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# Building Capacity for Action-Oriented Research in Arizona's Helium Extraction Boom: A Capabilities Model for Social Learning in Engaged STS

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## Abstract

Northeast Arizona's Holbrook Basin is an epicenter in the rush to secure new helium deposits in the U.S. While the helium boom has revealed unease amongst residents, significant knowledge and procedural gaps have prevented the public from making sense of the industry and its potential impacts. These gaps are produced by the opacity of critical minerals extraction, long-term regulatory neglect, and lack of commitments to public participation in environmental governance. However, we suggest that engaged STS scholarship can meaningfully assist at-risk communities in navigating these complexities. This is illustrated in a series of workshops developed by STS researchers and residents for the purpose of building local capacity for independent research and knowledge production. We detail the mutual affordances of these workshops and offer a potentially replicable framework: The Capabilities Model for Social Learning in Engaged STS. We conclude by arguing that this model is a useful lens for examining how STS critical thinking can be leveraged in collaborative research to pursue long-term social change.

## Keywords

engaged STS; capabilities approach; social learning; critical minerals; helium extraction; Arizona

## Introduction

In 2018, the U.S. Department of Interior (DOI) published a list of minerals deemed "critical" to national security and economic development (DOI 2018). Amongst cobalt, lithium, uranium, and other resource of national concern, helium was the only gas included on this list. While helium's scarcities may mirror those



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of other critical minerals, its uniqueness is defined by its regulatory history. After nearly a century of federal control in the helium industry, congressional privatization plans initiated in the 1990s are set to close the U.S. Federal Helium Reserve in 2021. Meanwhile, domestic sources of helium are in rapid decline at a time when global helium markets experience recurrent shortages. A significant private sector is now materializing in the U.S., with dozens of operators speculating for helium-rich gas reserves, particularly in Western States along the Colorado Plateau. Northeast Arizona's Holbrook Basin, the focus of our study, is an epicenter of this helium boom.

The helium boom has unleashed significant unease in the Holbrook Basin about gas extraction's potential environmental and social impacts in a region already pressured by extreme aridity and rurality. Lack of information on what extraction techniques might be used, and what regulations apply to the industry, has additionally led many residents to invest in an imaginary where hydraulic fracturing (fracking) at scales seen in the shale gas industry might soon be unleashed in the region. These knowledge gaps are amplified by long-term disinvestments in Arizona's regulatory policies, public participation processes, and government-sponsored geological science that might otherwise be utilized to make sense of a rapidly growing, but relatively unknown industry.

We argue, however, that Arizona's helium boom offers important insights into how residents in dispersed communities come together to make sense of the sociotechnical and geopolitical obscurities of critical minerals extraction in a neoliberal society. An emerging group of scholarship spanning ecological economics, sustainability studies, and environmental policy, examines relationships of supply and demand, economic nationalism, and risk assessments within the critical minerals industry (Jin, Kim, and Guillaume 2016; Buijs and Sievers 2011; Hatayama and Tahara 2018; Phadke 2018; Barandiarán 2019). STS is also increasingly concerned with critical minerals; bringing attention to the social constructions of how minerals are deemed "critical" and the double binds of extracting critical minerals to support green economies and energy transitions (Phadke 2018; ibid. 2020; Barandiarán 2019). In this paper, we contribute a deeper investigation of how the critical minerals industry is understood and experienced at sites of extraction. We also examine how "engaged STS" concepts and methods (Downey and Zuiderant-Jerak 2016; ibid. 2019) can provide foundational tools for advocacy groups seeking to fill knowledge gaps produced by critical minerals extractions' obscurities.

To make our case, we examine the story of a grassroots advocacy group called No Fracking AZ (NFAZ) that emerged to do research on the helium industry in order to educate the public, engage with regulators, and respond to extraction's potential encroachments. As part of their efforts, NFAZ contacted researchers in the Civic Science for Environmental Futures Collaborative (CivicFutures), a research lab at Arizona State University, for technical assistance. We detail how CivicFutures developed a research relationship with NFAZ, and how this shifted from a knowledge-sharing model to a process of building capacity for community-driven knowledge production. This was achieved through a series of participatory "research methods" workshops, informed by social learning (Lave and Wenger 1991) and capabilities approaches to environmental justice (Sen 1990; Nussbaum 2001). We evaluate the workshops in their ability to forward NFAZ's organizational objectives and reflect on how the process created cyclical opportunities for additional research partnerships and projects. We refer to this process as the Capabilities Model for Social Learning in Action Research, and conclude by suggesting that this is a potentially transferable model for engaged STS scholars seeking to mobilize their research through generative partnerships for social change.

## Government Control, Shortages, and Privatization in the Helium Market

Helium is the second most abundant element in the universe, but one of the rarest on Earth. Yet, helium is an essential resource for a range of industries. Helium is one of only a handful of inert, nonreactive gasses central to manufacturing microelectronics, fiber optics, and metal alloys. Helium also has the lowest freezing point of any other known substance. Aside from commercial uses, more than 400 research centers in the U.S. depend on helium to run various experiments—thousands of instruments, such as spectrometers, superconductors, and quantum computing equipment, run on helium (Bare et al. 2016; National Academy of Sciences 2010). However, helium's small molecular structure also makes it extremely rare. Helium is produced naturally underground as the final stable product of decaying radioactive substances, such as uranium and thorium. The majority of helium escapes the Earth's surface, drifting into space before it can be captured but, in rare circumstances, a small percentage does get trapped under dense salt-bed geologic formations (Sears 2015).

The federal government has maintained unusually tight control over the U.S. helium market for more than a century, due to helium's value as a strategic military resource—mainly keeping afloat a fleet of WWI airships and later for testing rockets in the Cold War space race. Beginning with the Mineral Leasing Act (MLA) of 1920 and the Helium Act of 1925, private industry was barred from extracting helium from federal lands (30th Congress 1920; 68th Congress 1925). The Helium Act also led to the establishment of the Federal Helium Reserve (FHR) in 1929, through which all U.S. helium purchasing was managed (Nuttall, Clarke, and Glowacki 2012). Growing demand from private electronics and aerospace sectors in the 1970s and 1980s resulted in acute shortages. To bolster a private helium extraction industry, the U.S. Congress passed the Helium Privatization Act (HPA) in 1996 (104th Congress 1996), which allowed government agencies to purchase helium from private producers. The HPA also set in motion plans to auction off the majority of the FHR's reserves and close the facility to all but governmental clients by 2015.

Establishing a reliable domestic helium supply since the HPA has proven difficult, with additional shortages occurring in 2007–2008 and 2011–2014 (Kornbluth 2015; Grynia and Griffin 2017). Congress responded to these instabilities by passing the Helium Stewardship Act of 2013, which forestalled the closure of the FHR through September 30, 2021 (113th Congress 2013). The helium industry again entered a crisis state in 2018, instigated by the Qatar economic embargo, which reduced global helium supplies by 30 percent for more than a year (Anderson 2017). Compounding these market disruptions, traditional U.S. helium sources are in a state of steady decline. Helium has historically been recovered as a byproduct of conventional natural gas drilling. Shale gas, which now accounts for nearly 70 percent of total U.S. natural gas production, contains no helium as its molecules are small enough to escape from shale rock formation (Milkov and Etope 2019).

The profound consequences of long-term helium shortages ultimately resulted in the DOI listing helium as a critical mineral in 2018, which set the stage for aggressive privatization measures (DOI 2018). The 2019 Conservation, Management, and Recreation Act, as well as recent changes to expedite the Bureau of Land Management's environmental impact assessment process, loosened federal gas leasing terms to encourage helium extraction, particularly in Western states along the Colorado Plateau (116th Congress 2019; BLM 2018).

## Uncertainties in Arizona's Helium Boom

Compared to its neighboring states of New Mexico, Colorado, and Utah—all of which claim significant hydrocarbon reserves—Arizona is not generally known for its oil and natural gas industry. Of more than 1,200 exploratory wells drilled in Arizona over the decades, 90 percent have resulted in dry holes (Wells and Wells 2021). However, Northeast Arizona's Holbrook Basin, a low-lying stretch of plains located along the southern border of the Native American Navajo Nation, is rich in non-hydrocarbon gas deposits, such as nitrogen, carbon dioxide, and helium (Selley and Sonnenberg 2015). Helium was first discovered in the Holbrook Basin in 1950 while prospecting for oil near what is today Petrified Forest National Park. Tests by the Bureau of Mines confirmed the presence of helium at record concentrations, as high as 10 percent (Rauzi 2003). Operated by Kerr-McGee Oil, the company went on to build two additional helium wells and one of the first privately owned helium purification facilities in the country (ibid.). While declining production closed the Kerr-McGee fields in 1976, these few wells produced more than 700 million cubic feet of grade-A helium—numbers that have captured the helium industry's imagination ever since.[1]

Beginning in 2014, several gas extraction operators seeking to capitalize on federal privatization plans returned to the Holbrook Basin in search of commercial-grade helium sources. These operators—mostly small entities spun off by drillers in the stalling shale gas industry—rapidly acquired hundreds of thousands of acres of mineral rights on state, federal, private, and tribal lands (Desert Mountain Energy 2018; Rare Earth Exploration 2019; Gibbons 2019). The Arizona Oil and Gas Conservation Commission (AOGCC) began issuing permits for exploratory wells in 2016, and the new helium boom was born (AOGCC 2020a). As one industry representative noted in communications with the authors—"We literally wrote our first royalty check for helium in Arizona in 40 years." However, the helium boom only came to the public's attention in May 2018, when a small operator applied for gas leases on 4,200 acres of federal land abutting Petrified Forest National Park (Gibbons 2018).

These developments raised concerns throughout the Holbrook Basin. Anxieties focused on what impacts helium extraction might bring to a region comprised of dispersed ranches, isolated Mormon communities, Native American border towns, off-the-grid homesteads, and a handful of medium-density population centers. Operators insisted drilling would utilize a process of passive acid-stimulation, where gas is extracted using low-pressure injections of water and small concentrations of hydrochloric acid into carbonate rock. These acids are neutralized in the process and gasses naturally rise to the surface (ADEQ 2018). Permits suggested operators had permission to use more aggressive measures, referred to as acid-stimulation or acid-fracturing, in the future (AOGCC 2020a). These methods exert higher pressures in order to fracture rock formations during injections. Permits also showed that operators would be exploring for helium at relatively shallow depths (1,000–2,000ft., compared to shale gas wells that average 6,000–

[1] To put these numbers into context, in contemporary markets, helium wells are considered profitable if helium makes up as little as 0.3 percent of the total gas (Bare et al. 2016). Meanwhile, domestic U.S. helium consumption in 2019 totaled 1.4 billion cubic feet, meaning that these three Kerr-McGee wells in the Holbrook Basin produced enough helium to supply the entire U.S. market for six months.

9,000ft.) proximal to the Coconino and Redwall aquifers—both major sources for drinking and agricultural water—as well as on land directly abutting the Little Colorado River. Only limited research exists on the potential environmental impacts of acid stimulation techniques (Long, Birkholzer, and Feinstein 2015; Stringfellow et al. 2017; Gandossi 2013). Industry documents obtained by residents, however, suggested that acid-fracturing processes increasingly use surfactants, gelling agents, and dispersant foams developed by the shale gas industry to maximize well production.


Figure 1. Members of No Fracking AZ (NFAZ) present their organization's research on helium "fracking" (Source: Laura Singleton, White Mountain Independent).

Public concerns also critiqued Arizona's capacity to manage the gas industry. The AOGCC consisted of only five part-time volunteer commissioners and a single staff person tasked with reviewing and enforcing all of the state's oil and gas permits (AOGCC 2020b). Furthermore, Arizona's oil and gas codes had not been updated since 2007 and did not account for contemporary gas extraction techniques now used by the industry (State of Arizona 2007). Meanwhile, the extent of the state's geological knowledge was also in question given that the Arizona Geological Survey—historically a resource for mining-related expertise across various agencies—was significantly defunded in 2016 (Briggs 2017), leaving industry as the primary generator of new scientific knowledge informing decisions about helium extraction. Adding to this momentum, the AOGCC and the Arizona Department of Environmental Quality (ADEQ) issued well-spacing exemptions, allowed companies to redact drilling data from public records, and approved aquifer protection permits allowing operators to drill near groundwater sources (AOGCC 2021).

In response to the Petrified Forest leases, loosening federal impact assessment requirements, and growing concerns in the Holbrook Basin about weak state regulatory oversight, the Center for Biological Diversity (CBD)—a national environmental nonprofit organization—released a widely distributed press release titled, "Trump Opens Door to Dangerous Fracking in Northern Arizona" (Center for Biological Diversity 2018). A regional advocacy group soon emerged, adopting the name No Fracking AZ (NFAZ) (see figure 1). NFAZ grew rapidly by tabling public events and publishing letters in local newspapers (NFAZ 2020), but the organization's strong oppositional stance was also seen as alarmist by local politicians and economic development advocates who viewed the helium boom as an opportunity for rural communities (Stone 2021).

## Making Sense of Critical Minerals Extraction

Heffron and colleagues (Heffron 2020; Qurbani, Heffron, and Rifano 2020) have argued that critical minerals extraction is ripe for producing conditions of environmental injustice in raising important questions such as, who gets to define what natural resources are deemed most critical? Who will bear the environmental, social, and health impacts of the global race for critical minerals? We add to this list of questions: how do knowledge gaps about the critical minerals industry—and the institutional structures that choose to ignore such gaps—contribute to these inequalities? In our research, we have observed that public understanding of the helium boom was significantly shaped by lack of resources explaining how the technical, regulatory, and risk dimensions of helium extraction differed from oil and natural gas extraction. These gaps created an informational vacuum where issues were quickly framed within public debates about hydraulic fracturing, and an environment where those who opposed helium extraction were dismissed as simply uniformed.

Given the prominence of fracking in national debates over the past decade, many people in the U.S. are generally familiar with oil and gas extraction, but often do not understand its complexities. Regulations governing the industry can vary state-by-state, and frequently shift with national policy goals, such as with the Trump administration favoring rapid extraction on federal lands (Walsh, Bird, and Heintzelman 2015; Lipton and Tabuchi 2018). Gas extraction processes are also highly technical in nature; requiring familiarity with geology, hydrology, chemistry, and engineering. Several studies have explored states of knowledge about the industry (Kreuze, Schelly, and Norman 2016; Jacquet 2012; Ladd 2013; Sangaramoorthy et al. 2016). Of note in many of these studies is how "fracking" becomes a highly contentious term due to its differing uses. Widely used by the public to define the entirety of the shale gas extraction—from drilling a well, extracting oil and gas, and commodity or wastewater transport by trucks or pipelines—industry only

uses the term to denote one step in this process—the high-pressure injection of fracking fluids (Evensen et al. 2014; Boudet et al. 2014). Several studies also suggest that residents living in oil and gas extraction regions are more likely to have higher states of awareness about these distinctions, but higher awareness does not necessarily equate to a greater likelihood of opposition to extraction (Mayer 2016; Alcorn, Rupp, and Graham 2017; Thomas et al. 2017).

The obscurities of critical minerals extraction are an added factor of confusion in the helium boom. There is no single definition of what "critical" means across literature examining the critical minerals industry (Jin, Kim, and Guillaume 2016; Hayes and McCullough 2018; Buijs and Sievers 2011; Andersson 2020; Lloyd et al. 2012). Nevertheless, institutions responsible for managing resource supplies offer up some common themes. For instance, the U.S. Congress' 1979 Strategic and Critical Materials Stockpiling Act states that "strategic and critical materials" are those that are needed to supply the military, industrial, and essential civilian needs of the U.S. during a national emergency; or those not available in the U.S. in sufficient quantities (96th Congress 1979). The National Research Council (2008) adds that materials performing essential functions for which few satisfactory substitutes exist should also be deemed critical.

It is often the case that critical minerals are located in hard-to-reach geological locations, require extreme forms of extraction, or are recovered in small quantities as the byproduct of other resources (Henckens et al. 2016; Henckens, Driessen, and Worrell 2014; Hayes and McCullough 2018; McCullough and Nassar 2017). But their scarcity is also co-produced by how national security and economic development concerns create convincing narratives on the importance of securing lands for resource extraction (D'Avignon 2018; Gilbert 2020). As Kinchy, Phadke, and Smith (2018) have noted, STS is well suited to examine such social constructions of natural resources and how they "come to be through interlinked political, economic, cultural, and technoscientific practices and processes." Phadke (2018) investigates how operators neutralize opposition and gain social license by framing critical minerals mining as a "green energy bargain" for renewable energy technologies. In other instances, critical minerals extraction produces new imaginaries that can reshape entire national governance structures and scientific institutions focused on economic development and modernization agendas (Barandiarán 2016; ibid. 2019).

## A Capabilities Model for Social Learning in Engaged STS

CivicFutures started its investigations into the helium boom in the summer of 2018 as a result of NFAZ's outreach activities. While NFAZ had built a sizable network of volunteers and working committees, their ability to make sense of the helium boom was hampered by their unfamiliarity with the gas industry. CivicFutures' director had nearly a decade of experience researching and organizing community engagement projects related to shale gas extraction, and was invited to participate in a series of public information sessions across the Holbrook Basin. These events revealed a strong desire to develop NFAZ's internal expertise and research capabilities. CivicFutures met this need by suggesting NFAZ participate in a series of capacity building "research method" workshops. The goal of the workshops would be to collaboratively establish working knowledge of the helium industry by utilizing information collected by CivicFutures and NFAZ's respective research teams. NFAZ would then use this baseline of knowledge to establish a public engagement and organizational research agenda.

CivicFutures' goals are to work with community partners to build more just and participatory forms of environmental science and governance. The group's projects are not unlike those of a nonprofit

organization, or ones pursued by European "science shops" in the 1970s (Fischer 2009; Hess 2007), in that they are responsive to requests emanating from the communities in which the group works. To this extent, CivicFutures is aligned with recent scholarship exploring how STS concepts and sensibilities can inform more practical, "engaged" research (Downey and Zuiderant-Jerak 2016; ibid 2019). Engaged STS takes many forms. STS scholars frequently utilize their expertise and institutional resources to serve as advisors in their empirical domains, or as boundary actors translating STS understandings across communities of practice (Wylie 2018; Ottinger 2013). STS critiques of historical deficit models in the public understanding of science have also provided pathways for non-professional contributions in research (Wynne 1992; ibid. 2006; Collins and Evans 2002). STS scholars have, in turn, actively participated in this reframing of whose knowledge counts through co-designed research with a broad range of stakeholders. As Zuiderent-Jerak (2016, 81) has observed of this locus of scholarship (more broadly embraced as "making and doing" STS), engaged methodological approaches allow the researcher to "explore what it means to live the multiple membership of societally and academically concerned communities."

The modalities of engaged STS research of greatest interest to CivicFutures are those that also seek to reshape power structures and enact social change. Creating actionable research programs requires deliberate design, however, and antecedent models can be found in several disciplines, including community-based participatory research (CBPR) in public health (Brown et al. 2006; Cashman et al. 2008; Minkler and Wallerstein 2003; Allen 2004), citizen science in the natural and environmental sciences (Irwin 2001; Kimura and Kinchy 2016; Conrad and Hilchey 2011; Ottinger 2010), and participatory action research in development studies (Freire 1970; McCormick 2009; Kindon, Pain, and Kesby 2007). Many of these approaches to research emerged in response to disproportionate impacts and discriminations experienced by segments of our extractivist-oriented society, as well as in response to increasingly neoliberal agendas in institutions tasked with protecting human health, environment, and science for public good (Lave 2012; Hess 2016; Moore 2006).

When imagining how CivicFutures might assist in building NFAZ's expertise and capacity for independent research, we drew particular inspiration from the community-action model—a cyclical process that emerged from the public health community for teaching research skills in CBPR projects (Lavery et al. 2005). The model assists partners in identifying core concerns, contributing factors, data explaining those factors, and actionable steps to advocate for systematic social and institutional change (Minkler 2010). We offer the community action model offers a basic framework for a more structured approach to engaged STS. However, in order to make it navigable to STS practitioners, we suggest that additional attention must be paid to: (1) the knowledge production process—particularly the interactional relationship shared by professional researchers and community participants, and how this impacts the practices of all those involved; and (2) how knowledge production in CBPR can draw upon STS's strengths in critical thinking about how social, technical, and institutional forces impact daily life. In the case of the helium boom, this applied to assisting our project partners with making sense of power structures constructing the various dimensions of critical minerals discourse.

In order to actualize a community-action model for engaged STS, we incorporate social learning from educational theory (Lave and Wenger 1991) and capabilities theory from justice studies (Sen 1990; Nussbaum 2001) into our research design. As Wenger (1998) observes, social learning is a nonlinear and collective process of parsing knowledge and realizing a shared community of practice. In the context of

making sense of oil and gas extraction, social learning can change the procurement and flow of information, validate the experiences of community partners, and build long-term capacity for civic empowerment (Wylie et al. 2014; Jalbert et al. 2019). Meanwhile, the capabilities approach offers that, without providing opportunities to achieve what individuals consider most valuable—concerns for personal health, collective well-being, and environment—interventions will fail to produce intended empowerment. Constantinescu and Devisch (2020, 2) argue that capacity building research projects must, therefore, account for the interdependence of "geographies, built environment, symbolism, life practices, and opportunities." We refer to our hybrid implementation of the community action model as the Capabilities Model for Social Learning in Engaged STS. In the remainder of this paper, we empirically demonstrate how this model functions using the workshops developed by CivicFutures and NFAZ as an empirical example.

## Designing Workshops for Engaged STS

The research partnership formed by CivicFutures and NFAZ was shaped by the principles expressed in the Capabilities Model for Social Learning in Engaged STS noted above. Workshops were designed to enhance NFAZ's expertise within an environment where few participants had direct knowledge of the oil and gas industry. It's important to note that NFAZ's intention in the workshops was not to execute a community-based research project in the traditional sense. Instead, the goal was to collectively imagine a roadmap for NFAZ's future engagements with regulators, industry, and the public that could be executed with minimal dependence on outside experts, such as CivicFutures.

To prepare for the workshops, CivicFutures graduate and undergraduate students with backgrounds in environmental economics, science and technology policy, sustainability, conservation biology, and ecology conducted three months of background research. Three workshops, each four hours in length, were held in August, September, and October 2018. Workshops were audio recorded, transcribed, and open-coded using MAXQDA software for later discourse analysis purposes. The three workshops respectively focused on: 1) articulating the broad range of concerns participants had about helium extraction; 2) refocusing concerns into problem statements, and again into pertinent research questions; and 3) proposing appropriate action items that NFAZ could execute to forward their organizational objectives. A total of 32 individual residents from the Holbrook Basin attended the workshops. All participants were NFAZ members serving on one or more of the organization's several emerging working committees. These included ones addressing educational programming, public outreach, volunteer recruitment, fundraising, legal actions, regulatory engagement, and scientific research. The priorities of these committees also informed the overall structure and objectives of the workshops.

### Workshop One: Scoping the Problem, Articulating Concerns

Our first workshop began by identifying the problem at hand—making sense of the complexities of helium extraction in the Holbrook Basin—then articulating how those complexities related to a broad range of issues relevant to NFAZ members and their extended community. This afforded an open platform for raising questions and concerns about the industry without imposing topical constraints. Ideas were written in brief phrases on Post-It® notes, which were then scattered across the room for the group to digest. In the discussion phase, participants reviewed each Post-It® note, raising questions and asking for clarification, which were then answered by fellow workshop participants. For instance, one participant described their

concern as "Fracking—coming to a town near you," which sparked conversations about how to prevent extraction from coming to the region.

Participants also expressed concern about how to identify which government agencies control land use policies in the region and dictated various permit requirements. Governance concerns evolved into questions about the agendas of agency stakeholders and newly elected local officials. As one participant commented, "we will have new representatives coming and we will need to educate them." Two additional concerns then focused on potential conflicts of interests and the amount of unilateral power held by the Governor's office to determine rural economic development in Arizona. In this way, our discussions operated in an iterative cycle until the group felt all issues had been raised.

Workshop One produced a total of 55 questions and concerns, covering a broad base of topics related to how helium is extracted, its potential environmental and health effects, who are the invested stakeholders in the helium boom, and why the Holbrook Basin is a target for helium extraction. Clear social learning patterns emerged in the workshop, both amongst NFAZ members, as well as in the knowledge transactions between NFAZ and CivicFutures. Questions such as "how is helium extracted," "what gas comes out of helium wells," and "what economics are driving helium extraction?" offered opportunities for CivicFutures to share knowledge and resources gleaned from the team's preliminary research in a less structured, dialogical manner. For instance, CivicFutures directed the group to resources on agency websites useful for determining land ownership and where to find regulatory statutes. In return, NFAZ's articulations of quality-of-life concerns, identifying locally sensitive areas, and stressing the importance of protecting water supplies, helped CivicFutures better situate its research in the personal experiences of those living in the Holbrook Basin. NFAZ's research committee was of particular importance to this bi-directional knowledge sharing process. The committee had gathered vast amounts of documents related to the helium industry leading up to the workshops that were readily inserted into the dialogical process. Ultimately, Workshop One initiated a process of realizing how the helium boom might have deleterious effects on a core set of values held by NFAZ, including one's right to bodily health, sense of place, and care for the environment. In this way, NFAZ and CivicFutures mutually benefited from the social learning process. Rather than reinforcing the deficit model of public understanding of science, a community of practice emerged with the shared goal of expanding our mutual knowledge of helium extraction.

### Workshop Two: Forming Research Questions

Workshop Two began by forming breakout groups loosely organized around NFAZ's several working committees. These breakout groups proceeded to sort ideas presented in Workshop One into thematic categories representing overarching problem statements. Ten categories were generated and labeled with summarizing statements, each containing as few as one to as many as eight of the initial concerns. These were, in weighted order based on the number of supporting concerns:

1. More effective science communication by NFAZ
2. Launching a "fracking ban" ballot initiative
3. Addressing the Governor's executive powers
4. Regional conflicts of interest
5. Lack of participation in regulatory decision-making

6. Lack of public awareness about helium extraction
7. Industry public relations campaigns
8. Pushback from industry and its supporters
9. Understanding helium extraction
10. Predicting the industry's future plans

We then began the process of developing a set of research questions that would accurately encompass the above themes. As Bickman and Rog (Bickman and Rog 2008) have noted in their analysis of applied research designs, re-articulating concerns as research problems and then again into research questions has two positive outcomes. First, the group is better able to realize how concerns are connected to larger social and political patterns. Second, as research problems transition to research questions, discussions focus on what new knowledge is needed to address the research group's initial concerns. We suggest that this transposing of concerns-to-problems-to-questions opens doors to introduce STS sensibilities into the research design process. For example, while discussing concerns nested under category six—lack of public awareness about helium extraction—one participant explained:

> You give somebody information that clearly states that fracking is taking place, and they come back and they want proof. You give them evidence, written evidence, that this is happening . . . They still come back to you and say, "Well, I need somebody official to tell me that this is taking place." Well, I just gave you all of these documents that say that it's taking place. It's kind of frustrating for me.

CivicFutures researchers offered new language to explore their predicament:

> In Science and Technology Studies, there are two concepts that relate directly to what you're talking about. One relates to expertise, or how people define and treat "expertise." You don't have expertise in some people's views. In this room, you would be seen as having lots of expertise. We [CivicFutures researchers] get credentialed because we have letters after our name but, in many ways, you know way more about this than we do. This kind of knowledge is called "situational knowledge." Finally, you have to push back against how many people imagine "public understanding of science." Many people feel the public needs somebody else to translate to them what they should and shouldn't trust in science.

Conversations about expertise, situated knowledge, and public understanding of science were followed by debates about deficit vs. generative models of public engagement in environmental science and governance. This exchange ultimately shaped a research question: "how can NFAZ become an organization that effectively engages with the public?" Meanwhile, other conversations offered opportunities for using STS critical thinking to unpack the critical minerals industry. In particular, how national policies and economic drivers had incentivized helium speculators to come to the Holbrook Basin. Workshop Two proceeded in this manner until a set of seven research questions were proposed by the group:

1. What processes and technologies of extraction are likely to be used in this area?
2. How do we identify who and what is at most risk from helium extraction?
3. Why is water a central issue in Arizona's oil and gas extraction debates?
4. What current regulations govern the industry and how do we shape them?
5. What is the state of politics related to extraction in Arizona and how do we influence it?

6. What tactics will industry use to push their agenda and how do we address them?
7. How can NFAZ become an organization that effectively engages with the public?

Interestingly, while all of the organizing categories at the start of Workshop Two converged on issues related to public engagement, regulatory decision-making, political influence, and industry actions, two of the research questions returned to the group's earlier concerns for people, places, and the environment. "How do we identify who and what is at most risk from helium extraction," brought attention to fragile desert ecologies, as well as the complex pressures experienced by Navajo and Hopi communities facing the double-binds of accepting extraction for economic development.[2] "Why is water a central issue in Arizona's oil and gas extraction debates?" emerged as the group realized how, unlike more water-rich areas of the country experiencing fracking, a gas boom in the arid southwest posed a unique set of challenges. The group felt this was worth understanding in order to appeal to residents who were dependent on scarce groundwater sources, as well as to large population centers that rely on water from the Colorado River Basin.

### Workshop Three: Developing Action Plans, Identifying Resources

Workshop Three focused on identifying action items in response to the research questions developed in Workshop Two. The conversation started by focusing on a single question, then asking workshop participants to propose hypotheses and potential solutions. The CivicFutures research team guided discussions by connecting responses to the foundational knowledge developed in the prior workshops. This process is illustrated in a discussion at the intersection of research question one and three; relating to how understanding the differences between acid jet fracturing and high-volume hydraulic fracturing was important to realizing why water was a central issue in Arizona's oil and gas extraction debates, and how NFAZ can effectively communicate those differences. The following exchange began by reviewing an early fact sheet that NFAZ had produced for public distribution:

> CivicFutures (CF): There is a line in here that says, "Approximately 97 percent of rural residents are not on city or county water." That required research to come up with that, to put into this document. But there are a number of inaccuracies in this document as well, such as "hydraulic fracturing requires millions upon millions of gallons of water, and uses a high-pressure injection operation." We need to be very careful of that as we develop our knowledge base—not to confuse acid jet fracturing with fracking for shale gas.
>
> NFAZ Participant A: So, it should be "well stimulation," because that would cover them all, right?
>
> CF: It would cover them all, right. But the thing is, fracking is what people know. You need to educate the public on what specifically you mean by fracking, because they are going to go online and they are going to look up fracking, and they are going to see Pennsylvania, Ohio, and Texas fracking that are massive

[2] While NFAZ did not have members from Navajo and Hopi tribal communities, NFAZ had on several occasions met with tribal leaders and presented at chapter houses in order to understand their concerns.

> tank farms and huge rigs and all of these operations that are likely not going to be accurate to what they see here.
>
> NFAZ Participant B: I have a question though. They are actually doing both. In fact, south of our ranch, they found this vein of oil and gas supposedly, and that's going to be different than what they are doing up in the Holbrook Basin. Plus, even up here, they are pulling permits for 4,000 feet deep.
>
> CF: So, the reason why I say this is important is because, in reference to our research question: "what are the current regulations that govern the industry." We need to understand the minutia between those regulations that apply to some things and not others.
>
> NFAZ-A: So, when we're dealing with the public, when we have different processes going on in our area and county, maybe we should show them all of the different processes . . . it should be worded in a way that says, "There are many different styles of fracking, or well stimulation," and then say it ranges from tens of thousands, to millions of gallons [of water], depending on the style they use.

CivicFutures also provided examples of how advocacy groups in other parts of the country had effectively or ineffectively responded to oil and gas development:

> CF: There was a book that was just published, and it's called Fractured Communities (Ladd 2018). There's a chapter about fracking in the Everglades. Concerned citizen groups were trying to form a coalition to get fracking banned in the state. Except, through all of their work, they hadn't differentiated between hydraulic fracturing and acid fracturing. So, they specified hydraulic fracturing in the ban language, which meant that the acid fracking in the Everglades could still happen.

This particular conversation was followed by cataloguing all local, state, and federal agencies with regulatory responsibilities for oil and gas extraction in Arizona. Representatives from NFAZ's research and regulatory engagement committees agreed to analyze these documents in order to determine how hydraulic fracturing and acid jet stimulation were managed differently at each of these levels in order to update NFAZ's public presentation materials accordingly. The process of identifying resources and imagining their usefulness helped NFAZ to imagine what would be necessary to translate lessons learned from community actions seen elsewhere to Arizona.

By the end of Workshop Three, NFAZ had developed a sophisticated understanding of how helium extraction in the Holbrook Basin was being shaped by exogenous sociopolitical and technoscientific forces. NFAZ's working committees also had a solid sense of how they should structure the organizations future work. This new agenda included requesting well permits, industry drilling data, groundwater data, and MSDS sheets; reviewing state water policies, mineral rights leasing, and the oil and gas health literature; researching applications of acid jet fracturing and critical minerals industry; as well as aligning with ranchers, tribal communities, and politicians to expand their coalition. As these action items emerged, however, participants raised new concerns about whether or not we had achieved a plan suitable to NFAZ's capacities. A significant body of research illustrates how community-based research is most effective when research agendas are scaled to the capabilities of participating organizations (Jalbert and Kinchy 2015; Wylie et al. 2014; Richter et al. 2018). In order to align action items with NFAZ's present and expected future capacities, the group proceeded to prioritize their research questions in ranked order. There was overall agreement that questions one, four, and seven required immediate attention. Interestingly, question five;

"what is the current state of politics related to resource extraction in Arizona and how do we influence it," found the least consensus. We discuss the implications of this decision in the next section.

## Discussion

Arizona's Holbrook Basin is an emerging epicenter in the drive to secure new domestic helium sources and residents in this region feel they are being left behind in decision-making processes that could dramatically alter their way of life. We suggest that this is, in part, due to a lack of capability to engage with information about extraction techniques, potential impacts, and the sociopolitical drivers of helium extraction. These gaps are further exacerbated by inadequate regulatory mechanisms for public participation. However, Arizona's helium boom also offers important insights into how communities can come to terms with the critical minerals industry and its impositions.

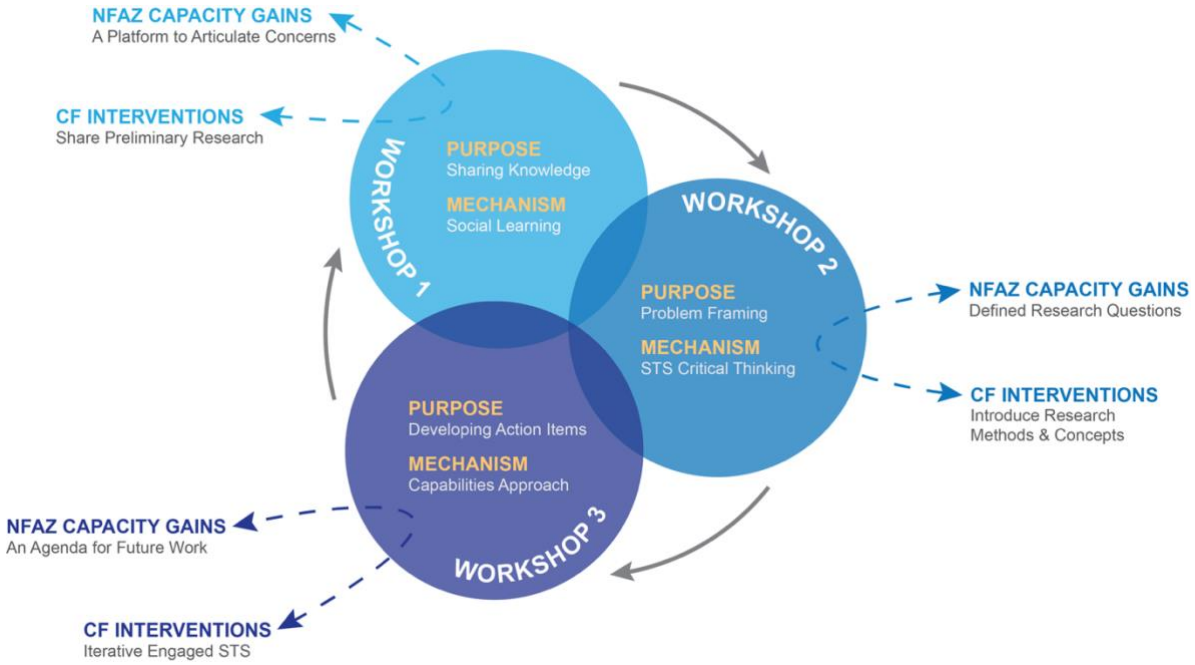


Figure 2. A Capabilities Model for Social Learning in Engaged STS.

We argue that engaged STS scholarship can meaningfully assist in this process, and have offered a framework based on our experiences in the workshops: The Capabilities Model for Social Learning in Engaged STS (see figure 2). For NFAZ participants, Workshop One created a space to articulate concerns about what helium extraction had introduced to the Holbrook Basin. Workshop Two framed NFAZ's concerns within broader social, political, cultural, and economic patterns shaping Arizona's helium boom, in order to form higher-level research questions. Workshop Three ended in an actionable agenda appropriate to NFAZ's resources and capabilities. Each of these stages in the process developed meaningful capacity gains for NFAZ to engage with regulators, industry, and the public, beyond what was present prior to the workshops.

Each stage in the workshop cycle also provided opportunities for CivicFutures to make interventions through engaged STS. CivicFutures had conducted extensive background research leading up to the

workshops, but the impact of developing and sharing this knowledge was greatly strengthened by social learning mechanisms employed in Workshop One. In Workshop Two, CivicFutures experimented with how STS critical thinking might offer new concepts for examining what precipitated the helium boom, as well as in identifying effective models of public engagement. Finally, Workshop Three not only created a new agenda for NFAZ, but for CivicFutures as well. NFAZ and CivicFutures would go on to co-produce a board game—*Helium Futures*, where players learn about helium extraction and act out competing futures in a boom-and-bust resource extraction cycle (Ball, Jalbert, and Test 2021). NFAZ now uses *Helium Futures* to enlist new members and educate the public. A second project, *Helium Rising*, uses participatory filmmaking, inspired by Parsons and Lavery's (2012) concept of brokered dialogue, to negotiate differing perceptions of helium extraction held by regulators, industry, and concerned publics (Bruhis and Jalbert 2021). These projects demonstrate the iterative potential of our model for engaged STS scholars.

These findings reflect Downey and Zuiderent-Jerak's (2016, 225) assertions that engaged STS should serve as "a mode of scholarship that involves attending not only to what the scholar makes and does but also to how the scholar and the scholarship get made and done in the process." To achieve this, engaged STS demands a reorientation of how academic practitioners consider their professional commitments to knowledge production, research subjects, and sites of study. The workshops detailed in this paper could have evolved as space for simply transferring knowledge from CivicFutures to NFAZ, thus reinforcing dependencies and the priorities of professional expertise. Instead, the workshops allowed CivicFutures and NFAZ to enact a theory of change where the group's combined knowledge and resources were mobilized to fill knowledge gaps produced by neoliberal disinvestments in public institutions. The process drew upon STS's strengths for critical thinking about how powerful social, physical, and institutional forces are influencing the helium boom. Finally, our model illustrates how these interventions are most impactful when commitments to maintaining long-term relationships and iterative capacity building are integral to the research process.

We also acknowledge a number of challenges and limitations to replicating our research in other contexts. In many instances, communities are skeptical of working with academic institutions perceived as having their own agendas. CivicFutures greatly benefited from NFAZ's enthusiasm to develop a long-term partnership and conceive of the workshops. However, CivicFutures also invested significant time and resources in relationship building with no guaranteed outcomes—activities that are not always possible in academic institutions that value rapid research-to-publishing turnaround cycles, or categorize such activities as community service as opposed to important research activities. We also recognize that, while the workshops were successful in addressing the concerns and needs of NFAZ, the organization is not representative of all voices in the Holbrook Basin. Future research might explore how our model could be used to enlist a broader range of stakeholders with differing perspectives on how helium extraction is executed, regulated, and communicated to the public—such as in public forums, consensus conferences, and other forms of participatory technology assessment. The *Helium Rising* filmmaking project is one attempt at diversifying our community of collaborators.

Finally, we offer a word of caution to those who might wade into the risky waters of pursuing social change through engaged STS. At several points in our research, CivicFutures faced significant criticism of its work to make sense of Arizona's helium boom. In one instance, representatives from industry and state agencies registered complaints with the university's administration, claiming that CivicFutures was

misleading the public by examining how opposition to helium extraction had become linked to concerns about hydraulic fracturing. We are grateful that the administration defended our work as an effort to unpack public confusions, and these critics have since become collaborators in more recent projects. We believe our success in overcoming these challenges came from consistently emphasizing the value of community-based research in generating meaningful stakeholder dialogue. Ultimately, we believe our intellectual investments in the Holbrook Basin community have contributed to realizing these objectives by complexifying existing narratives and co-producing resources for a more informed public.

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Lisa Test is a member and founding director of No Fracking AZ. She has been involved in environmental justice issues since 2006 and believes that equitable solutions depend on the voice of the community being included in decision-making processes.

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