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Smoke, Air, Fire, Energy (SAFE) in Rural California: Critical Reflections on an Interdisciplinary Research Collaboration

Deepti Chatti *<dc317@humboldt.edu> (Cal Poly Humboldt),* ***Carisse Geronimo*** *(Schatz Energy Research Center),* ***Cassidy Barrientos*** *(Schatz Energy Research Center),* ***Jana Ganion*** *(Blue Lake Rancheria),* ***Malcolm Moncheur*** *(Cal Poly Humboldt),* ***Peter Alstone*** *(Cal Poly Humboldt),* ***Shawn "Shay" Bourque*** *(Karuk Department of Natural Resources),* ***Tanya Garcia*** *(Schatz Energy Research Center),* ***Tesfayohanes Yacob*** *(Cal Poly Humboldt)*

Abstract

This article provides a synthesis of the interconnected problems of tenuous energy access, wildfires, and exposures to high air pollution in Indigenous communities in rural California through the lens of ongoing collaborative research being carried out by researchers at Cal Poly Humboldt, Schatz Energy Research Center, Karuk Department of Natural Resources, and the Blue Lake Rancheria Tribe. The collaboration is funded by the Strategic Growth Council of the state of California, and we hope is the beginning of a longer term relationship between all partners. We are an interdisciplinary team of researchers drawing on energy engineering, air pollution science, and qualitative social sciences to better understand the intersecting challenges of expanding clean energy access, and building climate resilience in Tribal communities in rural California in the context of the multiple challenges of climate change, increasing risk of dangerous wildfires, and high exposures to air pollution. Individuals and communities need to make decisions about energy and air quality infrastructure with implications for public health, climate change, energy resilience, and Tribal sovereignty. This article will reflect on the joys, challenges, ethical questions, and epistemological constraints involved with academic researchers working on interdisciplinary research projects across disciplines, and in partnership with Tribal nations. Grounded in the reflections and experience of an ongoing project, this article sheds light on the challenges and unique opportunities of conducting collaborative interdisciplinary research in close engagement with communities, and also reflects on the structural constraints posed within current institutional structures.

Keywords: wildfires, smoke, energy, climate change, Tribes, California

Wildfires, smoke, and energy access are intricately linked in Northern California. While California has always been a fire-adapted place (Pyne 2016), recent years have seen increasing incidences of catastrophic wildfires due to a constellation of reasons including climate change. In the last five years in California, 10 million acres have burned in wildfires and 151 human lives have been lost (CALFIRE 2022). These fires are linked not only with dangerous conditions for people, wildlife, and ecosystems, leading to tragic loss of human and non-human lives, homes, and habitats, but also cause extremely high air pollution levels in the region. Simultaneously, the electric utility serving much of the region, Pacific Gas and Electric (PG&E), manages fire risk by powering down the electric grid during conditions deemed unsafe and prone to spark wildfires. This practice means that residents in the region do not have electricity to run air filters when these technologies are most needed. As it is, rural and Tribal communities face precarious access to the grid (Sandoval 2018), and the quality of their energy services is made worse with the expanding fire season and the subsequent blackouts.[1] Wildfires become catastrophic with fuel accumulation on the landscape due to settler-colonial policies that criminalize Indigenous land management practices that use fire as a tool to tend to the landscape (Tripp 2020, Norgaard 2014, Norgaard 2019). And finally, this dynamic set of issues unfolds in a context where the state of California has committed to meeting its full electricity requirements from renewable and zero-carbon energy sources by 2045 (as laid out in Senate Bill 100), requiring an expansion and strengthening of its electricity infrastructure.

To begin addressing the nexus of issues surrounding wildfires, smoke, and energy access in Northern California, a diverse group of academics and practitioners came together to conceptualize a research collaboration set in Humboldt County. The Smoke, Air, Fire, Energy (SAFE) collaboration is a result of that engaged process, and is an ongoing interdisciplinary, community-engaged, research partnership co-led by faculty at Cal Poly Humboldt, the Schatz Energy Research Center, the Karuk Tribe, and Blue Lake Rancheria Tribe, with an overall goal of increasing energy and climate resilience in Tribal and rural California communities. The focus of the collaboration is on analyzing the interconnections between three entangled issues: wildfires of increasing intensity and frequency in Northern California, concomitant worsening air pollution levels, and precarious energy access faced by rural and Tribal communities. The collaboration goals include understanding the interconnections of these issues; foregrounding the political sovereignty, knowledge, and expertise of Tribes on fires; using new technologies to understand the air pollution impacts of fires; and making progress towards strengthening energy infrastructures in historically underserved Native and rural communities in the context of climate change.

As a community-engaged research collaboration, this program was conceptualized from its very beginning in conversations between the Karuk Tribe, Blue Lake Rancheria, and faculty from Cal Poly Humboldt. As an interdisciplinary research collaboration, this intellectual effort draws on varied disciplinary perspectives from academia including faculty in engineering and faculty in the critical social sciences. The epistemic and political orientation of the collaboration includes honoring Tribal sovereignty and expertise, and integrating Indigenous knowledge actively held and practiced by the Karuk Tribe, institutional and technical expertise held by the Blue Lake Rancheria with regards to energy resilience, and technoscientific approaches to air quality monitoring and clean energy, with an overall goal of enhancing the energy and air quality infrastructure in the region. Following feminist science and technology studies (STS) scholars who have pushed scientists and other producers of knowledge to "re-make" science, center questions of power, and interrogate what it means to conduct empirical research (see for example Subramaniam and Willey 2017; Liboiron 2021; Goldman, Nadasdy and Turner 2011), we have grounded our collaboration's questions around air quality and energy infrastructures in the

1. From 2014-2018, customers in Orleans experienced four times more outage minutes than the average PG&E customer (PG&E 2018).

knowledge of the historic and contemporary struggles of Indigenous peoples to practice their expertise and knowledge amidst the onslaught of colonial policies that actively perpetrate violence to erase Indigenous peoples and their knowledge from the land. From this starting point, practicing science as "neutral," or as not having a point of view (Haraway 1988), further perpetuates this erasure by obscuring its violent history. Our collaboration makes visible our political stakes in this process by actively supporting the needs of the Karuk Tribe and Blue Lake Rancheria Tribe.

Conceptualizing a cohesive research collaboration on these vast topics in a way that could be neatly articulated to a funding agency was no small undertaking. We were keen, from the outset, that this research collaboration be driven by community needs. We co-wrote and edited the proposal through an iterative process with all collaborators. Furthermore, the extremely different disciplinary genres of knowledge production that our diverse group engages with (and is accountable to) in our academic lives meant that we had to create new ways of producing knowledge together. In simple terms, we wanted this to be neither an engineering, air pollution science, or critical social science project in its entirety, nor did we want it to be three separate pieces of research under one program umbrella. We wanted to create something that drew on each of these ways of understanding the world and to have each component inform the others. To make this possible, we wanted to go beyond working in our distinct areas separately, and do more than speaking to each other now and then about how our individual research areas were coming along. Critical social scientists reading this article will appreciate the challenge of conducting research in a way that could inform engineering designs and air pollution sensor networks, and engineers and scientists reading this article will appreciate the challenge of including a consideration of political sovereignty and multiple epistemic frameworks while trying to size a microgrid or monitor particulate matter concentrations in the air. Academics of all disciplines will appreciate the challenges for junior faculty to meet tenure expectations while simultaneously building relations of trust with community partners whose priorities and needs may be substantively different than those of our colleagues within academia. We do not claim to have neatly articulated answers on how to do this; we do not think that we have solved interdisciplinarity nor resolved the tensions between the expectations of academic knowledge production and our collaborators' pragmatic needs outside it. But we offer our reflections on the challenges and opportunities of carrying out such work in collaboration with each other on pressing research topics of deep concern to the communities in which Cal Poly Humboldt is situated. It is our hope that our critical and candid reflections might inspire others to embark on similarly ambitious intellectual pursuits even when they are messy. Perhaps informed by our attempts and what we have learned, we can collectively and more effectively address contemporary environmental and societal challenges.

Research Context

This ongoing collaboration is located in Humboldt County in rural Northern California, about 300 miles north of the San Francisco Bay Area. Cal Poly Humboldt is located in Arcata and is part of the California State University. Cal Poly Humboldt holds an institutional vision to "be the premier center for the interdisciplinary study of the environment, climate crisis and resilience to climate change, and the conservation of ecological systems and natural resources" and to "partner with Indigenous communities to address the legacy of colonialism, and create space nurturing of traditional ecological knowledge, pedagogies, and curricula responsive to their identified needs" (Cal Poly Humboldt Vision 2022).

The Blue Lake Rancheria is a federally recognized Tribe whose vision is "to secure a better future for its people; protect its sovereignty and heritage; learn from the past; and build a resilient, healthy economy and environment, with benefits for the Tribe, the region, and the planet." The Karuk Tribe is located approximately 100 miles inland from the coast in ancestral territories in the mid-Klamath region. Prominent towns in Karuk territories include Orleans and Happy Camp. This region of the world experiences some of the worst air quality in the continental United States due to wildfires (Ford et al, 2018), and also experiences tenuous electricity service from electric utilities.

Details of the Interdisciplinary, Collaborative Research Partnership

Our interdisciplinary, collaborative research partnership developed over a number of years. Between 2014-2019, the Blue Lake Rancheria Tribe collaborated extensively with the Schatz Energy Research Center on numerous projects related to energy. These projects involved conceptualizing, designing, and building clean energy infrastructure systems, and established trust between the Tribe, the Schatz Energy Research Center, and faculty at Cal Poly Humboldt. In 2019, with increasing concerns around wildfire smoke in the region, conversations were begun regarding partnering on research on air quality as well, with a desire to explore the feasibility of using air filters to protect residents in the region during wildfire events. Since the air quality inland in Karuk ancestral territories is far worse than the air pollution levels experienced on the coast around Blue Lake Rancheria and Cal Poly Humboldt, a conversation was also started with the Karuk Department of Natural Resources to explore the possibility of expanding the collaboration to include the Karuk Tribe as a research partner.

Undergraduate students from Cal Poly Humboldt studying engineering were also included in this early stage. As part of their senior capstone project, students worked on air quality infrastructure designs useful for the Karuk and Blue Lake Rancheria communities. These included designing air filtration systems for community buildings and residences, developing plans for a sensor network, and considering management plans for community air quality. The student teams identified a number of themes that continue to inform the SAFE work in their designs: the need for much larger air filtration flow rates than are typical from commercially available systems to manage heavy smoke inundation, the value of low-cost sensors for situational awareness, and the difficulty of maintaining air quality infrastructure.

As these conversations and student projects were underway, the first “public safety power shutoff” events affected the region. PG&E de-energized the grid as a way to reduce the risk of the electricity infrastructure sparking wildfires. Faculty in the critical social sciences were keen to study the inequalities experienced by various communities in accessing the energy grid, and the inequalities in air pollution exposures as a result of historic and contemporary marginalization. Researchers across disciplines initiated conversations about studying multiple facets of these complicated and dynamic issues that were rapidly unfolding. These interdisciplinary conversations further emphasized the connections between wildfires, Tribal sovereignty, energy and electricity infrastructure, community perceptions of and responses to air pollution, and air quality infrastructures for monitoring and mitigation of air pollution. The SAFE collaboration grew out of these conversations.

A grant opportunity from the Strategic Growth Council of the Governor’s Office of the State of California presented itself. The team engaged in an iterative writing process including academic and Tribal partners, and drawing on the expertise of those involved. The process included engaging in conversations among all the partners, face-to-face and phone meetings of small groups at Cal Poly Humboldt, writing together as a large team in Orleans at the Karuk Department of Natural Resources (the document was projected on a large screen for editing), and sharing drafts over email and Google Drive for commenting, editing, revising, and rewriting. The final grant application was submitted early in 2019. In Spring 2020 we received funding for the collaboration.

Since we are co-producing knowledge, and not placing any one form of knowledge production or any one discipline of academia in a position of power over another form of knowledge production or academic discipline, the research partnership is a flat structure with five Principal Investigators (PIs) from across locales and expertise areas at the university and in the Tribes (see figures 1 and 2). The PIs are responsible for leading the intellectual work of the project, and additional research staff at the Schatz Energy Research Center and undergraduate and graduate students from Cal Poly Humboldt have been actively involved in carrying out research activities for varying lengths of time.

Figure 1: Location of the collaborative partners in Humboldt County; inset shows location of the partners in far Northern California

Research Objectives and Questions

To achieve the collective goals of the collaboration, the research team divided the intellectual work into three distinct overarching objectives within which research questions were formulated to be answered. The main objectives are:

***Objective A*: Accelerating climate-smart energy and air quality infrastructures**

We are developing engineering design tools, management plans, and financial strategies that accelerate deployment of energy and air quality infrastructure (that is identified as needed by the collaborative process) at three scales: households, critical facilities, and isolated community clusters of 10-50 households and businesses.

***Objective B*: Understanding social dimensions of change**

We are working with community members and leaders to advance understanding of the social dimensions of climate-smart and fire-smart infrastructures and practices.

***Objective C*: Advancing sustainable university-community research partnerships**

We are identifying the institutional needs and opportunities for universities to play a supportive, long-term role in connecting indigenous communities in their region with resources for environmentally just community development and research.

These overarching objectives were divided into research questions that would need to be answered to achieve the objective. A subset of research questions was on the more technical end of the spectrum, with their outcomes derived from quantitative calculations of energy systems and air quality data. Another subset of research question was more critical in nature and their outcomes were derived from qualitative data collected using semi-structured interviews, focus group discussions, and participant observations. Yet another set of research question were focused on the process of the collaboration itself, and self-reflexively analyzed the institutional challenges faced by the collaborators in working together on these topics.

Research Questions

1. How can we design clean energy microgrids that are resilient to wildfire-induced risk and serve critical needs at three scales: households, critical facilities, and isolated community clusters of 10-50 households and businesses?
2. How can we use low-cost air quality sensing networks and indoor air filtration systems in supporting healthy rural communities and healthy forests across the landscape?
3. How can people's understanding of smoke, air, fire, and energy help inform our approaches to managing infrastructure systems in support of climate goals and sustainable landscapes?
4. How can research partnerships between universities and the communities they are a part of transcend one-off reports and assessments, resulting instead in meaningful and sustained collaboration?

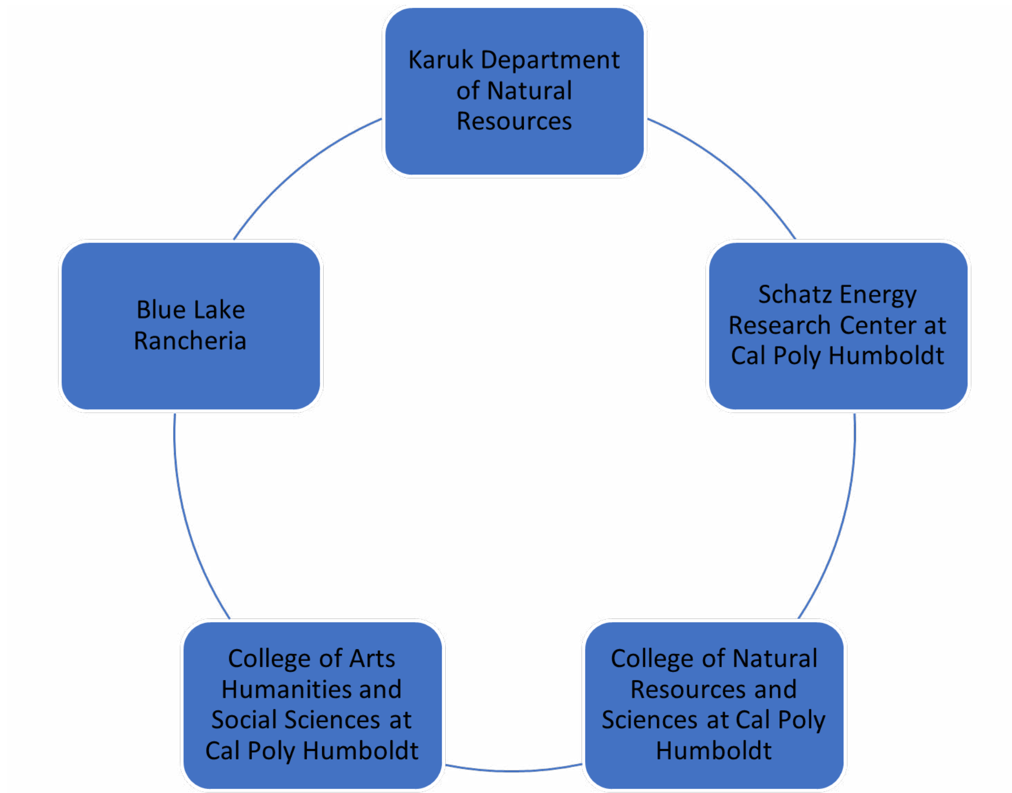

Figure 2: Primary institutional affiliations of the five Principal Investigators (PIs) of the collaboration

As we mentioned in an earlier section, these questions emerged and were developed through a series of iterative conversations. The way we approached working on this project was built on ensuring that lines of communication stayed open and active. We set up weekly virtual discussions where our collaboration team parsed out, reframed, and reconsidered many of these questions in the early parts of our work. A s a group, we decided to prioritize opportunities to impact policy and direct material resources to meet community needs. This decision meant that we prioritize writing grant proposals over research papers, and seek opportunities for strategic discussions with policymakers. These happen throughout the collaboration process rather than hoping someone will eventually read our final report. Developing follow-on infrastructure grants and setting up meetings with officials precipitated and motivated engagement with a range of people in the Tribal governments and community in their governance, personal, and cultural roles. It helped to make the research collaboration work towards tangible and specific infrastructure goals, which also let us reveal the cracks in the systems that would deliver that infrastructure.

Initial Projects of the Collaborative Team

While this work is an ongoing collaboration and we are actively collecting data on multiple research questions and engaging in different projects, we are able to share the following preliminary insights and outcomes from our activities. We also note that some of these activities are further along than others, and thus, some of our following sections are more developed than others. Where the research task is completed, we have so indicated in the subsection.

Improving Understanding of Smoke During Fire Events

The collaboration team relies on multiple ways of collecting information about smoke including semi-structured interviews with community residents, focus group discussions, and air quality monitoring and analysis using sensors. Many community members living in the Karuk ancestral territories have noted that the smoke during wildfire season has become increasingly worse in recent years in quality, intensity, and duration. The worsening of smoke has both temporal and spatial dimensions. Residents described that even 20-30 years ago, they would experience "bad air days" for only one week in the summer, whereas more recent summers have had such days for over two months. Spatially, residents described being able to "escape to the coast" in decades past, but now feel a sense of entrapment in the bad air.

Mountainous terrain, differences in elevation, wind directions, and proximity to fires all lead to highly variable levels of smoke across the landscape changing throughout the day. The installation of multiple air sensors at key locations in the region enhance our fine-grained understanding of the way smoke moves in the area during fire events, and are now used by residents of the Orleans-Somes Bar region to make logistical decisions regarding keeping windows open or closed, running air filters, wearing masks, or evacuating. As part of the SAFE collaboration, 11 "Purple Air" sensors have been installed so far across the region and are providing continuous data that is tracked by researchers (see figures 3 and 4). These sensors monitor levels of small particulate matter called PM 2.5, which is a key constituent of wildfire smoke and a pollutant of concern (Wagner and Chen 2019). The data from these sensors is available for anyone with access to the internet. The expanded sensor network is already used by staff at the Karuk Department of Natural Resources and some residents of the region to understand the smoke status.

While understanding smoke is extremely important during wildfire events, we are also keen to better understand the patterns of smoke from prescribed fires and cultural burns. In this article we are using the term "prescribed fires" to refer to intentional fires that are used to manage forests and grasslands for reducing the accumulation of flammable fuels in the landscape near communities. We are using 'cultural burns' to refer to intentional fires used for improving the health of specific types of plants determined as culturally significant by the Karuk Tribe. The purpose of smoke monitoring around prescribed and cultural fires is to support the Karuk Tribe's efforts to "*put good fire back on the land*", a desire expressed nearly universally by everyone interviewed for the collaboration. There is widespread support in the region for more actively managing the landscape in Karuk ancestral territories for two purposes: increasing the health of plants that are culturally important to the Karuk Tribe, as well as preventing catastrophic wildfires in the region by not letting fuels build up to high levels in the landscape. Both anecdotal experience and emerging research (Jaffe et al. 2020, Long et al. 2018, Prunicki et al. 2019) suggest that smoke levels during intentional fires are less intense and of shorter duration than wildfires. Karuk Tribe practitioners indicated that ongoing monitoring of air quality could help in the short-and long-term to both inform their work and also make the case to the community and regulators.

In October 2021, we measured smoke levels in close proximity to prescribed and cultural fires, building on work that the Karuk Tribe has done in the past to document the relatively low impact of prescribed burns compared to wildfires (Tripp 2017). The photos in Figure 5 show a prescribed burn from the 2021 Klamath TREX, which included operations to protect U.S.F.S. controlled areas in the "Patterson" burn unit (Western Klamath Restoration Partnership 2022). The data from the temporary smoke sensor installed just to the south of the fire operations, displayed in Figure 6, shows that community members living close to the fire operation experienced somewhat elevated, but not acutely hazardous, levels of smoke.

A cultural fire near Orleans on October 15, 2021 was focused on willows that were overgrown. Willows are significant as basket materials for the Karuk Tribe. Experts from the Karuk Tribe collaborated with the Prescribed Fire Training Exchanges (TREX) program for this burn event, and temporary smoke sensors were installed for monitoring, both in the main part of Orleans and close to housing just across the river (see figure 7). Data from the sensors, displayed in Figure 8, indicate that there was a short period of unhealthy to very unhealthy smoke levels in one part of Orleans, but only moderate levels in another neighborhood. This empha-

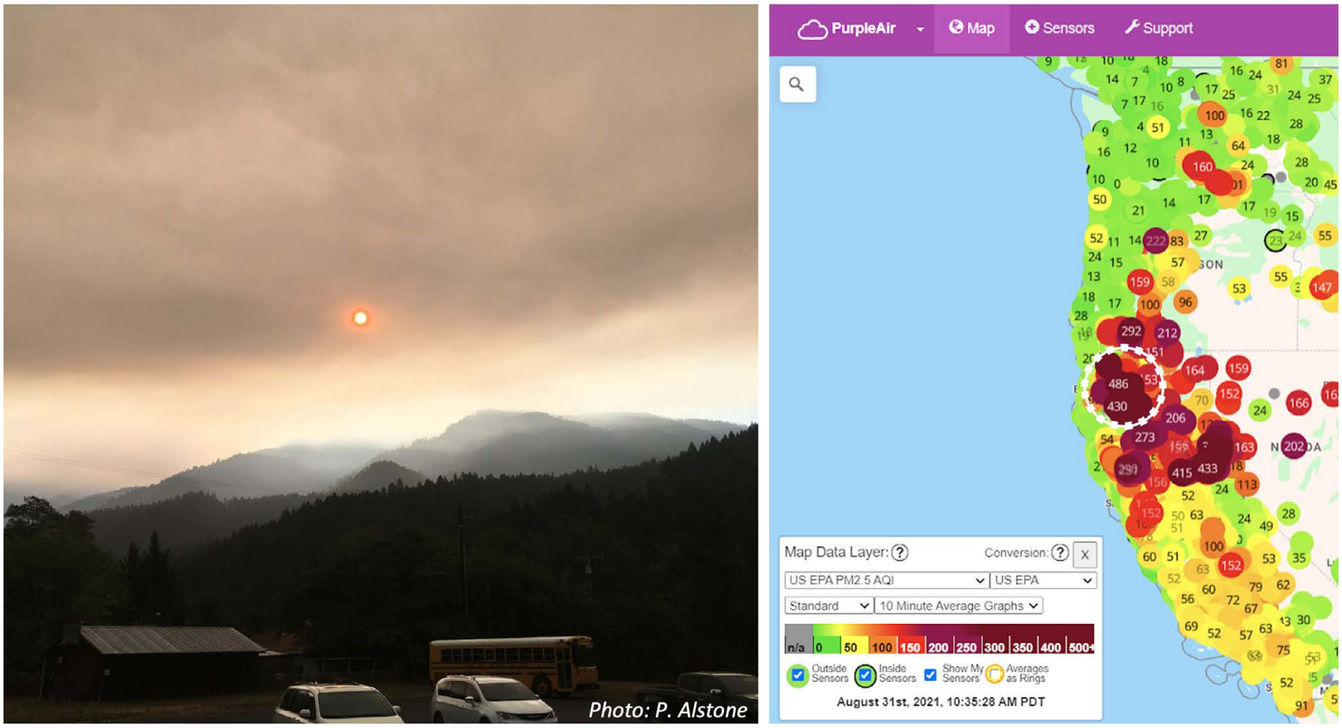

Figure 3: Smoky skies in Orleans, CA and a map of widespread wildfire smoke on August 31, 2021. Project areas circled in white.

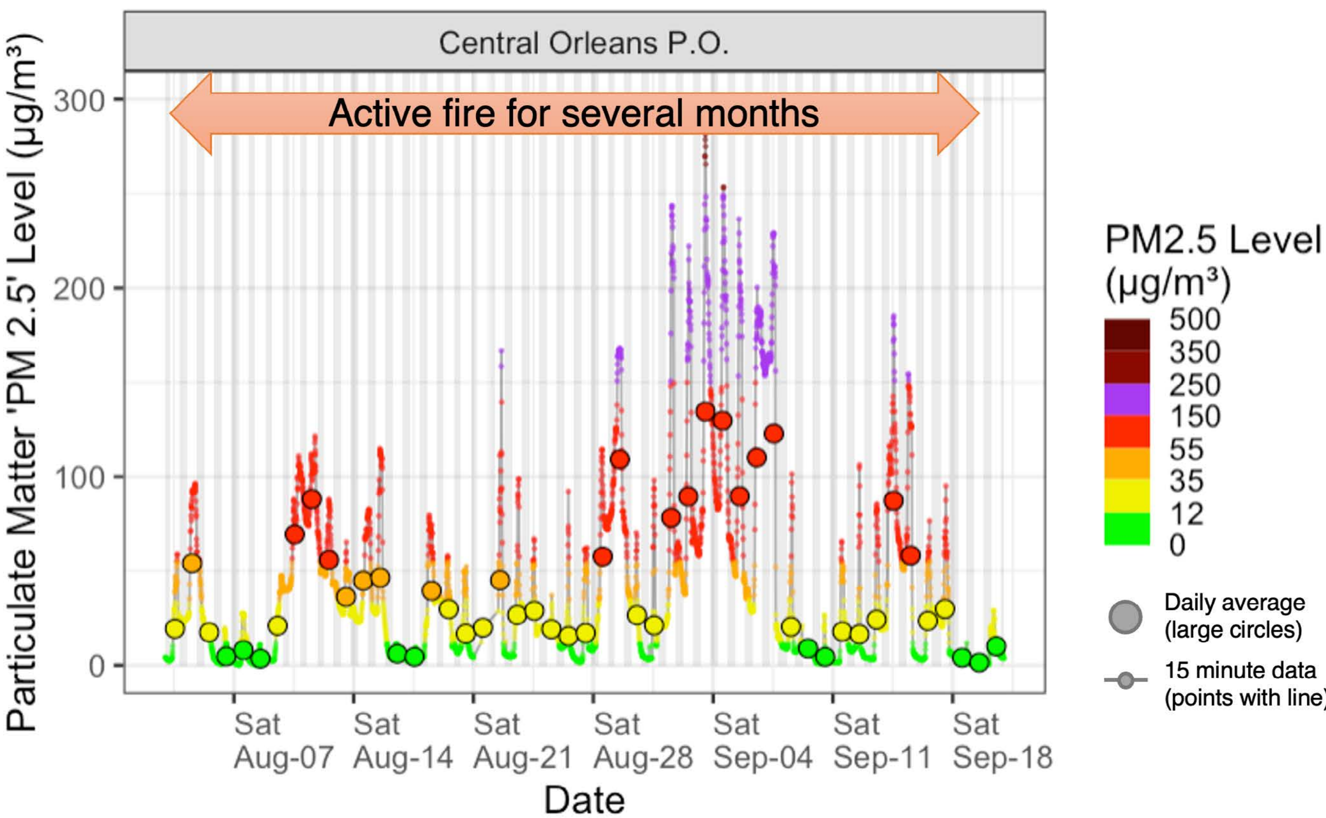

Figure 4: PM 2.5 levels in central Orleans, CA

Figure 5: (Left) Prescribed fire in the "Patterson" burn unit in Six Rivers National Forest in October 2021. (Right) A temporary air quality monitor powered by solar energy that was installed near the burn.

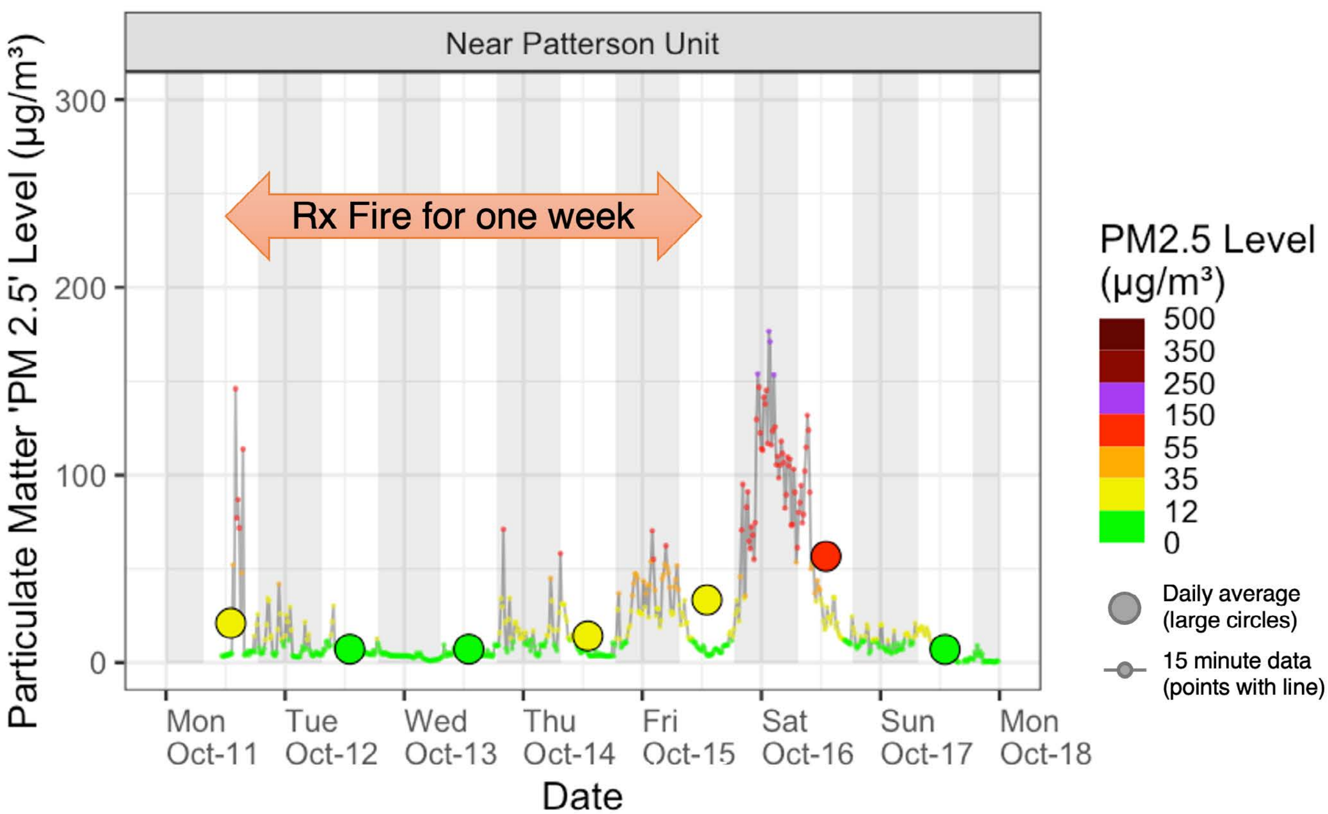

Figure 6: Smoke (PM 2.5) levels as measured by a temporary monitor near a prescribed fire in the Patterson Unit of the Somes Bar Integrated Fire Management Project in October 2021.

Figure 7: Figure shows fire practitioner igniting brush near the willows and a temporary smoke sensor at a cultural burn in October 2021.

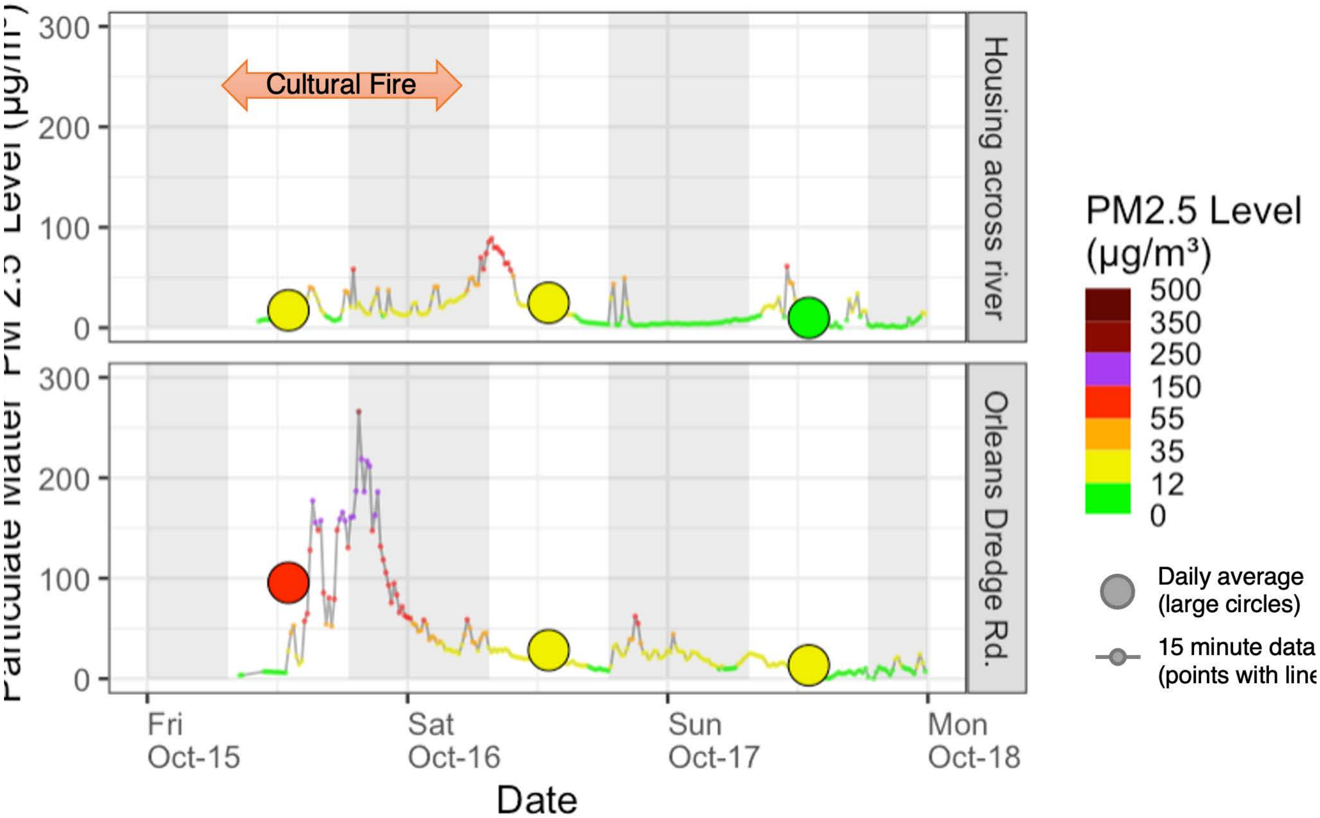

Figure 8: Smoke levels at two locations near the cultural burn in October 2021.

sizes the importance of localized monitoring to understand the smoke impacts from cultural and other intentional fires.

In addition to the variation in smoke levels associated with intentional fires and wildfires, it is noteworthy that all smoke is not considered the same qualitatively. Based on visual, olfactory, taste, and other sensory cues, community members differentiate between different kinds of smoke. For instance, one interviewee described the difference between "good smoke" and "bad smoke" as being related to its color and the way it moves through space. When done well, smoke from prescribed fires is seen in wisps of blue and grey, while smoke from wildfires is usually more intense and looks white and grey. The same community member described the bad smoke from wildfires as usually "dirty, dank, and moist," which lays in the valley and does not move, whereas good smoke is perceived as lighter, less moist, and does not linger in the valley. Interviewees also described the taste of smoke as being relevant to their assessment of air quality. One reported, "When you get up in the morning and taste it, it's really bad. It's funky, or close, or there is a lot of it."

Residents in the community are actively making qualitative, spatial, and temporal assessments of air quality, and taking actions for themselves and their community on the basis of these assessments. In discussions with intentional fire practitioners and community residents, several people indicated that the expanded Purple Air network was an additional and helpful source of information to them. For example, a leader in the Karuk Tribe's fire program described how people working on a prescribed fire used real-time feedback from the air sensor network (accessed through a mobile phone) to support hour-to-hour decisions on when to ignite certain portions of an area being treated, aiming to better protect nearby communities while still advancing goals for the treatment area. Another person described how the air sensor network was valued by seasonal fire workers who lived in the area. They use the network to monitor the smoke levels both near large wildfires and in the fire camps to understand and reduce their overall exposure levels and maintain health. Residents described the sensor data as validating what they already knew was bad air quality in their community, while some described the data as striking due to how high the levels were. People also described using the sensor network to identify when and where the air was appropriate for recreation, particularly for children. Some described how having better visibility through the sensor network was helpful for prioritizing outdoor activity, but also noted that some outdoor jobs just needed to be done anyway—in spite of the smoke.

Collection of different kinds of data aids our understanding of smoke across fire events. These data could also help residents in making individual and community health decisions. No single information source provides a complete view of smoke. Peoples' visual and olfactory sensations identify fundamental differences in the qualities of smoke that are not easily measured by low-cost sensors. Still, when the air pollution levels go from moderate to severely unhealthy, people want less subjective measures. The same smoke that appears to be thick and orange, backlit by the sun, could be difficult to perceive hours later. The Purple Air network and other sensors and monitors fill this perception gap and provide more information across time and landscape. Combining visual, olfactory, and taste perception data with numeric information from the sensor network could be valuable for community health and decision making.

Assessing Indoor Air Quality Infrastructure

Many interviewed residents described staying indoors with doors and windows closed as a common strategy used for protecting themselves from poor air quality. Some described using masks (even in pre-pandemic times) for protecting children, the elderly, and other residents with respiratory vulnerabilities. However, outdoor and indoor air quality are related, so the program also focused on analyzing strategies for improving indoor air quality with a focus on homes and community buildings. This portion of the work includes identifying the needs and priorities for air filtration to clean indoor air, and analyzing the utility of indoor air sensors to monitor their performance.

While early discussions included the concept of clean air shelters that could be set up on days with particularly hazardous air, it became clear that these would not be effective or desirable to community members because hazardous air is simply too frequent. It would be disruptive to community life and livelihoods to shelter from frequent events. Therefore, we shifted our focus toward other strategies for clean indoor air such as providing more smaller scale filtration units for residences and community spaces. Presently, researchers are analyzing the relationship between outdoor and indoor air quality in several homes in the Orleans-Somes Bar region, with and without the use of filtration systems. The aim of this portion of the program is to appropriately size air filters for homes in the region given specific building types and high outdoor air pollution levels.

Planning for a Fire-Adapted Energy System

Residents in the Karuk ancestral territory, which is in rural and inland Northern California, face extremely tenuous energy access. During multiple interviews, residents identified power losses a s one of the main issues faced by the community. This problem is exacerbated during wildfire season when utilities increasingly turn off the grid to reduce the likelihood of causing fires. Lack of electricity creates twin problems: 1) not being able to run air filters; and 2) not being able to access information about potentially fast-moving wildfires since communication services are also affected during blackouts.

Analysis of the qualitative and quantitative data identified need for a fire-adapted energy system that would provide electricity to Orleans and the nearby region. The system would enhance the energy resilience of the region, reduce the number of days people would need to live without energy, and allow the Tribe to own and operate its own energy system thereby prioritizing the needs of this specific area of Northern California. Furthermore, having more reliable energy services would allow people to stay connected with the wider world through internet and cell phone communications. The system would also support preservation of culturally significant foods like salmon and acorns: these are harvested at specific times in the year and are stored in freezers vulnerable to power outages. Finally, reliable power would also support air filtration systems and air sensor networks identified as vital for community health.

As part of this study, we assessed the potential of local distributed renewable energy and battery storage to meet Orleans' energy needs today and in the increasingly electrified future. This study included the preliminary design of a solar-powered front-of-the-meter microgrid with a target of $12 million in funding for capital expenditures from Pacific Gas & Electric's Microgrid Implementation Program (an upcoming funding program). Selected results from this study are shown in Table 1.

As shown in Table 1, a $12 million system could provide autonomous power to Orleans for up to three weeks. We also estimated the impacts of electric vehicle and heat pump adoption on days of autonomy. Given 25% adoption, the microgrid could provide up to twelve days of autonomy. At 50% adoption, the microgrid could provide up to 6 days of autonomy, and at 100% adoption, up to four days of autonomy. This type of microgrid could provide improved resilience to community members in Orleans, helping to keep the lights on,

Table 1. Sizing & performance of a $12 million system

Electric Vehicle & Heat Pump Adoption	Solar Size (MWDC)	Battery Power (MW)	Battery Capacity (MWh)	Days of Autonomy
0%	2.0	8.0	31.8	21
25%	2.8	6.1	24.4	12
50%	3.5	4.3	17.0	6
100%	0	12.6	50.2	4

fridges cold, and air purifiers running during wildfires and blackouts.

Working to Bring More Resources to the Tribes in the Region

As a collaboration that has been, from its inception, self-reflexive about the research process and its benefits to entities and people involved, our goals have been explicitly linked to not only research outcomes and academic publications, but also grant writing and fundraising. In other words, bringing resources into Tribal and rural communities has been one of the objectives of the collaboration. The principle of reciprocity is central to the Karuk Tribe's ethos, and guides the process for collaborating with academic institutions, as encapsulated in the Practicing Pikyav document that outlines the process and guidelines by which the Karuk Tribe engages with researchers (*Practicing Pikyav: A Guiding Policy for Collaborative Projects and Research Initiatives with the Karuk Tribe*). The SAFE collaboration has been guided from its inception by the principles outlined in the Practicing Pikyav document. The resources from the SAFE collaborative grant pay for staff time at the Karuk Department of Natural Resources and Blue Lake Rancheria. Furthermore, the research tasks carried out through the collaboration enabled the identification of energy and air quality infrastructure needs in the community. Rather than leaving these identified needs as abstract goals for the future, this collaboration has worked to apply for state and federal funding to enable the identified infrastructures to come to fruition. This practice is part of the partnership's attempt to transcend one-off engagements and create longer term relationships between academic researchers and Native Tribes on shared climate goals.

Thus far, three additional grants have been received by this collaborative group for future work identified by this team's activities. These include a planning grant from the Transformative Climate Communities Program of the Strategic Growth Council of the State of California, with the goal to support and develop community infrastructure in affordable housing, clean energy, air quality, electric transportation, and food security; a grant from the United States Environmental Protection Agency (US EPA) to establish a more extensive air quality monitoring network (for both indoor and outdoor air quality monitoring) across the Klamath River Watershed in partnership with the Blue Lake Rancheria and Karuk Tribe; and a CA100 grant to support the Karuk Tribe's Health and Human Services efforts to develop, implement, and evaluate an updated air filtration program that distributes air filters to an additional 100-200 households. While securing funding for implementation activities is not usually a part of academic research projects, this grant work emerged as a crucial component of properly valuing staff time spent on research at the Karuk Tribe and Blue Lake Rancheria and ensuring that the outcomes of this particular interdisciplinary research partnership benefited all our collaborators in both intellectual and material ways.

Conclusion: Imperfect and Emergent Collaborations can Still Lead to Meaningful Insights

While being far from perfect, our ongoing partnership has illustrated exciting ways that collaborations can bring the critical social sciences together with more technocratic approaches to pressing societal challenges like air pollution, wildfires, energy access, and climate change. While we have experienced numerous challenges of bridging disciplinary divides for the mutual benefit of the intellectual work of the partnership, and several of these challenges are not solvable in the short or medium term, we have also found exciting ways to collaborate and generate insights that are more meaningful and impactful when thought about together.

While many within academia are keen to explore interdisciplinary collaborations, there are very real intellectual and pragmatic challenges in conducting interdisciplinary research. We offer our reflections on these challenges not to discourage our readers from attempting to work across disciplinary divides, but as an honest account of the way the collaborative process has unfolded, and to offer outcomes of collaboration as forged in the struggles of interdisciplinarity.

Most critical social scientists work alone on projects, or on rare occasions with collaborators who are peers, while most STEM-based researchers tend to work in teams with specific tasks allocated in hierarchical ways. Practices of collecting, storing, analyzing, and sharing data are also widely varied between these intellectual traditions. What is considered "data" is fundamentally different and is protected in different ways. For example, "field notes" are closely protected and guarded by ethnographers, while engineering teams consider them in less hallowed terms. The norms of interviewing vary depending on the disciplinary orientation of the researcher. Many critical social scientists prefer semi-structured interviews with questions functioning more as prompts to have a wide-ranging conversation. The grounded, open-ended method of collecting data in this disciplinary context serves an important revelatory function: to use the research to arrive at topics that are most pressing to the field context, rather than to identify them in advance based on the prior beliefs of the researchers. On the other hand, when engineers conduct interviews, many prefer neatly delineated questionnaires with answers kept short and objective. Neither is a universally better method of collecting information; they both allow us to learn different things. These differences extend beyond the open-ended or closed nature of the interview. For instance, while both may be asking relatively direct questions about community experiences of looking at air quality data, an engineer would be interested in whether color coding data in particular ways conveyed information more clearly to viewers, while a critical social scientist would be interested in how the numerical air quality information was assimilated into visual, olfactory, and other sensory perceptions of air quality that residents already relied on. This is just one, albeit illustrative, example of the divergences that emerged through the process of our work together.

Norms around data collection, academic writing, conference presentations, and publishing also vary widely. Critical social scientists are usually expected to publish solo-authored works, rather than writing journal articles with multiple authors, the latter being the norm in many engineering and natural science disciplines. Furthermore, some of the researchers on this collaboration work adjacent to academia, operating within the intellectual and managerial norms of an engineering firm, leading to its own unique advantages and disadvantages of accomplishing research tasks in collaboration with faculty who operate with different incentives and ways of thinking about the labor of intellectual work.

Furthermore, programs that consist of collaborations between university researchers and Tribes can have unique institutional constraints to navigate. Like universities, Tribal governments have their own bureaucratic structures to work within, and academic-Tribal collaborations often need to learn each others' institutional processes and vocabulary of operation in order to successfully navigate working together. In addition, when working on research projects funded by state or federal resources, Tribes could be asked to waive their sovereign immunity as a condition of receiving research funds. This clause acts as a disincentive for Tribes to receive state or federal funds, which limits the research partnerships that Tribes can enter into. On the other hand, university research is funded by state and federal sources, and faculty are incentivized to apply for prestigious state and federal research grants.

Tribal sovereignty is recognition that Tribal governments are independent nations vested with powers. Interactions and contracts with Tribes are with their sovereign governments, through their officials. Sovereign immunity is a protection offered to sovereign entities such that a lawsuit brought against the actions of a state or its officials does not bear adversely upon the citizens served by that state (such as member of a Tribe). It was important to all of us on the research team that we honor Tribal sovereignty, and so a creative administrative workaround was devised by which Cal Poly Humboldt accepted liability for this research collaboration on behalf of our Tribal partners. We also looked for opportunities to address this issue so that the workaround will eventually not be needed. With the platform of a state-funded research project, our team was able to raise the issue of sovereign immunity with staff and leadership at several state agencies through the course of this collaborative work. We hope this will lead to a policy change within state agencies when they are collaborating with Tribes, so that future collaborations with universities on state-funded research are encouraged rather than discouraged by the conditions of state funding.

While our ongoing research partnership has highlighted numerous challenges of carrying out interdisciplinary research in collaboration between researchers in different academic departments, and between universities and Tribal partners, our work has also emphasized some of the benefits of such engaged scholarship. We hope that this short and reflexive article highlights both the joys and frustrations of collaborative and community-engaged scholarship. We believe such partnerships are building blocks for our collective efforts to address contemporary environmental and societal challenges.

References

California Department of Forestry and Fire Protection (CAL FIRE), Stats and Events, accessed here: Retrieved November 14, 2022. https://www.fire.ca.gov/.

Cal Poly Humboldt 2022. "Vision." Arcata, CA: Cal Poly Humboldt. https://strategicplan.humboldt.edu/#hsu-purpose

Ford, Bonne, Maria Val Martin, S. E. Zelasky, E. V. Fischer, S. C. Anenberg, Colette L. Heald, and J. R. Pierce. 2018. "Future Fire Impacts on Smoke Concentrations, Visibility, and Health in the Contiguous United States." *GeoHealth* 2(8):229-247. doi.org/10.1029/2018GH000144.

Goldman, Mara J., Paul Nadasdy, and Matthew D. Turner, eds. 2011. *Knowing Nature: Conversations at the Intersection of Political Ecology and Science Studies*. Chicago: University of Chicago Press.

Haraway, Donna. 1988. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist studies* 14(3):575-599. doi.org/10.2307/3178066.

Holder, A. 2020. Personal Communication.

Jaffe, D. A., S. M. O'Neill, N. K. Larkin, A. L. Holder, D. L. Peterson, J. E. Halofsky, and A. G. Rappold. 2020. "Wildfire and Prescribed Burning Impacts on Air Quality in the United States." *Journal of the Air & Waste Management Association* 70(6):583-615. doi.org/10.1080/10962247.2020.1749731.

Liboiron, M. 2021. *Pollution is Colonialism*. Durham, NC: Duke University Press.

Long, J. W., L. W. Tarnay, and M. P. North. 2018. "Aligning Smoke Management with Ecological and Public Health Goals." *Journal of Forestry* 116(1):76-86. doi.org/10.5849/jof.16-042.

Norgaard, Kari Marie. 2014. "The Politics of Fire and the Social Impacts of Fire Exclusion on the Klamath." *Humboldt Journal of Social Relations* 36:77-101.

Norgaard, Kari Marie. 2019. *Salmon and Acorns Feed Our People: Colonialism, Nature, and Social Action*. New Brunswick, NJ: Rutgers University Press.

Pacific Gas And Electric Company. 2019. "2018 Annual Electric Reliability Report."

Pyne, Stephen J. 2016. *California: A Fire Survey*. Vol. 2. Tucson, AZ: University of Arizona Press.

Sandoval, Catherine J. K. 2018. "Energy Access Is Energy Justice: The Yurok Tribe's Trailblazing Work to Close the Native American Reservation Electricity Gap." In *Energy Justice: US and International Perspectives*. Northampton, MA: Edward Elgar Publishing:166-207.

Subramaniam, Banu, and Angela Willey. 2017. "Science Out of Feminist Theory Part One: Feminism's Sciences." *Catalyst: feminism, theory, technoscience* 3(1).

Tripp, Bill. 2017. "Too Much Fire Elsewhere and Not Enough Here." In Allison Jolley, ed. "Good Fire on the Ground in 2017: Seven Controlled Burns to Learn From." Fire Adapted Communities Learning Network. https://fireadaptednetwork.org/7-controlled-burns/.

Tripp, Bill. 2020. "Our Land Was Taken. But We Still Hold the Knowledge of How to Stop Mega-Fires." *The Guardian*, September 16. https://www.theguardian.com/commentisfree/2020/sep/16/california-wildfires-cultural-burns-indigenous-people.

Western Klamath Restoration Partnership. 2022. "Somes Bar Integrated Fire Management Project." https://www.wkrp.network/orleanssomes-bar.