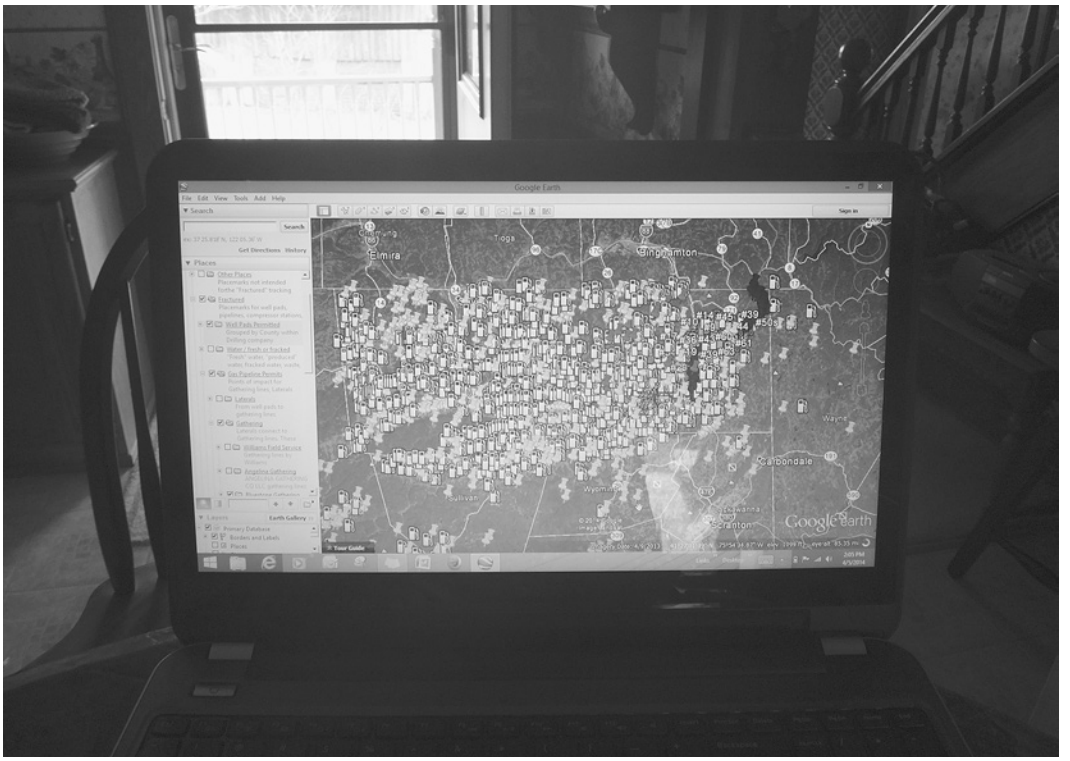


Figure 2.5. A Google map created by Meryl Solar to document fracking infrastructure in northeastern Pennsylvania. Photograph by Citizen Sense.

Figure 2.6. Participant showing fracking permissions and infrastructure in Bradford County, northeastern Pennsylvania. Photograph by Citizen Sense.

wide-ranging impacts. This is not to say that this is a pristine landscape, since Pennsylvania is well known for industry such as steel mills, and earlier forms of mining and energy production, including coal extraction. But precisely because there is a prior history of extraction, new extraction economies and practices have brought concerns about what it means to commit now and in the future to these natural-resource and energy economies.

Although attention to fracking's environmental impacts often focuses on the well pads where gas is extracted, the landscape of fracking is not limited to one site. Instead, it consists of an extended infrastructure: horizontal, underground, and emerging at discrete points, interconnected by trucks hauling equipment and waste material, and contributing to airborne and waterborne impacts. Fracking technology uses extensive horizontal drilling with a mix of hundreds of proprietary and often untested chemicals. These chemicals—together with water, sand, and lubricants—are injected into wells under high pressure as fracking fluid to blast out gas from shale layers, which in turn can release methane as well as

radiation into the air. Fracking fluid can leach into groundwater and contaminate drinking water.[26] The injected chemicals that return aboveground are stored in impoundment ponds or trucked away to wastewater treatment facilities. The mix of wastewater differs from site to site and can include radionuclides, including strontium and barium, from underground radiation.[27] Fracking is provisional not just because it is an emerging energy technology but also because every fracked site has distinct geological and subsurface features, producing widely different environmental impacts. Yet these impacts are rarely monitored.

In some cases, unconventional shale-gas extraction is referred to (by proponents) as a long-standing technology that has been in use for nearly sixty years. However, other energy researchers suggest that the high-intensity ways fracking is now being undertaken are new, even less than ten to fifteen years old, and have unforeseen and under-studied impacts.[28] As with many technological "innovations," fracking is unfolding as an experiment in the world,[29] where earthquakes, untested and proprietary chemicals, groundwater contamination, and air pollution are among the emerging material-political and environmental configurations and inhabitations that are generated through this mode of energy extraction. This emerging technology contributes to environmental effects that both presently and at some future point could impair living conditions for many within the catchments of fracking operations.

Residents who feel the effects of fracking search for ways to register these impacts on environments and health. Environmental monitoring can be one way to document and evidence environmental change and harm. At the same time, monitoring technologies might not necessarily capture those compounds, events, pollutants, and effects that occupy more liminal, indeterminate, or even unknown and future registers of harm. While individual pollutants can be relatively well studied, their accumulation, amplification, and interaction are less understood.[30] How might it be possible to monitor environments and air if pollutants fall outside the designated list of compounds to monitor and regulate, or if governmental infrastructures are not in place to monitor pollutants? How might it also be possible to monitor and evidence fracking's indeterminate effects, particularly if environmental monitoring detects a select number of substances within a categorical present and does not attend to ongoing interactions of accumulations?[31]

Citizen-sensing practices could challenge more "official" monitoring infrastructures by developing speculative approaches to the uncertain effects of pollution. Different ways of evidencing harm and materializing care can surface through these practices by attending to the overlooked, unacknowledged, newly emerging, and future effects of pollution that could be overlooked by established

Figure 2.7. Fracking protest signs and installations at residences in northeastern Pennsylvania. Photographs by Citizen Sense.

expert-driven monitoring practices. As mentioned in the introduction to this chapter, while governmental air-quality networks could be sited at disparate locations and provide a limited picture of an individual's exposure to air pollution, citizen-sensing technologies intend to provide a more immediate and granular record of pollution. Beyond mapping individual exposure, however, citizen-sensing technologies can produce data where there might be an absence of official monitoring technologies. In this way, sensors can provide alternative data sets to address specific community concerns, such as a polluting roadway or industrial site or the possible pollution of a proposed development. This is a different way of mobilizing public engagements with technology, since communities are not engaged in modes of reflexive deliberation with yet-to-be-introduced technologies and wondering about their potential effects.[32] Instead, they struggle to evidence the uncertain and indeterminate impacts of technological operations as they are already unfolding in lived environments.

In research and fieldwork looking at both scientific and citizen monitoring practices, it has been interesting to note the extent to which atmospheric scientists worry about how citizen-sensing technologies could be deployed in ways that generate inaccurate or unhelpful data.[33] Their concern is numerical accuracy and not compromising the data that would support possible actions attempting to enforce air-pollution policy.[34] However, advocates of citizen-sensing technologies have made the case that the absolute numerical accuracy of the data is of less concern when the process of assembling communities of makers or environmentally engaged "citizens" could be facilitated through the development and use of these toolkits. Others have suggested that data can have increased relevance through the sheer quantity of monitoring underway when distributed across multiple citizen-monitoring sites. Data sets could become relevant by detecting changes in data patterns rather than precise numerical readings. In this way, a greater ability to work with "just good enough data" could be developed to enable situated engagements with environmental problems.[35]

Here, citizen-sensing practices do not necessarily constitute a project of collecting data to raise environmental awareness. Instead, they form more speculative undertakings that register overlooked experiences and exchanges. These practices work toward building breathable worlds, worlds where evidence of harm can register and be redressed. A speculative approach to monitoring air pollution could transform ways of engaging with fracking on the Marcellus Shale. In developing this speculative approach to monitoring, processes of evidencing harm could move beyond an evidentiary tracing of pollutants, whether through high-tech or low-cost instrumentation, to engage with how facts or evidence "take hold" to mobilize relations, practices, and forms of relevance.[36] Monitoring practices

Figure 2.8. Impoundment pond for holding fracking flowback fluid. Residential swimming pool adjacent to new fracking infrastructure. Photographs by Citizen Sense.

are not simply a question of what to sense and how to document pollutants. They also direct attention to some impacts and not others, and inform the possible attachments and expressions of care that monitoring can mobilize. Practices for evidencing harm could generate responsive practices of care, which seek to redress or mitigate harm by attending to impacts that do not ordinarily register. It is these processual approaches to care and practices for evidencing harm that I discuss below.

How to Establish the "Facts" of Pollution

It goes without saying that fracking is a contentious issue on many levels. It can divide communities and create diverging understandings and experiences of pollution and harm. Pollution is unevenly distributed. Residents who live downwind rather than upwind of a compressor site will notice acrid odors and noise. People who live in an area with a contaminated water supply will have to source bottled water. And those who live on a road with constant industry traffic will experience diesel pollution, noise, and congestion at all hours. Many residents in these communities, including those who have leased their mineral rights, have sought to document and understand the impact of these extraction techniques on environments and human health.

People living near fracking sites, compressor sites, waste pits, roads, and other infrastructure have collected evidence of numerous environmental disturbances and health effects, from noise and constant light, to smells from emissions, to a range of symptoms that are characteristic of VOC exposure, as well as asthma and other pulmonary diseases, cardiac diseases, and cancer. Residents near compressor sites notice odors and metallic tastes, which some have suggested are linked to the cleaning fluids used to flush compressors, or to the substances emanating from glycol dehydration processes. Across these multiple sites, residents report experiences of chronic and acute nosebleeds, headaches, dizziness, and a range of symptoms that are difficult to tie into a cause-and-effect logic of how fracking may be affecting environments and bodies. Chronic illness can also take decades to manifest. The ongoing and accumulative health and environmental impacts and harms that could be related to fracking do not always translate into immediate data sets or legible evidence.

The inconsistent occurrences of illness, chemical exposure, and evidence as provided through monitoring make this less a space of demonstrable proof and more an uncertain atmosphere of effects. For instance, tests of drinking water in households where residents complain of illness have at times shown an absence of any substances of concern, and in other instances arsenic, benzene, and heavy metals are evident at high levels.[37] Environmental monitoring does not simply

reveal the "facts" of pollution but is entangled with complex environmental, chemical, and bodily interactions. While monitoring might indicate care, care is always yet to be realized, since it requires engaging with the speculative aspects of how harm, evidence, and care could yet unfold.

Indeed, even attempts to generate comprehensive lists of harm often indicate how environmental exposures create uncertainty. The Pennsylvania Alliance for Clean Water and Air has established a "List of the Harmed,"[38] which documents residents in locations across Pennsylvania and the wider United States who have experienced harm from fracking. The list records the specific gas facilities near to which residents live, as well as suspected or evidenced exposures and symptoms for humans and animals. It also includes press and online reports, which can include videos and photographs of harm experienced. Reaching over 23,000 records and 192 pages in length, the list documents residents living next to a compressor station who experience "headaches, fatigue, dizziness, nosebleeds," with one sample "blood test show[ing] exposure to benzene and other chemicals," as well as the death of goats, cows, chickens, cats, and dogs in areas with contaminated water. Also recorded are environmental nuisances such as seismic testing, noise, dust, heavy machinery sounds and emissions, and "bright industrial lights" throughout the night. The list documents how the light of flaring gas wells can trigger post-traumatic stress disorder, including causing flashbacks for people who have served in the Iraqi conflict.

As a form of evidence, this "List of the Harmed" might be considered to fit within multiple forms of citizen reporting often dismissed as "anecdotal" in contrast to more "scientific" methods for gathering evidence and documenting harm. However, not only is "the science incomplete"[39] when it comes to establishing links between fracking and harm, but residents are often uniquely situated to record their lived experiences of exposure to shale-gas production, and so to contribute different forms of citizen data. Care emerges here by indicating the harm experienced by listed individuals and events, which can inform additional ways of addressing the harm and potential harm experienced by communities. What counts as harm, how it is documented, and how this documentation comes to form evidence are questions about the how-to that citizen-sensing practices similarly generate. Practices of how to evidence harm could become as contingent and responsive as the impacts that they would document and address.

How to Sense Pollution

Practices for sensing pollution involve much more than measuring a pollutant. Questions loom about what to monitor, who is monitoring, and how to act upon monitoring results. Concerns surface about what is unmonitored, unaccounted

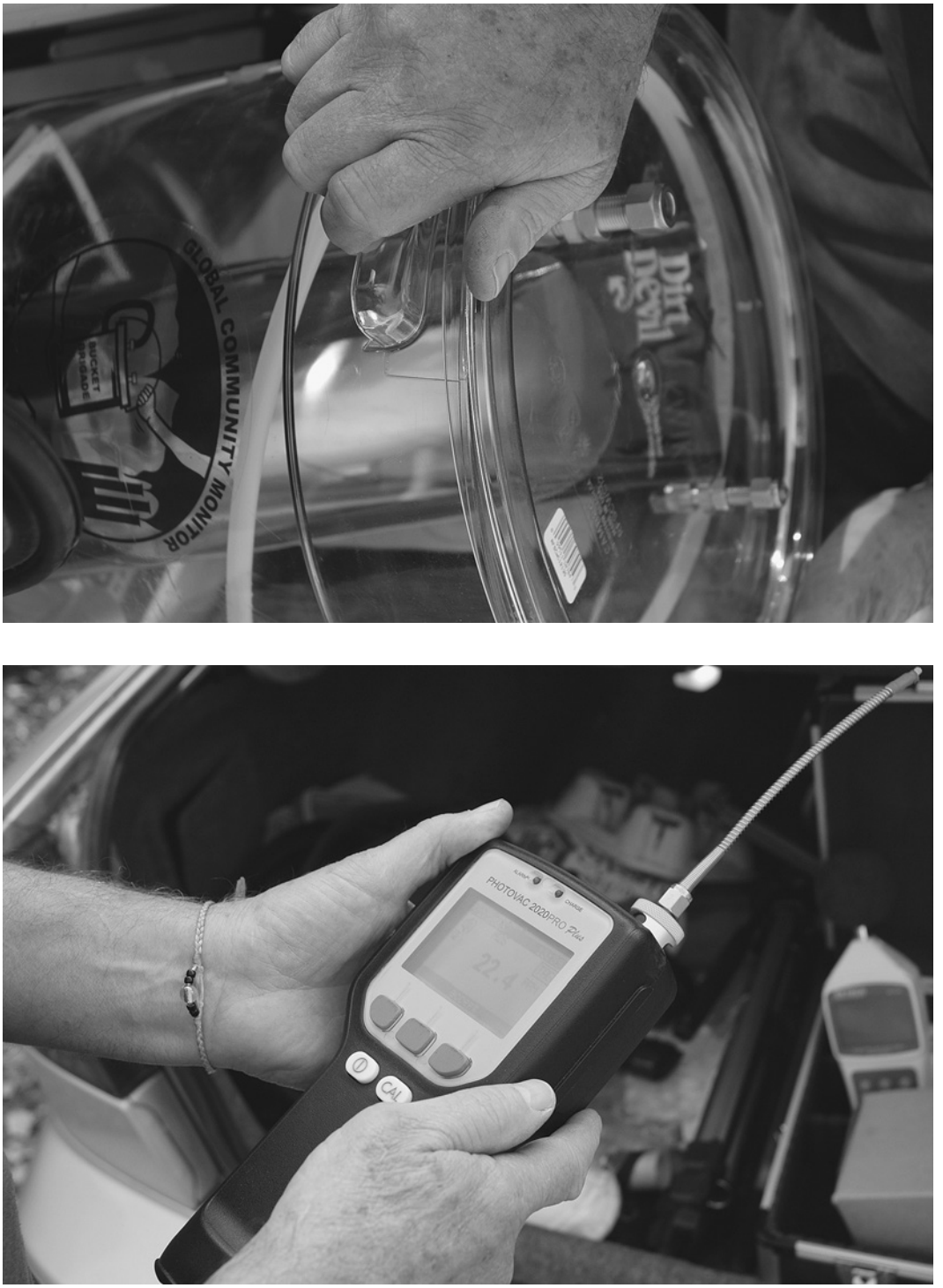


Figure 2.9. Frank Finan showing different devices for measuring VOCs, including a Global Community Monitor bucket for collecting air samples, and a handheld VOC monitor. Photographs by Citizen Sense.

for, yet still could lead to harm. At the same time, the regulatory and enforcement infrastructure for monitoring pollution has not caught up with fracking technology. As a result, it is often ill-equipped to monitor and regulate this industry's complex processes and impacts. Here, speculative forms of citizenship and practices for documenting environmental pollution materialize together as people gather evidence and attempt to make sense of the effects of fracking.

In this context, the Citizen Sense group began fieldwork and desk research in the summer of 2013. We found that many citizen-sensing practices to monitor air and water quality near fracking infrastructure were underway. These practices included various instruments, techniques, sites, pollutants, and environmental media. Residents used devices such as a high-end Photovac 2020PRO Photoionization Detector that can be used for humidity-compensated VOC detection in air, water, and soil. They regularly set up a FLIR Gas Finder that detects seventeen gases at –20°C to +300°C through infrared thermal imaging that, as mentioned in the introduction to this chapter, some have used to document the effects of compressor sites. They participated in installing NGO-loaned summa canisters for testing a range of air pollutants.[40] They set up and wore badges for detecting BTEX chemicals for university studies.[41] And they contributed to bucket-brigade community monitoring, a long-standing analog technique using a bucket with a vacuum-powered pump and bag to draw in air and test for more than seventy VOCs and twenty sulfur compounds—a process that requires samples to be sent off to laboratories for analysis. The data from these citizen-monitoring efforts were collected and presented as lab reports and community organization documents. Many image- and video-based forms of monitoring were circulated online and through video-hosting platforms such as YouTube and Vimeo. Initiatives such as FracTracker provided community-mapping data, and MarcellusGas.org provided monthly reports on fracking production.[42]

While individuals in northeastern Pennsylvania had been undertaking environmental monitoring by using low-tech and high-tech instruments, one of the primary groups contributing to and mobilizing evidence about air pollution was Breathe Easy Susquehanna County. Made up of around twenty members, this citizen group came together in early February 2013 to protect local communities from poor air quality and its health effects, primarily due to the growing fracking industry. In addition to its mission to address air quality, the group outlines its strategy as one of "respectful dialogue between the natural gas industry and our Susquehanna County community." The group's intention was to work with industry to improve air quality across all aspects of the fracking infrastructure, but to encourage voluntary industry efforts in this area rather than seek new

legislation. As the chair of the group, Rebecca Roter, writes on the Breathe Easy Facebook page:

> Breathe Easy Susquehanna County PA (BESC) is a fledgling community group attempting to bring together divergent voices who have been pitted against each other around one common concern, air quality. The marcellus [*sic*] train left the station six years ago in our county. We all live with the same impacts to our community whether we signed a lease or not, whether we were on that train or not. Many of us from across the table share the same concern about keeping our air as clean to breathe as we can. We cannot choose to not breathe as we see more compressor stations and well pads permitted weekly. We need to act now together, to bring our community together now over air quality, to try to keep our air as clean as we can.[43]

The call to work toward breathable worlds, expressed in the very name of this community group—to "breathe easy"—became the basis for developing actions to care for the air, but in ways that would require collective forms of inquiry to establish where pollution was occurring and how to address it.

Air quality was an increasing focal point both for this community group as well as for multiple other residents in the area who were engaged in diverse projects and initiatives to address air pollution. Some residents felt that Breathe Easy's attempt to work with industry but not advance regulation did not hold fracking operators to account. Other groups and residents focused on development plans and used environmental data to contest further industrial activities. While not the only group concentrating on air quality, Breathe Easy was especially vocal about this issue and worked with NGOs, including Shale Test and Earthworks, to collect environmental data on pollution from fracking. The group's members had contributed to VOC testing with buckets and badges and had purchased their own array of monitoring instruments to test air and document industry processes. As Frank Finan, a member of Breathe Easy, noted on the reasons for monitoring air, "We decided on air. It affects everybody."

Although residents and community groups had undertaken water-quality monitoring to assess pollution from fracking, individual residents could have very different exposures to water pollution. Some private wells could be contaminated while others were not, and some residents might obtain their water from municipal supplies. In contrast, air pollution was a more pervasive problem, yet it too was unevenly distributed in the community. Those who lived downwind of compressor stations might suffer much worse air quality than those who have not yet had infrastructure encroach on their home or work environments. Nevertheless,

Figure 2.10. Participant showing use of a Flip video camera for documenting increase in traffic due to the fracking industry and transport of equipment. Photographs by Citizen Sense.

air provided a "focus," since as Frank explained, the group sought "to be focused, to forget about every other aspect of our lives that got screwed." For Frank, this focus on air involved buying and using monitoring toolkits. He bought a toolkit to test water and air as well as radon. He purchased a "four-gas sniffer," and many other instruments that he noted required considerable labor to learn about and use. Because of the effort in using these different instruments, he decided to focus on the "gas finder camera" (the FLIR introduced earlier in this chapter), along with photography, to document the effects of the fracking industry and poor air quality.

Some of these monitoring practices required residents to collect samples for lab analysis. For this reason, citizen-sensing practices that produced "real-time" data on air-pollution levels generated considerable interest as a way to expand ongoing environmental monitoring practices. By comparison, while buckets and similar techniques for monitoring air pollution have been used for fence-line monitoring at refinery sites and as part of environmental justice campaigns, buckets do not generate real-time data.[44] Sensors could provide a more immediate picture of environmental conditions. However, they do not lead to a direct trajectory from data collection to environmental action as change. As it turns out, many complications arise when citizens collect data about air quality.

The gathering of "evidence," which monitoring technologies initially seem to enable, raises more questions about how monitoring is undertaken, how data are collected and managed, how to translate the data into policy and action, and how practices for sensing pollution could expand potential infrastructures of care. Citizen-sensing practices collect data about particular pollutants. At the same time, they can attend to parallel "qualitative" data such as noxious smells, noise, and health effects, which in turn can shift the categories and procedures for how evidence forms. Yet these diverse data types can be challenging to mobilize for political change. They might not easily align with or circulate within regulatory frameworks.

As Michelle Murphy has suggested in her comparison of toxicology tests to citizen-led monitoring practices of indoor air pollution, these diverging evidentiary practices can make present or "perceptible" different aspects of chemical exposure.[45] Toxicology tests focus on how individual chemical concentrations create distinct bodily effects. Yet these practices might not register the diffuse and multiple modes of exposure that are difficult to describe within singular and causal dynamics. By comparison, citizen-led health studies could present a more situated and lived experience of chemical exposure. By registering lived experiences of chemical exposure, such citizen practices could "instigate" other forms of political action, even if they do not align with regulatory frameworks.[46] The

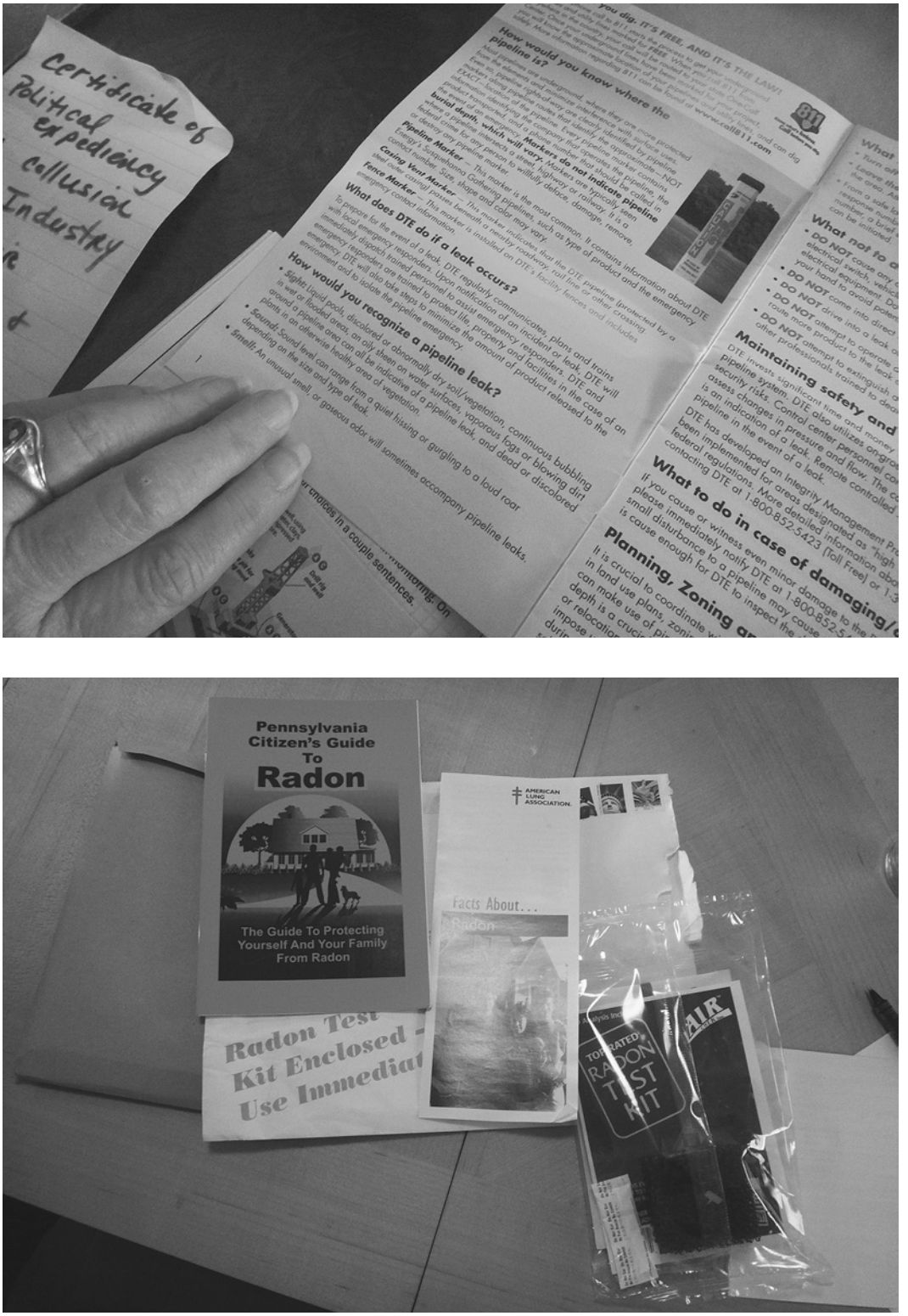


Figure 2.11. Participant showing different brochures and guidebooks for detecting and reporting a pipeline leak and for monitoring radon. Photographs by Citizen Sense.

Figure 2.12. Participant showing decibel meter for documenting noise from fracking industry and showing photo album documenting the changing landscape. Photographs by Citizen Sense.

process of making pollution present and sensible could be differently approached as concentrations, experiences, and lived encounters that anticipate harm to environments, bodies, and politics. At the same time, future effects could evade present perceptibility.[47] Speculative citizenships materialize through this anticipation of indeterminate future effects that mobilize current practices to document, analyze, and struggle toward more breathable worlds.

COLLECTIVE ENVIRONMENTAL INQUIRY

While reviewing monitoring practices already in use within this particular community affected by the fracking industry, the Citizen Sense research group further engaged in participatory and practice-based research to build, install, and test sensor technologies. These mostly digital devices could generate real-time data. They offered different ways of documenting harm and, potentially, of acting on polluting conditions. Through this approach, we then worked with communities to understand how monitoring practices emerge and change as they attempt to account for lived experiences of energy extraction.

When undertaking this research, the Citizen Sense project worked with residents to develop a monitoring toolkit that could monitor air pollution in everyday settings. As part of the collaborative aspect of the research, we established a dialogue with residents of northeastern Pennsylvania about which pollutants and environmental disturbances they were already in the process of monitoring. We studied how and why they undertook environmental monitoring practices, what wider networks were important for communicating their findings, and how it might be possible to work together to develop a citizen-sensing toolkit that would be useful for monitoring air pollution from the fracking industry.

Through a back-and-forth exchange that included several in situ meetings and remote teleconferences with residents, we developed a "Logbook of Monitoring Practices." As detailed in the previous chapter, this was a preliminary toolkit for participants to document their existing monitoring practices, note their particular observations and concerns about how fracking was changing landscapes, and indicate who should be monitoring and what should be monitored. We collected nearly thirty of these completed logbooks. Based on the logbook entries, along with images and video submitted by residents documenting their environments, we identified several possible monitoring technologies and practices that we began to assemble into a Citizen Sense Toolkit for use and testing.

We then developed a Citizen Sense Toolkit for monitoring fracking-related air pollution over several months, spanning from autumn 2013 to the summer of 2014. We designed the kit through ongoing discussions with residents and

participants about the primary pollutants of concern, from nitrogen oxides to particulate matter and noise. Environmental science research that university researchers had conducted in the area also informed people's interest in monitoring particular pollutants. Nitrogen oxides from compressor stations were of concern due to continuous emissions and blowdowns. Nitrogen oxides are also criteria pollutants[48] and can indicate ozone formation. Methane was a pollutant of interest because it could offer a way to detect leaking gas across multiple sites within the fracking infrastructure. While not an air pollutant per se, noise was a topic of considerable discussion, since many people experienced disturbed sleep from the noise and vibration of infrastructure. Particulate matter, which was emitted from diesel trucks and generators and multiple other sources, was of concern as a pollutant particularly hazardous to human health. And VOCs from BTEX to glutaraldehyde were discussed as pollutants specific to petroleum and fracking production that could be monitored to indicate emissions from these industries.

Through research into which sensor technologies might be most adaptable, affordable, and accessible over a longer period of use, we then developed and assembled a Citizen Sense Toolkit of multiple components that were off-the-shelf or developed specifically for the monitoring situation. The toolkit included a Speck $PM_{2.5}$ digital monitor, which sensed, displayed, and recorded particulate matter levels in real time; industrial analog badges, which passively sampled air and monitored personal exposure to BTEX compounds; and several custom-made Frackboxes developed by Citizen Sense, which were placed next to compressor stations and monitored nitrogen oxide, nitrogen dioxide, ozone, and VOCs, as well as temperature, humidity, and wind speed.[49]

The Citizen Sense Toolkit was an assemblage of newly developed instruments as well as existing sensors. We borrowed the Speck monitor from the Create Lab at Carnegie Mellon University, which was making its device widely available for environmental and health groups to use throughout the state. Create Lab was distributing Speck sensors at public libraries in Pennsylvania, loaning devices to environmental health groups, and donating monitors to communities to use in their local areas.[50]

Along with the Speck monitor, we tested and developed our own Frackbox air-quality monitors that housed sensors and a weather station in jumbo black-steel post-mounted US mailboxes. Designed to blend into the rural landscape, the Frackboxes included sensors for monitoring ozone, nitrogen oxides, and VOCs, along with temperature, humidity, and wind direction. A prototype technology, the Frackbox used newly emerging sensors from Alphasense, a research group and factory in Essex, UK, which was developing low-cost air-quality sensors. In parallel to these digital devices, we also included analog BTEX badges from health and

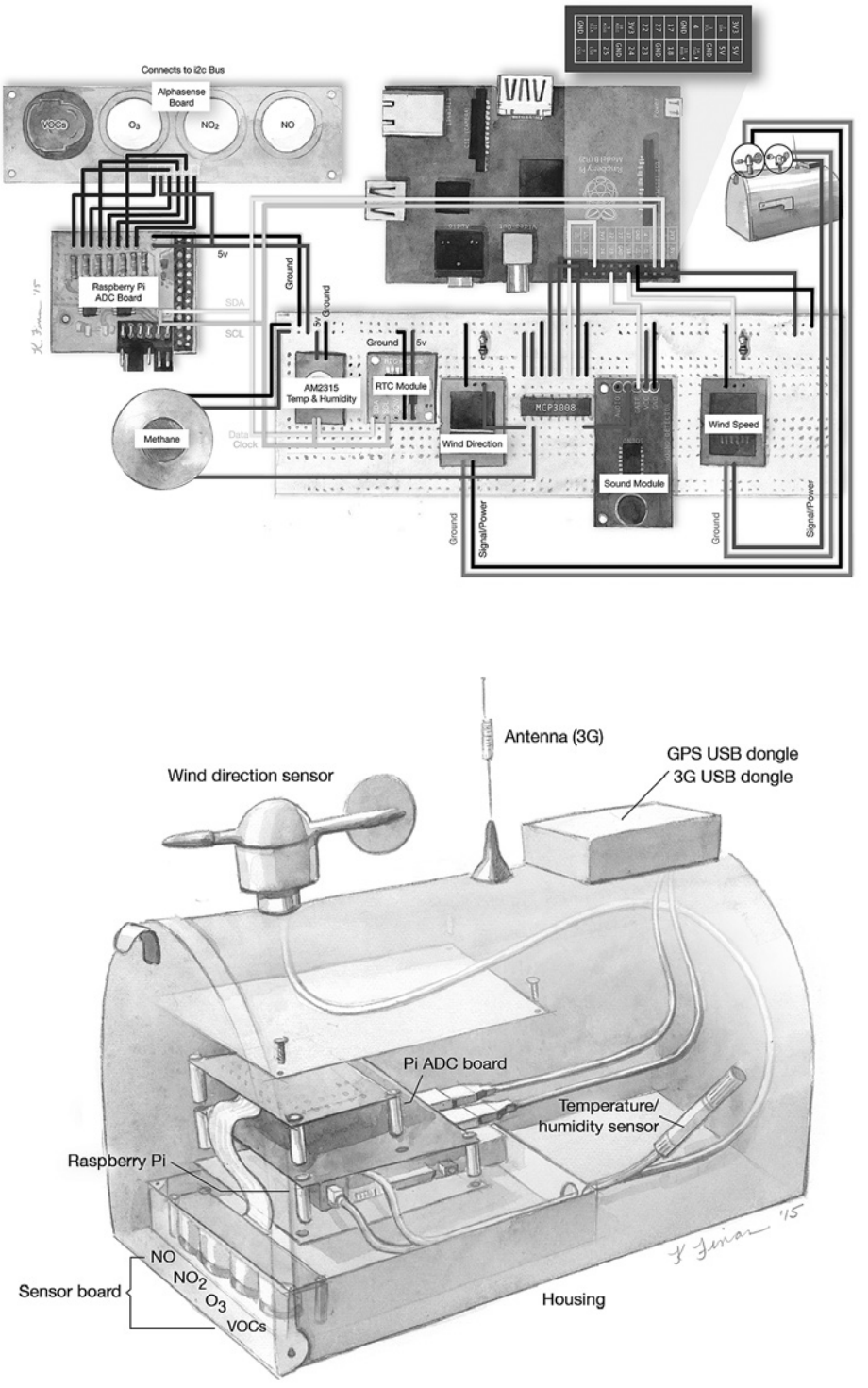


Figure 2.13. Diagrams of Frackbox wiring and Frackbox components. Illustrations by Kelly Finan; courtesy of Citizen Sense.

safety suppliers to test and compare monitoring techniques that local residents had used. These multiple sensors formed the kit of parts that became the Citizen Sense Toolkit and were differently bundled into networks of technology, research, health, communities, and infrastructure in ways that informed the practices and circulation of these devices and their data.

In addition to these different air-quality sensors, the toolkit included a custom online platform. The platform located, logged, and displayed environmental sensor data so that participants could access data and see how the community-monitoring network was forming in relation to sites of concern. Because people felt the monitoring activities could uncover sensitive or controversial findings, we set up the platform as a private site only accessible to participants during the monitoring period to ensure that monitoring locations were not disclosed. Together with the platform and sensors, the Citizen Sense Toolkit included a second logbook, which consisted of a how-to guide and instructions for using the various components of the toolkit. The logbook and online platform provided space for recording observations related to health effects, changes in the environment, and industry activity underway that could be used to explain patterns in citizen data sets.

The Citizen Sense Toolkit was assembled through a process of collectively asking how-to: how to monitor pollutants, how to develop or source sensors, how to site monitoring equipment, and how to record data. Each of these points of collective inquiry opened into discussions of previous research on pollutants and contributors' experience with monitoring, as well as knowledge of instruments and ways of collecting and presenting data as evidence. The how-to aspects of developing an environmental sensing toolkit formed through practices of making and testing while also drawing on earlier monitoring studies and experiences.

The tension between following set protocols for monitoring—which in many cases were not fully established for citizen monitoring—and working in a more experimental register became a dynamic that was collectively yet differently negotiated to make room for the more prospective aspects of these open-air toolkits. The point was not to replicate findings from research that scientists might have carried out previously in the area, but rather to study and document the lived experiences of residents who brought multiple insights to bear on the problem of air pollution and fracking. At the same time, participants were keen to generate "hard data" that would be taken seriously by regulators and ensure that their experiences of harm would be taken into account and addressed. Here, data collection becomes continuous with anticipation, if not speculation, of how to organize to address pollution. As part of this how-to mode of inquiry, not only is the separation between observing and acting undone,[51] but also modes of action

Figure 2.14. Specks set up for a workshop and loaning to participants. Photograph by Citizen Sense.

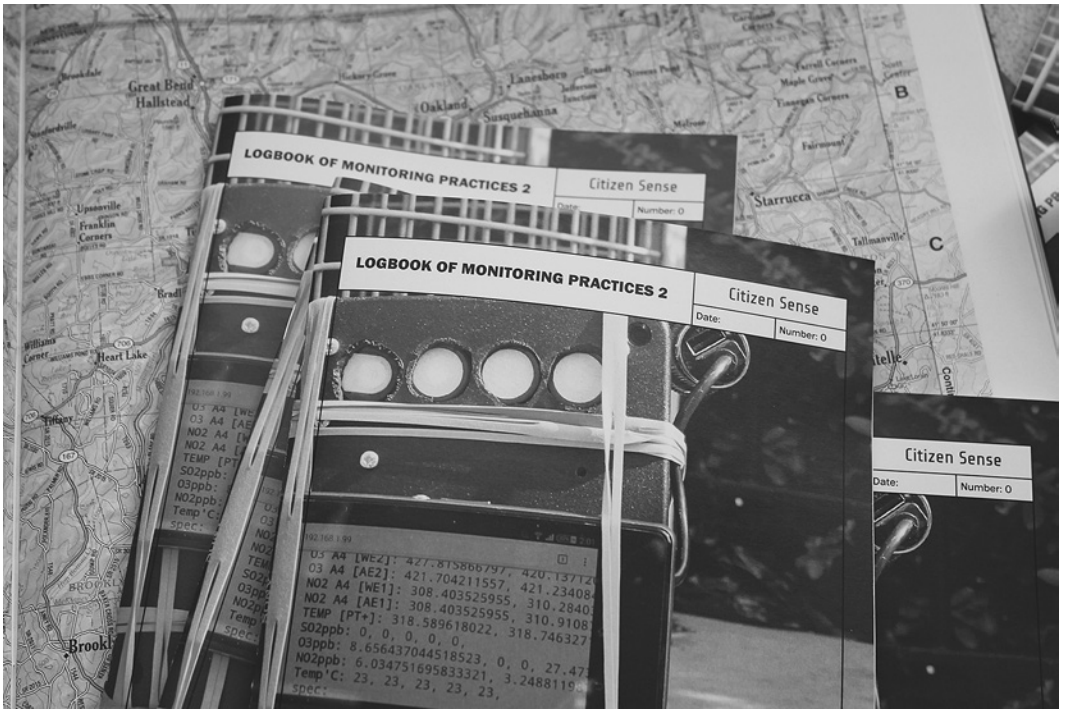


Figure 2.15. Second logbook developed by Citizen Sense, providing instructions for participants for air-quality sensors in the Citizen Sense Toolkit. Photograph by Citizen Sense.

influence the relations that empirical research is meant to have—or might have, in a more speculative register. Here is a method of radical empiricism aligned with open-air instrumentalism, where citizen-sensing practices generate and propose distinct relations, practices, and engagements that work toward more breathable worlds.

How to Activate Open-Air Inquiry

As part of the process for distributing toolkits, in October 2014 the Citizen Sense research group hosted a series of events in northeastern Pennsylvania. The events included a community workshop where the Citizen Sense Toolkit was introduced, a walk along fracking infrastructure on which various monitoring equipment was tested, and a roundtable to discuss broader issues related to fracking and community organizing.[52] We invited community members along with speakers who had experience with environmental monitoring, public health, and fracking to contribute. Participants included residents, technologists, environmental-health practitioners, local ecologists, and community organizers.

During the workshop, we distributed the Citizen Sense Toolkit to residents to test, take home, and install. But even more than learning about the monitoring toolkit, the workshop created a forum for the how-to. This was a space for working through and asking how to monitor air pollution from fracking, what to monitor and where, how to analyze and communicate data, and how to connect findings to other experiences such as health effects. While the workshop sought the input and experience of all involved who might help to identify problems and discuss ways of monitoring, the gathering was one where many people in the room were not necessarily on speaking terms, since the pressures and strains that fracking had placed on the community had led to lasting rifts between people. Monitoring and data collection were perceived to offer a possible neutral zone. Infrastructure could be studied to establish whether it was contributing to elevated pollution levels, and actions could be taken based on evidence. Neutrality was a movable condition that relied partly on our role as "third-party" researchers external to the community and partly on the role of sensors and data as the evidentiary techniques that could be used to hold industry to account.

In this sense, the workshop was also a chance to air concerns and develop a more collective approach to inquiry. As part of this process of inquiry, our research group communicated what our project motivations were for studying pollution in the area, since this information helped residents to understand what our commitments were and decide whether they felt the research was organized to facilitate their own questions.[53] People wanted to know whether we were funded by industry and our views on oil and gas extraction. We explained how

the project was studying the rise of citizen-sensing technologies and practices, and how or whether these were contributing to new or more effective approaches to documenting environmental concerns. We also noted we were interested to understand what practices and questions emerge when people undertake monitoring and use data to address environmental pollution, which we also hoped to address.

This more speculative aspect of the research relied on a collaborative approach to working with the sensors to see how they could contribute to different forms of environmental engagement. We noted that monitoring data could be used in many different ways to document environmental concerns. At the same time, monitoring data alone might not be sufficient to address problems and regulators or industry might not accept citizen data. Documentations of experience alongside sensor data could, in this sense, begin to develop a more compelling narrative about air pollution in the gas fields. We also emphasized that the research process involved open development, where neither the technology nor the research design was entirely "finished" and that the project would continue to take shape as the sensors were installed and used. As a process of open-air instrumentalism, this research was at once speculative and collaborative. It attempted to undertake collective inquiry to respond to changeable conditions while suspending the rush toward specific outcomes. Such an approach could allow other kinds of inquiry—or science—to emerge.[54] This speculative process of open-air instrumentalisms sought to understand how sociotechnical engagements unfold in worlds, as they also work to make breathable worlds.

As part of the citizen-monitoring project launch events, we then took monitoring toolkits out on a drive and walk to infrastructure sites to test monitoring practices and technologies. The drive–walk allowed us to discuss issues related to fracking as well as how best to monitor in particular settings. The walk became an extension of the workshop as inquiry, and yet here we literally moved into the open air. We tested an array of monitoring equipment while also experiencing numerous infrastructural sites and the distinct patterns of pollution that they created.[55]

We began our outing as a group by first driving to the Tennessee Transmission Pipeline. We undertook a walk to see the patterns of forest clearing, land grading, and pipeline installation that characterize this part of the natural-gas infrastructure. A local ecologist, Nancy Wottrich, explained the effects pipelines had in carving up larger ecologies into more fragmented spaces; she noted that this often led to reductions in biodiversity, since many organisms required larger intact ecosystems to survive. Next, we walked from the pipeline to a nearby compressor station, where we had gained permission from the landowner to install

Figure 2.16. Gas pipeline infrastructure encountered during walk with participants. Photograph by Citizen Sense.

a Frackbox to monitor emissions. As we walked to the compressor station with handheld methane monitors, ultrafine particle detectors, badges, and several other monitoring devices, we detected a palpable and acrid wave of air. The churning of the compressor station made it difficult to talk above the noise, and Nancy mentioned that noise was also a pollutant that could damage local ecologies and organisms.

As a mode of open-air inquiry, the walk moved the experience of fracking infrastructure to a more central if even debilitating aspect. We decamped to the road to discuss further how best to monitor and record emissions from these sites. We then drove to our next stop, a gathering line and well pad where active

construction was underway. We first looped around the well pad by climbing an adjacent hill and overlooking the construction site. Diggers and trucks mechanically scraped, leveled, and hauled dirt to create an expanded well pad location, where additional wellheads were being added to the site. Erosion fences were in place next to an extensive area of land that had been seeded after clearing. However, the seed mixes mostly consisted of fescue and clover, a greatly reduced palette that Nancy reminded us bore little resemblance to landscapes prior to disturbance from fracking. Here, new fracking ecologies were being shaped, affecting air, water, soil, plants, animals, and people.

We turned back down to a dirt road near an adjacent gathering line. At this stop, we heard from Laurie Barr, a resident of Pennsylvania who had started a project for monitoring lost, abandoned, and orphaned wells. Because Pennsylvania has been the site of extensive activity from the extractive industries, there are also numerous leftover pipelines, abandoned wellheads, and leaking infrastructural components that continue to affect environments. With her citizen-led project, Laurie had begun an initiative to document, map, and monitor these lost, abandoned, and orphaned sites. She passed around maps of wellheads and showed night-vision photographs of deer drinking briny water at leaking wellhead sites. She also showed her "gas finder" monitor for detecting methane, which she used to assess whether gas leaks might occur at these sites.

As a how-to mode of inquiry, the walk visited infrastructure to observe and document industry operations underway. We observed a Frackbox installation next to a compressor station, investigated a new well site under construction, and listened to community organizers describe their own practices of undertaking environmental monitoring and gathering data. We spoke to residents living near infrastructure to learn more about their day-to-day experiences of industry operations. We also heard about attempts to work with state and federal regulators to understand existing monitoring infrastructures and environmental data, and how these could address fracking-related pollution.

The walk offered a chance to investigate ecological disturbances and learn how new gas-field ecologies form through linear excavations carved into soil and forests, along with grading and clearing that reshaped environments for wellheads and compressor stations. In this way, the walk formed a collective experience of studying these infrastructural ecologies. It also made palpable the unequal experiences of harm from fracking. Some people lived surrounded by compressor stations, and others had second homes in the area. As researchers, we were primarily located in London, far from fracking but not removed from the problem of air pollution. We added to the inventory of harms experienced through the walk and conversations. And we considered how to document pollution with

monitors, diaries, data, platforms, social media, and community organizing as part of the more extensive proposal for how to work toward more breathable worlds.

The walk, workshop, and roundtable served as collective modes of inquiry as well as forums for discussing the problems of air pollution. The concerns and proposals that materialized informed the next steps of the monitoring process, which involved setting up components of the Citizen Sense Toolkit in monitoring locations. How and where to set up sensors, how to monitor and for how long, how to ensure the data would be useful and be listened to: these were all recurring topics in our multi-sited and multi-day conversations as we installed sensors. We visited residents, often at their homes, to help set up devices, ensure that connections were made to the data platform, and discuss issues related to monitoring. Participants were interested in monitoring at several sites, comparing infrastructural locations, and even surrounding infrastructure with sensors. While we had a limited number of monitors, we began the process of visiting locations of concern, working with participants to set up sensors, and establishing a connection between sensors and our platform so that participants could view data in real time and over time, as well as compare their data to other monitoring locations in the network.

Numerous questions arose in the process of setting up Specks, which was often far from straightforward. Sheltered outdoor locations needed to be identified, power cables needed to be sourced, duct tape had to be procured, and Wi-Fi had to be connected. The minor digital infrastructures that enabled monitoring became sites to identify, adapt, and stabilize to undertake monitoring. The online platform similarly required tussling with home PCs and ancient operating systems, Internet Explorer browsers, and multiple components that were not part of our original testing of the website. Eventually, multiple monitoring locations came online and a community-monitoring network began to take shape and grow, surrounding infrastructure, roadways, and homes in this three-county area of Pennsylvania.

Along with the Speck monitor setup, we placed Frackboxes at three strategic locations next to compressor stations to monitor this industry infrastructure that was of particular concern. Setting up the Frackboxes required installing mailbox posts (in some cases) or sourcing stands, along with power for the Frackbox to function. One Frackbox was powered by solar energy, and this required setting up the PVC panel and battery in a plastic tub in the woods. Data were piped over a 3G dongle to the internet, forming an at times precarious connection in this remote location. While they were a provisional and test device, the Frackboxes and their data were of considerable interest in the community. In the early stages of setup, Fox News learned of the devices through a community member and

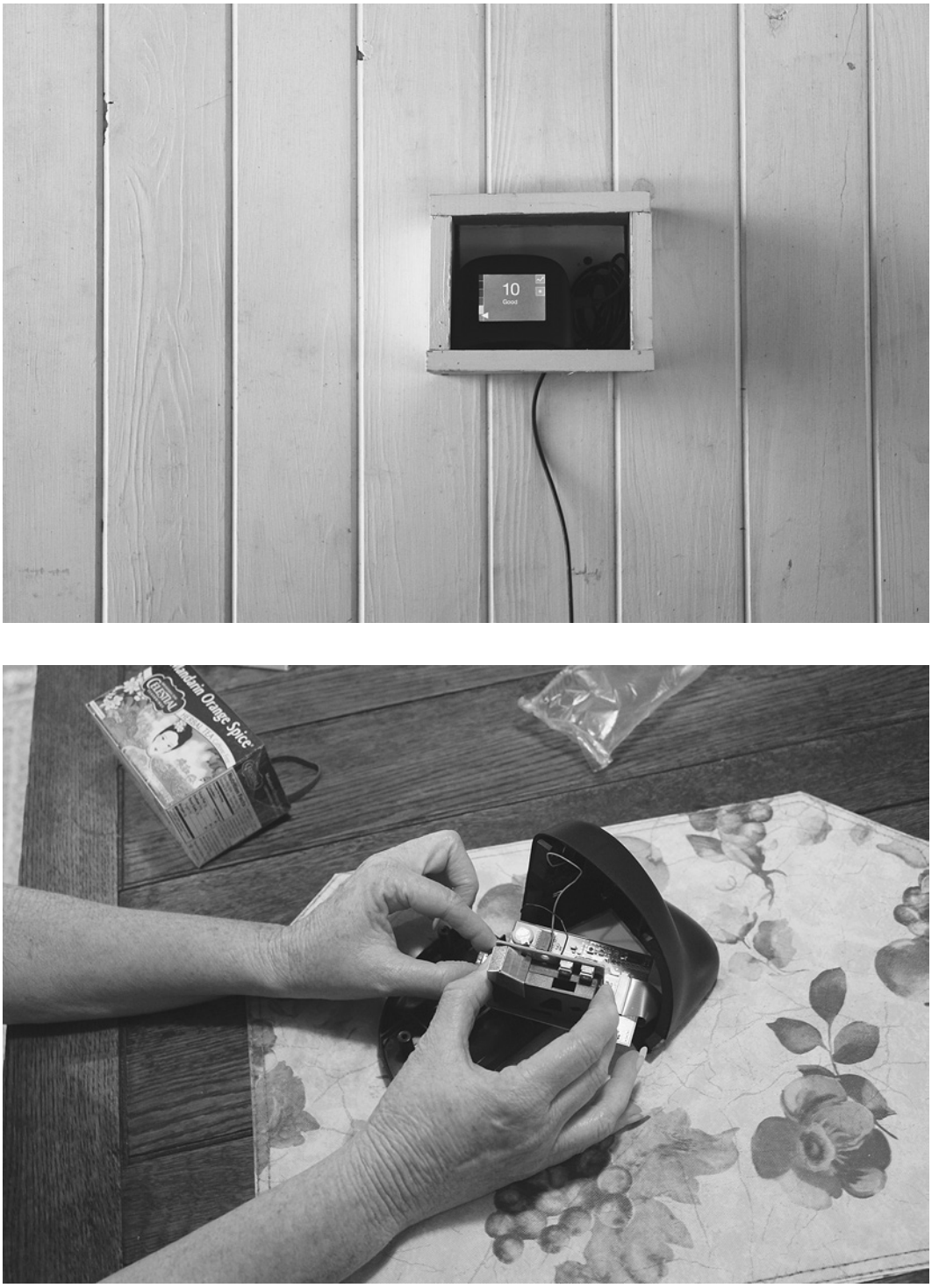


Figure 2.17. Setting up Specks for monitoring particulate matter at participants' monitoring locations. Photographs by Citizen Sense.

contacted us about the data. We told the reporter that the locations were confidential and that the data had yet to be analyzed or verified. Nevertheless, a cat-and-mouse game ensued, with one Citizen Sense researcher having to duck out of a hotel early in the morning when learning of the reporter's plan to intercept the researcher in the hotel parking lot. Working with technologies in the open air, we learned, was also a process that could lead to overlapping and controversial forms and worlds of inquiry.

How to Transform Data into Evidence

In all, we distributed nearly thirty Citizen Sense Toolkits to participants, which they used over a period of seven months. We also installed three Frackboxes that ran for the duration of the study, even in the depths of winter during blizzard conditions. We had initially planned to monitor for three months, but new participants continued to join. A broad range of monitoring practices materialized across multiple locations. Some participants produced long-term, continuous data sets while recording their experience of pollution. Others contributed data for a few months or weeks until devices had to be moved or unplugged. Participants logged their approximate monitoring location on the Citizen Sense Toolkit platform, primarily through the use of the Speck $PM_{2.5}$ monitor, but also by logging their observations of industry and other activity that might generate high $PM_{2.5}$ levels. Data were available to view both in real time on actual Speck devices and on the platform once uploaded. Observations and readings could be compared across distinct monitoring locations, and in some cases discussion arose about the multiple readings, techniques, and events that might cause elevated pollution levels. Participants considered whether nearby gas infrastructure caused elevated readings, or if high pollen counts or other industries nearby were causing spikes in their data.

This collaborative process unfolded an ongoing set of questions about how to monitor, what to do with their data once it was collected, and how to ensure regulators take their data seriously. At various points, participants suggested that their data were not indicating anything of significance, which often meant that their lived experiences of odor or nuisance or perceived emissions did not match up with real-time displays on the Speck or in the data collected and available on the platform. There was a sense that an immediate register of harm should be evident, or else the device was failing to perform. Here, the device did not make pollution evident in the way it was expected to. The sense that pollution must be present created dissonance across machinic and bodily experiences of environmental events.

Figure 2.18. Setting up Specks for monitoring particulate matter at participants' monitoring locations, and analyzing citizen data using the Airsift 1.0 platform. Photographs by Citizen Sense.

On other occasions, Speck monitors would provide high readings, or spikes in $PM_{2.5}$ levels. There was often a process of troubleshooting to understand what could be causing the high readings: Was it a device malfunction, or was a pollution episode or some other atmospheric event underway? On one occasion, two participants and members of Breathe Easy, Chuck and Janis Winschuh, called the Pennsylvania DEP in order to lodge a complaint in relation to a high $PM_{2.5}$ reading on their Speck. Chuck and Janis found that when they were visited by the DEP, industry representatives also came to their home to find out what monitoring equipment was in use and how the study was organized. The participants' concern was that neither the DEP nor industry actually attended to the high readings they recorded, which occurred over several hours and were not due to a faulty device.

Chuck and Janis subsequently took their story to the media, which documented how regulators and industry responded to their citizen-sensing activities and concerns about pollution.[56] In the process of attempting to evidence harm, Chuck and Janis found that their data were of less interest than the act of citizen monitoring. Here, the "evidence" of harm materialized not through data sets but through participating in a citizen-sensing study and having that participation queried. Such an arrangement resonates with Murphy's suggestion that monitoring can be as instigatory as it is evidentiary, since the DEP and industry were apparently more attentive to the "fact" of community organizing than to the data they were collecting.

Yet this is by no means to discount the importance of data collected by citizens, since it has also been used to document pollution levels of concern. Other participants, Meryl Solar and Rebecca Roter, found that the intense and rich data sets collected, which numbered over five million data points by the end of the monitoring period, could be mined for patterns using Microsoft Excel spreadsheets to indicate that harmful levels of $PM_{2.5}$ were occurring at several sites across the community-monitoring network. Meryl and Rebecca used these data to arrange a teleconference with the Pennsylvania DEP, the Pennsylvania Department of Health, the federal Agency for Toxic Substances and Disease Registry (ATSDR), and the Centers for Disease Control, along with Citizen Sense, to discuss their findings. Agencies and regulators were skeptical about the citizen-sensing devices and raised queries about their calibration and use as well as the validity of the data. Yet Meryl and Rebecca were able to use a combination of data and experience of lived exposure to make a case for regulators to undertake follow-up monitoring at one of their homes.

While we were analyzing and communicating preliminary findings from the data, it became clear that the graphs available on our provisional platform could

not fully convey the different patterns of pollution experienced. How to analyze data then became part of the long list of how-to items that unfolded through this collaborative research. While working with a King's College London atmospheric scientist, Benjamin Barratt, we learned of an open-source software, openair,[57] which we could use and adapt to analyze citizen data. With the objective of making a DIY data-analysis platform, we then made a citizen data toolkit, Airsift, which would allow participants to analyze their data more fully according to the time of pollution events, the direction of pollution, and the likely source of pollution based on wind speed, humidity, and a host of other variables. We were assembling an expanding community-monitoring infrastructure that adapted to conditions taking place quite literally in the "open air," in response to political engagements and pollution events. These open-air instrumentalisms did not arrive at a finished condition as such but rather worked through ongoing processes of inquiry to generate practices for evidencing harm. They were, in this sense, forming speculative citizenships that struggled to create tactics and forums for reducing and mitigating environmentally destructive practices.

With the plots and graphs we were able to generate from the Airsift toolkit, we worked with participants to collect on-the-ground observations and experiences of pollution that together formed narratives for five key locations in the network. We developed these narratives into data stories according to the township where the monitoring had taken place.[58] The data stories documented pollution levels in Bridgewater, Brooklyn, Dimock, Mehoopany, and Liberty Townships. The data stories analyzed the citizen data and observations of pollution events, while providing indications for how to mitigate or reduce pollution based on findings. Citizen Sense launched the Pennsylvania Data Stories in April 2016 and, along with participants, shared the findings with state and federal regulators.[59]

Soon after we launched the data stories, the ATSDR released a report that documented the results from their parallel follow-up monitoring.[60] Their report documents how they found elevated $PM_{2.5}$ levels at the test monitoring location, and higher pollution levels were likely attributable to nearby infrastructure. The report corroborated the citizen data findings at this Brooklyn Township location. These findings also led the ATSDR to recommend that the Pennsylvania DEP develop more robust practices for monitoring and mitigating emissions, particularly from industry.

Just after the ATSDR made its report public, the Pennsylvania DEP announced that it was undertaking an "unprecedented expansion" of its $PM_{2.5}$ monitoring network.[61] In turn, the fracking operator whose particular infrastructure was near the ATSDR monitoring location responded that it was disappointed by the DEP's decision to undertake additional air-quality monitoring and that it found

the ATSDR's report to be based on "speculative" data.[62] Commenting on this news, Rebecca indicated that a speculative approach was in fact not a bad thing, since waiting for harm to be done and then conducting "retrospective public health studies" was less advisable than taking action before harm was done.

The process of evidencing harm drew on multiple forms of data and evidence, some of which could be considered "speculative" exactly because they were generated through provisional practices. Yet these practices enabled residents and agencies to make a case for greater levels of care in the form of monitoring and attending to exposure from fracking to avoid harm before it occurs. Speculative monitoring practices became a way to evidence and work toward reducing harm. Rather than wait for harm to be done, the citizen-sensing practices demonstrated that pollution was occurring at elevated levels and that action should be taken to prevent future harm. Speculative citizenships materialized here as a practice for proposing political subjects and engagements that could work and struggle toward more breathable worlds. Rather than simply document pollution once it has affected environments and health, here speculative citizenships sought to prevent pollution before it occurs.

In 2018 the Pennsylvania DEP installed a regulatory air-quality monitor for $PM_{2.5}$, carbonyls, and VOCS in an area where citizen sensing had taken place.[63] Situated in the township of New Milford, the monitor signals to the community that the DEP has begun to take their concerns about air quality more seriously.[64] However, the expansion of this network also raises questions about the extent to which monitoring can become a practice of preventing harm, or whether it can become a mechanism for allowing an "acceptable" level of pollution to occur. Monitoring practices could create an uneven relationship to improving or detoxifying environmental conditions, since polluting industries could potentially expand if an official monitoring location can demonstrate that pollution levels do not exceed regulatory guidelines. Moreover, under a new administration, the federal EPA dialed back regulations for oil and gas, in a move that suggests evidence and harm can be the least of concerns where extractive industries are concerned.[65]

The overall inquiry of "how to evidence harm" that guides this collaborative research is how or whether evidence could be sufficient to address or forestall harm. Here, somewhat remarkably, citizen data contributed to evidence-based policy that led to the expansion of a state air-quality monitoring network. And yet, the influence that citizen data had in this process and decision was not always publicly acknowledged.[66] Evidence and recognition of harm were not necessarily communicated through the more accountable and transparent channels and forums of governance and industry engagement that communities sought.

Moreover, not all residents who undertook monitoring would necessarily have equal access to creating and communicating evidence. For instance, property ownership might seem to confer more rights on people who monitor air quality than on those who do not own property. These forms of speculative citizenship might in turn reinforce, rather than transform, unequal forms of property-based citizenship formed through economic inequality and settler colonialism. At the same time, it is a curious contradiction that property ownership does not confer as many rights as might be expected, where eminent domain is frequently exercised to install pipelines and infrastructure across the gas fields. In a related way, homeowners in Flint, Michigan, did not seem to have greater sway over the problem of water pollution.

While certain evidence can count in distinct situations when communicated by well-connected actors, it might also be overlooked or ignored, depending upon prevailing political interests and socioeconomic power relations. In other words, the drive toward creative democracy and inquiry that would work through a Deweyan critical and engaged intelligence is thwarted by power struggles and inequalities. As Cornel West writes in his study of pragmatism, such striving toward radical democracy can present severe limits for "the wretched of the earth, namely, the majority of humanity who own no property or wealth, participate in no democratic arrangements, and whose individualities are crushed by hard labor and harsh living conditions."[67] Rather than unfolding as participatory democratic exchanges, practices of gathering and presenting evidence could reinforce and exacerbate inequalities. Indeed, regulators and industry could issue a repeated demand for evidence—to prove that pollution is occurring—but then disregard that evidence.[68] The gathering of evidence could then lead to exhaustion and injustice, a topic that will be taken up and further expanded upon in the next chapter. Yet here it is important to note the variable and uneven ways speculative citizenships can materialize when attempting to evidence harm and generate responsive practices of care.

How harm registers, the forms of evidence that are admissible, the subjects that can convey and act on evidence, and the worlds that are varyingly configured or denied—all of these are expressions of power. How to evidence harm asks how it could be possible to account for more and other experiences in struggles for more livable and just environments. Speculative methods, as Ruha Benjamin notes, can be a way to extend social practices toward possibilities for greater equity in the facts that are taken into account and how they are acted upon. Working in a register of speculative fiction, Benjamin suggests that these modes of inquiry can offer a way to "experiment with different scenarios, trajectories, and reversals, elaborating new values and testing different possibilities for creating more

Figure 2.19. Frackbox installations at two different locations near compressor stations and other fracking infrastructure, including a toolkit hosted by Paul Karpich in Dimock. Photographs by Citizen Sense.

just and equitable societies."[69] As processes of open-air instrumentalism and collective inquiry, citizen-sensing practices demonstrate that evidencing harm is a complex process that organizes sensing, facts, relations, environments, and speculative citizens toward different possible environmental inhabitations. How-to as a process of evidencing harm can designate a speculative mode of inquiry. How-to can also demonstrate the politics whereby decisions are made, as well as propose how to struggle toward and realize more breathable worlds.

HOW TO EVIDENCE HARM

In this account of working with residents in the gas lands of northeastern Pennsylvania to monitor air pollution, it becomes clear that citizen-sensing toolkits materialize as much more than digital gadgets or makerly gear. By tackling concrete problems, citizen-sensing practices and technologies quickly become bound up with environments, communities, institutions, and wider politics. The accuracy of monitoring devices, the monitoring protocols used, the legitimacy of the data, and the agendas of communities all influence citizen-sensing practices and citizen data. Here, participation involves much more than merely using a sensor to collect data about a particular pollutant. Instead, it sprawls into struggles for how to be and become citizens, and how to make more breathable worlds.

This discussion of collaborative air-pollution research examines how citizen-sensing practices generate alternative forms of evidence to document harm that is often overlooked or neglected. Citizen sensing here moves beyond the narrow outline of "data to action" to open into distinct worlds of inquiry and political struggle. Different relations and communities might be activated through monitoring practices, or existing communities might reencounter persistent problems while finding ways to hold environmental regulators and industry to account. Moreover, the citizen-sensing data do not always readily circulate to relevant agencies. Instead, data are potentially generated in excess, difficult to collate and present, and subject to disputes about their legitimacy.

Attempts to "care about air" generate speculative citizens and worlds in the making. Multiple practices and infrastructures of care could materialize as speculative approaches for evidencing harm. These practices even become necessary to express how harm materializes outside of or in the absence of protocols and practices recognized by environmental regulation and policy. Speculative forms of citizen-led environmental sensing could facilitate the process of generating new approaches to what counts as evidence to include registers of experience that might ordinarily be dismissed or overlooked. By opening up air-pollution monitoring to these expanded approaches to data and evidence, it could then be

possible to incorporate speculative engagements not as the opposite of evidence and "proof" but rather as an indication of how citizens are demonstrating what matters to them in their lived environments and how they are attempting to bring their experiences into spaces of recognition and relevance.

Sensor technologies often promise an ease of participation and contribution to environmental problems. Such promises could be tested and even critiqued. Yet sensing technologies can also give rise to struggles to democratize environmental monitoring and evidence. New forms of environmental politics and expanded approaches to capacity building could be generated through these efforts to address environmental problems. At the same time, a scientific approach to encountering environmental issues—establishing a hypothesis, evidencing this with data, and bringing forward findings—does not necessarily fit so neatly with a potentially more distributed, community-driven, qualitative as well as data-based set of concerns about the environmental effects of fracking. If emphasis is primarily placed on gathering data to evidence claims, then other modes of organizing might be less foregrounded, even though they are crucial to developing collective approaches to environmental problems.

The Citizen Sense project has been committed to investigating community-monitoring practices already underway as well as rethinking and reworking what monitoring practices might become through practice-based research. Research into environmental monitoring could, in this sense, attend to how diverse modes of evidencing harm are generative of collective practices of care. In relation to social research and practice, this could generate distinct approaches to engaging with environmental communities, speculative citizenship, and participation—as collective inquiry and struggle. These are undertakings that often proceed from more apparently epistemic and information-based starting points: how to gather evidence to demonstrate the facts of pollution. And yet, what might it mean to undertake an environmental monitoring project from the perspective of *experience* as a form of evidence in the making, and not just from information and awareness? Such a question, as I have discussed in relation to citizen sensing and citizen data, is concerned not simply with how facts take hold, but more centrally attends to how experience is a critical part of speculative propositions and their effects that might generate more breathable worlds.

In this sense, I understand speculative practices for evidencing harm to offer up as much an opportunity as a dilemma, a challenge as a creative opening, since these sensing practices might generate more accounting-based ways of understanding environmental problems by limiting speculation. In other words, they could document pollution without providing any clear indication of how to act. Alternatively, citizen-led monitoring could generate open-air instrumentalisms

and speculative configurations for addressing situated environmental concerns.[70] Practices for evidencing harm could then anticipate and speculate toward ways of addressing harm through attending to lived experiences of environmental destruction.

As discussed in the previous chapter, this is a more propositional approach to evidence, or as Dewey has suggested, a focus on "consequent phenomena" rather than "precedents" that attends to the "possibilities of action" and the constructive functioning of thought.[71] West refers to this approach as a "prospective instrumentalist viewpoint."[72] Open-air instrumentalism outlines this prospective approach to evidence, where ways of observing and experiencing worlds also constitute potential courses of action. Open-air instrumentalism encompasses such collective and multi-agential modes of experience: these actions exceed a willful liberal subject in their reliance on pluralistic relations and worlds of influence.

This discussion proposes that citizen sensing, when undertaken in a speculative register and through speculative trajectories of citizenship, could draw out the potential and instigatory—rather than simply descriptive—registers of these practices. If speculation is a practice generative of possible futures, then a speculative approach to evidencing pollution and harm from fracking could rework the problem of how to register fracking's impacts as well as work toward practices for mitigating emissions and exposure. Such an approach to researching environmental monitoring practices seeks simultaneously to engage with the more speculative aspects of monitoring as they are undertaken and to rework the subjects and potentialities of monitoring by adopting a more deliberately propositional approach to pollution sensing and to evidencing harm.

Environmental sensing and monitoring are practices of inquiry that set in motion speculative subjects and worlds. Speculative citizens form here as distinct political subjects and collectives through attempts to evidence and to prevent harm. They manifest less as predefined entities than as subjects that form by working through perceptive and affective problems in milieus.[73] Speculative citizens are thus less figures of belonging to a predefined territory in the usual sense of citizenship, and are more expressive of operations that contribute to the formation of politically engaged subjects. This way of parsing subjects is also not de facto human-oriented, since the actual entities of citizenship might form as conjugations of experience across sensors, data, toolkits, collectives, environments, pollution, air, and organisms. In other words, speculative citizens are designations of political pluralities and collectives. Speculative citizens are citizens of worlds, where both citizens and worlds are in the making within open-air sensing practices.

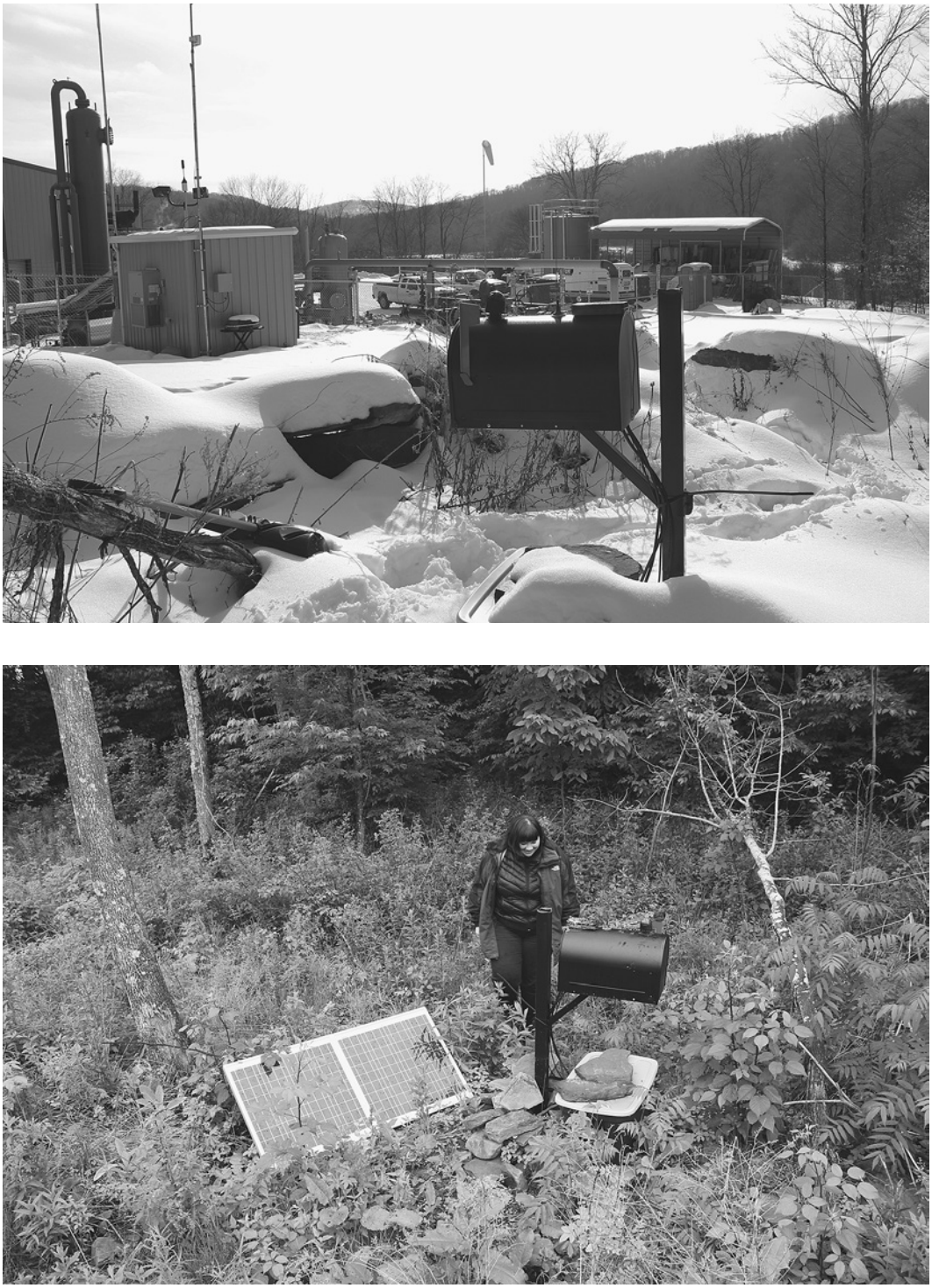


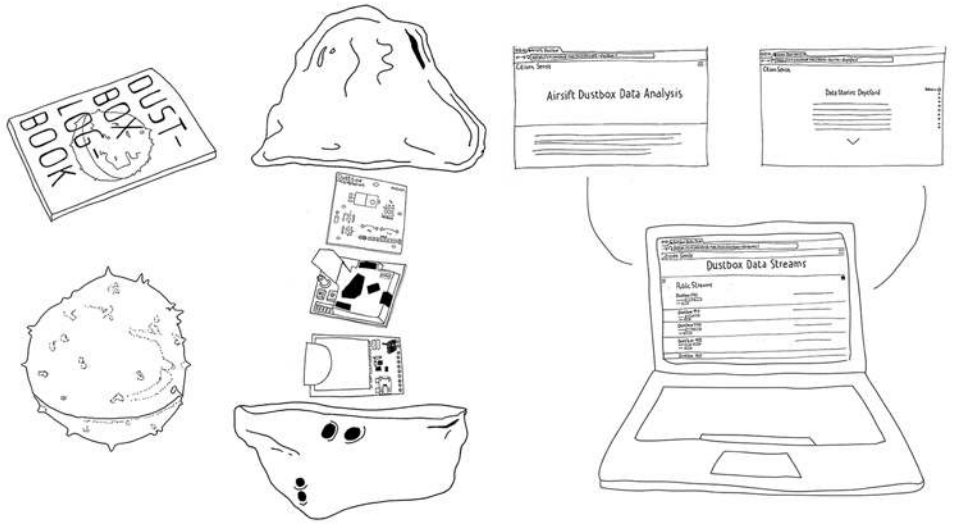
Figure 2.20. Frackbox installations through winter 2014 and summer 2015 at compressor station. Photographs by Citizen Sense.

Extending monitoring into a speculative register makes it possible to develop an account of the entities that are drawn together within pollution sensing to speculate about environmental events, politics, and futures. A speculative and collective approach to pollution sensing could help articulate environmental politics—and citizenship—differently. In other words, a speculative approach to environmental monitoring could recast or reformulate the problem that monitoring is meant to address. Monitoring, as a speculative proposition, could in this way be approached as an adventure not just in making things possible but also in making things (and worlds) matter in particular ways. Monitoring expresses a way of being for distinct worlds; it presents a proposition and its effects that allow worlds to take hold. It articulates a "feeling for the datum" that issues from ways of "possessing" a world.[74] Citizens, in this way, materialize along with care and concern for worlds. Because propositions are generative of effects, Stengers reminds us to attend to the question of what is required for any particular foothold to persist. In other words: "From what wager does your success proceed?"[75] Such a question points to how particular commitments form worlds in which speculative citizens, sensing practices, and breathable worlds come to matter.[76]

From this discussion of air-pollution monitoring, I suggest that it could be possible to rethink care not as a prescriptive or normative relation but rather as a speculative mode of encounter. Care materializes here through monitoring practices that work to evidence experiences of harm to environments, health, and breathable worlds. Such an approach further points to the importance of adopting a deliberately speculative engagement with citizen-based monitoring, since many experiences could have been overlooked, exposures could be undocumented, and harm could be yet to be understood. In this way, it might be possible to approach monitoring as an evidentiary practice and as distributed formations of experience. The "taking into account"[77] that monitoring puts into play is more than a practice of producing a set of data on pollutant concentrations. Instead, this practice involves attending to how the speculative effects of fracking register, whether through data, bodies, sensors, environments, water, air, health, or political struggles. From this perspective, practices and policies for "caring about your air" could shift both to address overall emission levels of criteria pollutants and to consider the multiple ways in which exposure occurs, is experienced, and continues to be generative of new practices and entities—and harmful effects. Practices for acting on air pollution could then become as speculative and responsive as the conditions they would address.

TOOLKIT 3

DUSTBOX TOOLKIT



Dustbox particulate-matter sensor and monitoring kit developed by Citizen Sense for monitoring air quality in Southeast London. Illustration by Sarah Garcin; photograph by Citizen Sense; courtesy of Citizen Sense. This toolkit can be found in a more extensive form online at https://manifold.umn.edu/projects/citizens-of-worlds/resource-collection/citizens-of-worlds-toolkits/resource/dustbox-logbook.