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Energy Service Security for Public Health Resilience: Perception and Concerns in Western Upper Peninsula of Michigan☆

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Abstract The Western Upper Peninsula of Michigan includes six rural counties and one Tribal Nation. The region is characterized by long winters, legacies of the extractive mining economy, and the infrastructural features of extreme rurality, including aging housing and low health service density. The region also faces exceptionally high electricity prices. There is limited research on the public health implications of energy service disruption in rural regions resulting from the increasing intensity and frequency of weather events caused by climate change. This article presents research findings examining the readiness of health facilities in this area to manage the rising intensity, severity, and frequency of severe weather that could disrupt energy services. The study also considers how this knowledge can guide decision-making to improve energy service access and maintain resilient public health services in the region. This exploratory study utilized a qualitative approach that combines semi-structured interviews with public health stakeholders and a short survey to triangulate the findings from health facilities. Given the pivotal role of dependable energy services in community health, these findings underscore the community's perception of self-reliance as both an asset and a hurdle. This perception aligns with the realities of rural communities at the "end of the line" regarding critical infrastructure, which also serves as a formidable barrier to social organization and infrastructure access during energy service disruptions that can severely impact public health.

Practitioner Points

1. People living in the Western Upper Peninsula of Michigan perceive themselves as self-reliant, which can hinder socially organized responses to disasters.
2. Energy access is a key component for providing public health services, and the perception of self-reliance may limit proactive planning for infrastructure access to support public health needs during a disruption.
3. Focusing on energy services in rural communities is critical to developing resilience.

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Introduction

The field of public health involves safeguarding and enhancing the well-being of individuals by considering how social conditions precipitate vulnerability, looking beyond risk factors at an individual level (CDC 2022; Link and Phelan 1995; Susser et al. 1996). These social factors include socioeconomic status, gender, community dynamics, and the topic of consideration for the research presented in this paper: energy service security.

Energy use today is central to human health, with increased reliance on electricity as the predominant end-use energy to provide energy services, including but not limited to cooling, heating, cooking, and refrigeration (Tiwari et al. 2022). Energy services directly and indirectly influence public health outcomes (Cook et al. 2008; Khan et al. 2020). This relationship is conspicuous among disadvantaged communities, both domestically in the United States and globally, where insufficient infrastructure constrains the availability of energy services, which in turn can limit access to life-saving medical equipment, vaccinations, and other medications that require refrigeration, etc. The importance of access to energy services for public health resilience is visible amid sudden disasters that affect the functioning of energy grids (Dargin, Berk, and Mostafavi 2020; Rose 2007).

This paper presents an exploratory evaluation of the energy services needs of the health facilities (hospitals) covering the population of six counties of the Western Upper Peninsula (U.P.) of Michigan. The area holds a distinctive historical, geographical, social, and cultural identity, making it particularly vulnerable to adverse effects from disasters. For instance, in parts of the peninsula, the single-season snowfall averages over 300 inches (Keweenaw County 2022; Manzullo and Siacon 2019). Residences within this area contend with some of the highest electricity costs in the contiguous United States, even though their income level falls below the state of Michigan's average (Michigan Public Service Commission 2023; Prehoda, Pearce, and Schelly 2019). Further, the region faces demographic and infrastructural challenges like those of many rural communities, including poverty, an aging population, and aging and inadequate housing, transportation, and energy infrastructures. As a result, individuals in the U.P. are especially susceptible to climate change-induced risks and disasters that affect their ability to access energy services.

This study aims to understand the existing energy service delivery, requirements, and susceptibilities of healthcare facilities in the region. Our focus is on understanding the readiness of healthcare facilities to manage climate-related disasters, like snowstorms and flash floods, which are highly prone to causing interruptions in energy services. These service disruptions carry substantial implications for public health, including vulnerabilities for those who rely on electrical energy for medical devices, medication, etc., both within health facilities and at home (Chobanov 2021; Cox 2021). Through the study we aim to highlight energy as a means rather than an end by demonstrating how the services derived from energy support community resilience and public health. The study seeks to answer the question, to what extent are public health facilities in the Western Upper Peninsula prepared to navigate the increasing occurrence and intensity of storms with a high likelihood of power system disruption? The paper also discusses how understanding perceptions and priorities for disaster preparedness in rural public health systems can inform decision-making

to enhance energy service access and ensure resilient public health services in rural communities in this region.

The research provides evidence that rural health facilities preparedness and capacity to provide services to the community in addition to their in-patient care in case of disasters is essential for energy access during and after the disaster. Public health facilities at present do not prioritize proactive planning with a sense that disruptions can be navigated as they unfold and do not require the building of networks beyond the local region to address acute community-wide energy service needs. The study further indicates that a cultural perception of self-reliance persists in people of the region which is both a strength and a challenge. The finding reveals a dynamic that is likely relevant to rural communities throughout the United States as they navigate the uncertainties associated with climate change, infrastructure access, and community well-being. It further suggests the need for convergent future research looking at this intersection of energy service security, public health infrastructure, and cultural self-perceptions in rural communities.

Background

Literature on public health has expanded over the decades to include social determinants of health and to consider how community context, such as rurality, impacts health outcomes, including during disasters and disaster response. Considering the role of energy services in public health during and after disaster-induced energy outages can help address preparedness and response in rural communities to ensure public health access for the most vulnerable populations.

Public Health

Traditionally, community health was assessed by examining individual health concerns such as cancer or heart disease, and by scrutinizing personal health habits such as tobacco use and physical activity, and their influence on overall well-being (Link and Phelan 1995; Susser et al. 1996). However, research demonstrates that although these factors are crucial, concentrating solely on disease prevention and management is insufficient for fostering healthy and resilient communities and necessitates an examination and incorporation of social indicators (Braveman and Gottlieb 2014; Hill-Briggs et al. 2021).

Public health aims to protect and improve the health of people and communities (CDC 2022; Link and Phelan 1995), ranging from a local neighborhood to an entire country. Public health attempts to addresses how socioeconomic factors are linked to the fundamental cause of diseases and the vulnerability of people to these diseases, hence going beyond risk factors at individual level (Link and Phelan 1995; Susser et al. 1996; Susser, Watson, and Hopper 1985). According to Link and Phelan (1995), it is crucial to place risk factors associated with social conditions within their proper context, as they may serve as the underlying cause of diseases. These social conditions not only contribute to illnesses but are also influenced by illness. Therefore, solely enhancing medical care is insufficient for effectively enhancing public health outcomes. Addressing the social conditions that affect illnesses is equally imperative (Braveman, Egerter, and Williams 2011; Johnson 1991).

The concept of Social Determinants of Health (SDOH) represents a public health model that emphasizes the circumstances under which individuals are born,

develop, reside, labor, and age as essential factors influencing both individual and community health (Braveman and Gottlieb 2014). The Centers for Disease Control (CDC) delineates SDOH across five domains: economic stability, education, social and community context, health and healthcare access, and neighborhood and physical environments (CDC 2022). Public health effects, particularly in children in rural communities, are found to be affected by the location, such as rural regions and the social factors associated with the region (Grineski 2009). As the health effects are dependent on community characteristics including difference in access and choice of health care for retirement age residents and migrants living in a community (Sander et al. 2015) The connection between SDOH and disparities in health becomes more pronounced during and following disasters (Marmot and Allen 2014).

As humans continue to face the ongoing and escalating impacts of our influence on the Earth's climate, impacts that disproportionately affect those who have had the lowest contribution to causing climatic change, the heightened impact of disasters on global public health is prevalent (Leaning and Guha-Sapir 2013; Lee et al. 2023). Climate change intensifies the occurrence and strength of hazards like heat waves, floods, and droughts, morbidity associated with cold-related events, the distribution of vector-borne diseases, and overall risk of adverse disaster outcomes and need for vaccines (Haines et al. 2006; Lee et al. 2023). Therefore, public health strategies need to prioritize the crucial impact of these climate change-related disasters.

Public health assumes a pivotal role throughout the disaster cycle, encompassing activities related to disaster resilience, including safeguarding against environmental threats, preventing injuries, responding to disasters, and aiding community recovery post-disaster (Shoaf and Rottman 2000; Tiwari et al. 2022). There is a growing emphasis on convergent interdisciplinary approaches in disaster research, particularly regarding public health implications for vulnerable populations affected by climate-induced disasters (Peek and Guikema 2021). In this study, we consider the role of energy services to public health provisioning during acute hazards, specifically in the context of a rural community with low population density, aging and inadequate infrastructures, an older and poorer human population, and disperse access to public health facilities, bringing a new and novel consideration and approach to studying SDOH. The study contributes to the SDOH literature as energy services are an understudied area of public health in the context of increasing climate-induced disasters, specifically focused on SDOH dynamics in rural community contexts.

Role of Energy Services in Public Health

Electricity is an instrumental good and serves as a provider of services rather than being merely the flow of electrons through electricity circuit (Fell 2017; Tiwari, Tarekegne, and Schelly 2021). The electrical requirements of any establishment or institution expand in correlation with the growth in functions and the increasing complexity of services, a phenomenon especially pronounced in healthcare facilities (FEMA 2019). For instance, electricity serves as an essential resource for various indispensable services including maintaining thermal comfort, enabling refrigeration, facilitating communication, and powering life-saving devices (Tiwari et al. 2022). Patients in healthcare facilities often need acute medical care heavily

reliant on uninterrupted electricity (FEMA 2019; Skarha et al. 2021). Individuals with functional access needs or chronic health conditions rely on electricity to operate crucial durable medical equipment such as powered wheelchairs and ventilators, cardiac devices, and blood pressure monitors which require electricity either for recharging or to maintain Internet connections (FEMA 2017). Vulnerable groups, particularly immunocompromised or elderly populations unable to regulate their body temperatures, face heightened vulnerability in the absence of environmental controls like heating and air conditioning due to power disruptions (FEMA 2019). Overall energy services hold a pivotal role in sustaining healthcare facilities and contribute significantly to bolstering community resilience (Smith et al. 2013).

Healthcare facilities (hospitals), particularly in rural areas, are anchors that provide healthcare, employment, economic development, and facilitation of critical communication (Cronin et al. 2021). During or after a disaster, hospitals are critical anchors as providers of emergency services. Hospital buildings rely on electricity for almost all their operations, including but not limited to lighting, security systems, fire alarms, environmental controls, electronic health records, refrigeration, and an array of electricity-dependent durable medical equipment and devices to provide care (Bawaneh et al. 2019; FEMA 2019). In addition, health facilities (hospitals) provide energy-dependent support, including food, water, and transportation (WUPHD n.d.). These establishments have added responsibility to address the energy needs of local communities during and following a disaster, especially when individuals lack energy access in their residences and require essential energy services for their survival.

These demands, coupled with the inability of healthcare facilities to typically halt their operations, render them particularly vulnerable to infrastructure breakdowns caused by power blackouts or insufficient supply and distribution of oil and gas. These shortages can significantly impact the outcome in critical situations during a disaster, potentially being the deciding factor between life and death (Casey et al. 2020; FEMA 2019). In the absence of energy access, these facilities might necessitate evacuation, a process laden with significant risks, particularly in remote rural areas that become challenging to reach during severe weather conditions like winter or have very sparse populations and extensive distances between population centers, as observed in the Western U.P.

Various forms of end-use energy carry inherent health risks, prompting public health experts to scrutinize the health implications associated with different energy sources at local and global levels (Rabl and Spadaro 2000; Smith et al. 2013). Currently, the intersection of public health and energy predominantly revolves around studies investigating the impact of fuel types on community health, particularly concerning local or regional air pollution arising from biomass utilization for cooking purposes (Greenberg 2017; Rabl and Spadaro 2000; Wilkinson et al. 2009). Research has extensively documented and analyzed the effect of indoor air pollution, particularly on women and adolescent girls attributable to the use of biomass for cooking, within the broader context of public health (Gall et al. 2013; Khandelwal et al. 2017; Pratiti 2021).

Properly designed energy systems with the inclusion of renewable energy (RE) systems benefit efforts to address climate change; however, the impacts of RE for public health outcomes are thus far described as either tangential or co-beneficial (Pratiti 2021; Wilkinson et al. 2009). There exists a scarcity of research regarding the influence of energy services on shaping the resilience of healthcare facilities; to address this gap, this work explores the perceptions of health facility professionals regarding the provision of energy services security for public health facilities and communities more broadly, particularly in a rural community within the context of an increasing potential for energy services disruption.

Secure and dependable access to energy services significantly contributes to community readiness, resilience, and response during disasters; this area has been inadequately studied, particularly concerning its implications for public health in rural areas (Casey et al. 2020). Temporary solutions such as using generators only offer short-term relief and neglect the possibility of prolonged outages in remote and secluded communities, such as those in the Western U.P. This study aims to bridge this gap in the literature by examining the perspectives of professionals working in public health facilities within this region regarding the risks associated with energy services and exploring potential strategies to ensure energy services security for rural communities facing escalating hazards.

Public Health and Energy Service Resilience in the Upper Peninsula of Michigan

The focus area of the study is the Western Upper Peninsula (U.P.) of Michigan, which comprises six counties (refer to Figure 1). These counties represent some of the most remote and northern areas within the Great Lakes region of the United States (Tiwari et al. 2023).

This research centers on the disaster preparedness of the public health facilities (hospitals) in this rural region. The Western U.P. frequently encounters severe weather conditions, enduring over seven months of lengthy winters with an average snowfall of over 300 inches (Keweenaw County 2022). Winter temperatures consistently drop below 10°F, and the region faces extreme weather events like polar vortexes. For instance, in 2019, temperatures plunged below −6°F with wind chills ranging from −25°F to −30°F (Manzullo and Siacon 2019). Additionally, a significant disaster known as the "Father's Day flood" struck Houghton County in 2018 during the Father's Day weekend. During this event, the area experienced over 7 inches of rainfall within a three-hour span. The estimated damages amounted to $30 million for public infrastructure, imposing significant financial strain and challenges on community access to services (kreport 2018).

The geographical location and historical influence of copper and iron mining industries have significant implications for the health indicators of individuals residing in the U.P. Approximately, 20 percent of the non-incarcerated population is aged 65 or older, contrasting with the statewide percentage of 15 percent. Moreover, in two of the six counties examined, over 30 percent of the population falls within the 65 years or older bracket (Census 2021). As the prevalence of chronic diseases tends to be higher among older adults and this demographic requires increased home health services, assisted living, and nursing home care,

Figure 1. Map of Counties in Michigan with Inset of the Six Counties of the Upper Peninsula of Michigan (DTMB 2023).

Table 1. Population Changes in the Six Western U.P. Counties in Michigan (Census 2021)

County/Year	2010	2015	2020	% Change (10–20)
Michigan	9,883,640	9,900,571	10,069,577	1.88
Baraga	8,860	8,690	8,140	−6.33
Houghton	36,628	36,660	37,238	1.55
Ontonagon	6,780	6,298	5,805	−14.38
Gogebic	16,427	15,824	14,346	−12.66
Keweenaw	2,156	2,198	2,068	−4.08
Iron	11,817	11,507	11,628	−1.60

a demographic shift toward older age groups within a community profoundly impacts healthcare and elder service needs. Additionally, these counties are experiencing a decline in population, potentially exacerbating resource shortages and instability (Table 1).

Prior to the enactment of the Affordable Care Act (ACA) in 2014, around 19 percent of individuals aged 18–64 in the U.P. lacked health insurance coverage. By 2017, this percentage had decreased significantly to an estimated 7 percent,

primarily due to Michigan's Medicaid expansion and the establishment of a new health insurance marketplace. Moreover, each of the six counties in the Western U.P. contains areas designated as Health Shortage Population Areas (HSPAs). The HSPA designation is conferred upon places, populations, or facilities meeting specific federal criteria for shortages, which could be geographic, population-based, or facility-based. Health Professional Shortage Areas (HSPAs) highlight deficiencies in primary care, dental health, and mental health providers. Even urban areas within the region exhibit a lifestyle that aligns more closely with rural settings (HRSA n.d.) (Table 2).

The Western U.P. faces an increased susceptibility to power system breakdowns due to its harsh cold climate, aged infrastructure, and its position at the extremity of the electrical power network (Casey et al. 2020; Chen, Thorp, and Dobson 2005). This poses a significant concern for the region's healthcare facilities, which directly encounter the difficulties of catering to underserved individuals and communities within the context of persistent disaster threats and limited financial resources. Severe and unpredictable weather patterns pose a risk to the resilience of energy services and the overall reliability of the power grid (NERC 2022). Considering the potential fallout from infrastructure failures, especially for those reliant on equipment needing uninterrupted energy service access, ensuring the robustness of energy systems is crucial to safeguarding public health (Casey et al. 2020).

The Western U.P. grapples with the disparities in urban–rural health commonly prevalent in many rural areas across the United States (Leider et al. 2020). Rural inhabitants typically confront poorer health outcomes and elevated age-adjusted mortality rates in comparison to their urban counterparts (Harris et al. 2016; Moy et al. 2017). Moreover, approximately 17.5 percent of individuals in rural areas across the United States are aged 65 or older, exposing them to additional health risks associated with aging (Census 2021). This percentage is notably higher in the U.P., where the estimated proportion of individuals over 65 years old within the non-incarcerated population surpasses 20 percent (Census 2021). The U.P. contends with considerable patient–physician ratios, amplifying the challenges associated with accessing healthcare services within the region (University of Wisconsin

Table 2. Selected Social Demographics for Six Western U.P. counties (WUPHD n.d.)

County	% of Children under 18 in Poverty	% of People in Poverty	% of Population over 65	% of Household over 65 Living Alone	2016 Unemployment Rate
Michigan	*23.5*	*16.7*	*15.4*	*10.9*	*4.9*
Baraga	24.9	15.6	18.7	16.9	7.9
Houghton	18	21.4	16.1	13.1	5.9
Ontonagon	21.5	15.5	31.7	17.1	8.3
Gogebic	34	20.2	23.3	16.7	6.5
Keweenaw	26.3	15.2	31.1	18.8	8.4
Iron	24.8	15.6	28.4	19.8	6.5

The italics value represents a different geographical area than the non-italic value. Italics values are representing the data for Michigan which is a state. Non italics values are representing the data for the counties in the western upper peninsula region of the state.

Population Health Institute 2021). When combined with the precariousness of energy services security in the area, these factors become a concern for both residents and regional planners, and these concerns motivated the research efforts described here.

Research Design

This research included interviewing relevant stakeholders and implementing a short survey for health facilities to understand their energy service needs. Interviews were selected as the primary method for data collection given their adaptability and the capacity to gather comprehensive information from each respondent on potentially sensitive topics (Adams et al. 2022). Following interviews, a short online survey was utilized to collect data related to the health facilities' operations, providing a greater in-depth exploratory understanding (Creswell 2014). The approach in this study aligns with the advocacy for more convergent research spanning social and behavioral sciences, public health, and hazard and disaster research (Peek et al. 2020). The research protocol and all related research instruments were approved by the University's Human Research Protection Program prior to any engagement with participants.

Interviews Sampling Strategy

Two stakeholder groups were identified through purposeful sampling (Creswell 2014). The first group included professionals working in health facilities in the Western U.P., while the second comprised professionals involved in public health and planning on a broader scale. Two distinct interview protocols were employed, and individuals were chosen based on their specific roles within the involved organizations.

The interview team contacted various health facilities (encompassing hospitals, county, or Tribal health departments) and key planning stakeholders like emergency managers and health-oriented non-profit organizations operating in the region. Certain facilities like long-term care and outpatient facilities were excluded from the data collection process. Due to the study's nature, the selection of initial organizations and individuals was deliberate rather than utilizing a random sampling method. Employing a snowball sampling technique, initial participants were asked to provide names and contact details of other potential participants. This facilitated the research team's access to additional interviewees who might have otherwise been challenging to reach—a recognized advantage of the snowball sampling method (Naderifar, Goli, and Ghaljaie 2017).

Participant recruitment and consent From the identified stakeholders, 14 individuals (respondents) participated in a total of 11 qualitative, semi-structured interviews. Three of these interviews were conducted jointly per the participants' request. Further details regarding the interviews are available in Table 3.

Participants received copies of the proposed questions and the consent script via email. At the beginning of each interview, the consent script was read aloud to ensure that each participant could provide informed consent. Participants were requested

Table 3. Interview Participants' Characteristics

Interview	Number of Participants	Organization
1	1	County
2	1	State Agency
3	1	State Agency
4	1	Local Agency
5	2	State Agency
6	2	Health Facility
7	1	State Agency
8	1	Health Facility
9	1	County
10	2	Health Facility
11	1	County

to verbally agree to participate in the interview and were also asked to consent to the interview's recording before the interview proceeded.

Interview data analysis procedure The recordings and transcripts underwent a cleaning process to remove any identifying information. The recordings and transcripts were anonymized by numbering and saved without any identifiable details. All participants were offered an opportunity to review and request revisions to their interview transcripts post-cleaning and before data analysis. One of the project team members analyzed the interview transcripts using the qualitative analysis software Nvivo, while other team members cross-checked for consistency. Codes were developed based on the literature review, interview questions, and, in some cases, frequently occurring themes found in the transcripts during the iterative coding process. No codes automatically generated by Nvivo were utilized during the analysis process.

Survey

Upon concluding the interviews, administrators at local health facilities were asked to take an online short survey. The survey aimed to gather data concerning the healthcare facility's size, electricity usage, instances of outages, as well as details about backup power and heating sources. Because of the factual nature of the data, these data were not collected during the interviews. Five health facilities were contacted (one in each county except for Keweenaw County, where there is no relevant facility), and survey responses were obtained from four out of the five facilities. The survey was not designed for generalizing the results. Instead, in line with the study's objectives, the survey was used to complement findings by adding quantitative details to the findings related to health facilities that were not obtained from the qualitative interviews (Babbie 2015; Creswell 2014).

Research Findings

The study investigates to what extent public health facilities in the Western Upper Peninsula of Michigan are prepared to navigate power system disruptions and the perceptions and priorities for rural public health systems in case of disasters. In

this subsection, we expound on the analysis of the interviews that unveiled various themes associated with the initial set of 14 codes. These codes were separated into three main categories of energy services needs and uncertainty, provision of services and resilience, and risks and concerns. The frequency of themes in three main categories is shown in Figure 2 and is further elaborated in the subsequent subsections.

Energy Service Needs and Uncertainty as Barriers to Preparedness

Rural health facilities are smaller in size and capacity when compared to their urban counterparts, which is reflected in their energy service needs. This is true for health facilities in Western UP, with two health facilities having less than 25 beds and the other two having less than 50 beds. The respondents discussed the energy service needs of their respective facilities and stated that they relied on three major types of end-use energy: electricity, gas, and oil. Electricity was predominantly used for appliances, lighting, refrigeration, and emergency operations. Respondents described electrical outages as the most common type of outage they experienced. Natural gas was utilized for thermal energy service needs. Respondents from the broader sample raised concerns about the natural gas infrastructure and its ability to service residents in the region, but health facility administrators and officials did not. Lastly, respondents noted the prevalence of oil, notably diesel fuel, for backup electricity generation. Multiple administrators noted their facility stored and utilized diesel for backup electricity generation. This was further supported in the survey responses, which all identified utilization of diesel generators as a primary electricity backup. Survey results further showed that most redundant backup energy systems are diesel or natural gas generators.

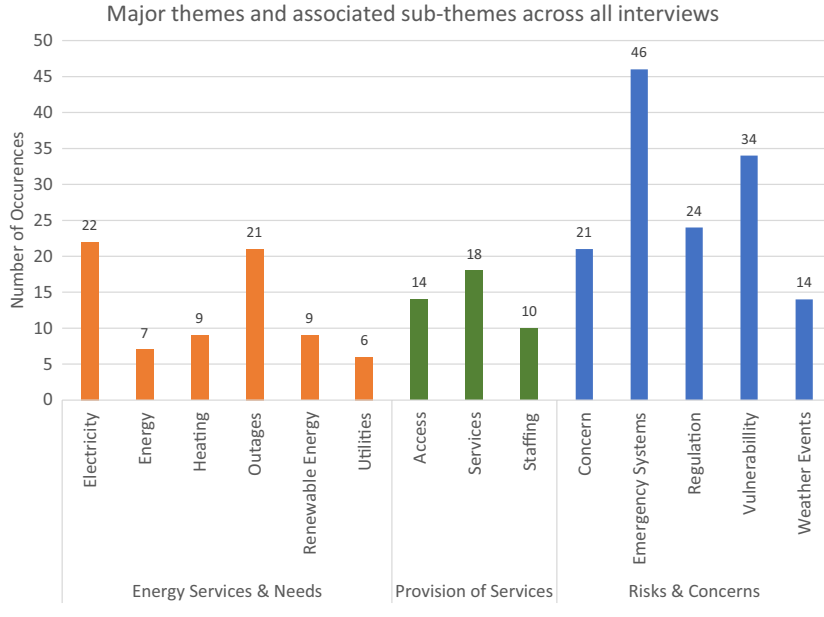

Figure 2. Major Themes and Associated Sub-Themes across the Interview Participants (Findings of the Study).

Responses regarding electricity conveyed a sense of hesitancy concerning the reliability of the electrical system. This hesitation stemmed from concerns over the limited count of electricity providers in the area, aging infrastructure, and doubts regarding the utility companies' capability to manage outages. One respondent stated:

> We have 3–4 different power companies that run through the county. They're supposed to be redundant. I mean, the grid is allegedly set up so that if one section goes down, it can reroute the other way. It's happened in the U.P. east end where that system is not very robust and having an unknown, lengthy time period without electrical power will definitely have an impact on people's ability to even feed themselves or have their oxygen. When the power went out in [redacted] for just 16–20 hours, we were bringing down oxygen from [redacted].

Another respondent expressed:

> The utility companies were saying, well, it is a double circuit line, but they all go through the same poles. It really was one truck driver away from plowing into one of the lines, and it could take us a month to replace that line. If somebody hits one of these things, that would knock out power to virtually everything east of Marquette in the U.P.

These responses carry a similar sentiment, questioning how reliable electricity truly is in the region to serve the energy service needs of the community. After being asked about the biggest vulnerabilities for health facilities in the region, another respondent shared that:

> In the U.P., we have several vulnerabilities that really stick out. One is hospital surge capacity in a mass casualty event […] and one of them is the power reliability through the U.P.

This echoes the concerns about reliability raised by other respondents for the energy services requirements. Health facility administrators and officials did not make comments related to electrical reliability for the Western U.P. While some interviewees shared specific instances that made them question system reliability, it is unclear if other events exist that support reliability concerns among certain respondents but not health facility officials.

When asked to consider the energy needs of health facilities, respondents primarily described different types of energy services, energy access, and energy providers. Respondents highlighted electrical outages or disturbances as the most prevalent energy disruptions. Many indicated that these outages were generally weather-related, had minimal impact, and were infrequent, referring to them as "flickers" and "minimal." One respondent described the outages as a blink, stating:

> We typically just notice a blink and then it comes back.

The frequency of shorter-term outages was reaffirmed by survey responses, indicating that all reported outages were less than 30 minutes and occurred less than five times a year, with only one instance exceeding 15 minutes. Several respondents mentioned that it had been several years since they recalled experiencing a long-term power outage, leading them to express relatively low concern about such events. Long-term outages were self-described by one broader planning respondent as "… outages more than, say 20 or 30 minutes" and were characterized as "few and far between across the district." Another respondent stated that "we don't necessarily experience a lot of power outages here, so I'm not too concerned about that." While electrical conditions vary in the Western U.P.'s counties, respondents from each county expressed little worry about electrical outages given their relatively infrequency or short durations. This may contribute to the limited backup power resources seen in the region. The relationship between a lack of perceived risk from electrical outages and the level of preparedness for these outages would benefit from further study.

Provision of Services and Resilience in Event of Power System Disruption

Health facility administrators and officials specified their ability to address energy service requirements during an electrical grid failure by restricting services and utilizing backup electricity generators. Respondents provided a range of estimated duration (days) indicating their capability to fulfill essential electricity service requirements for their premises, with two separate facilities referencing a 96-hour plan required by the Joint Commission, a healthcare accreditation entity. Under a 96-hour plan, facilities maintain supplies of all resources needed to operate for 96 hours without aid. However, facilities are not required to remain fully functional for those 96 hours and instead are only expected to have an operational plan for the time period to understand their capabilities and limitations. One respondent, after describing their facility's plan, shared:

> That's the golden rule—can you get through 96 hours?

Although respondents discussed extensive planning, they emphasized the absence of a known guideline determining the number of days their backup fuel supplies should cover their peak energy service needs. One respondent estimated they could manage from 4 to 14 days on backup power, depending on the time of year. Another respondent believed the hospital could survive for "many, many days" on backup fuel alone. Additionally, while health facility administrators and officials discussed testing their backup fuel supply to comply with the Joint Commission, none could cite a state of federal mandate for testing. Further exploration should be conducted regarding the standard procedures for storing and testing oil and gas in health facilities to ensure backup electricity services. This exploration is necessary due to the potential vulnerabilities it may pose in addressing energy service needs during a disaster.

In addition to a lack of standard procedures, the reliance on oil and gas resources for backup power raises its own concerns. Facilities with backup power utilized generators running on diesel or propane, potentially leading to complications if supplies deplete,

prices surge, or additional fuel cannot be brought in during prolonged outages. None of the interviewed facilities indicated the use of battery storage, and no respondents used renewable energy (RE) resources for backup power. Several respondents indicated their facility had considered RE, but only one was actively contemplating its installation. Others referenced the high cost as a significant barrier, noting that they currently considered electricity a relatively small expense which deterred them from pursuing RE installation. Respondents also emphasized their willingness to explore RE if there were grants or other forms of financial support available from the state.

Multiple facilities intended to transport new equipment or additional fuel for backup power in the event that their primary backup generators malfunctioned or there were fuel issues. This process would consume a substantial amount of time, especially in unfavorable weather conditions, which respondents seemed to recognize. Other interviewees highlighted the scarcity of locations even equipped with backup power aside from hospitals. Plans for backup power during prolonged outages occasionally depended on arrangements between local facilities, such as hospitals or schools, ensuring there were places equipped with power and heating available for community members. These plans, both formal and informal, might contribute to the level of community reliance in disaster scenarios.

While respondents expressed confidence in the ability of local hospitals to continue providing services through an energy service outage, some were uncertain about how well these health facilities could support community needs for energy and health services during an extended outage. When asked if health facilities had the capacity to support people with home health needs in the western U.P., one respondent did not feel hospitals could support community home health needs on any official scale. This respondent revisited this concern repeatedly, sharing:

> Hospitals don't normally just allow people to go in and plug-in in the hallway.I think on a local scale we could probably work with that, but I didn't realize… It's a hospital unless there's an emergency declaration or something like that. You're either a patient or an employee or whatever. I was just inquiring about people that wanted to plug in their oxygen machine. […] But technically that's not allowed.Officially, I'm going to say no [hospitals do not have the capacity to support community home health needs.] On a local level, though, because I know everyone, we could probably do it, but I'm thinking on an official scale. The answer is it's not used or not intended for that.

Administrators and officials were asked directly about their ability to meet the home health needs of community members during a long-term outage, to which they each responded cautiously:

> Health Facility A: "It would depend on the situation. That's a tough question to answer. Would we be willing to help our community? Yes."Health Facility B: "It depends on the disaster, largely."Health Facility C: "Probably to a certain degree. Yeah, I think we'd be able to [help] during one of those outages."

Health facility administrators and officials indicated that their ability to support community home health needs would depend on the circumstances. While only one

respondent brought up these concerns, their responses also indicated that circumstances mattered, albeit differently than those implied by health facility respondents. While the respondent thought they could meet community home health needs, they indicated they believed this primarily because of their own connections. Health facility respondents spoke little of their community relationships, focusing instead on the nature of the disaster.

Discussions varied regarding what measures could enhance the energy service resilience of the Western U.P.'s energy system. Two participants highlighted energy conservation as a means of resilience, citing LED lighting conversions in one instance and LED lighting conversions combined with temperature control in another. Natural gas, widely used and perceived as stable due to its community-wide distribution, was considered by some respondents as a solution for U.P. energy resilience. However, one respondent referenced a recent incident involving a natural gas system failure in a Western U.P. community. Another individual raised concerns about potential natural gas pipeline failures due to the proximity of the system to major roadways, stating:

> Think of an ice storm scenario. It is icy, knocks the power out, and somebody goes off the road and hits your natural gas station. That is a real, real possibility.

What will define resilient energy services and infrastructure in the region is not currently clear. Resources like natural gas are an option, though it may fail to serve enough residents and provide a stable energy resource. Discussions around implementation of RE may be valuable to understand why, beyond costs, businesses are not choosing to pursue RE options.

Risks and Concerns around Weather-Driven Outages: Community and Self-Reliance

Certain respondents expressed specific concerns about the secondary consequences of weather-related outages, including heightened use of indoor heating elements potentially causing house fires and other public health issues. Regarding weather-related concerns, some individuals were apprehensive about their ability to commute to health facilities or work, citing an example of the challenges faced after Houghton County's 2018 Father's Day Flood:

> Our biggest challenge was getting people to work because so many roads were washed out.

Another interviewee, when asked about accessing health facilities following disasters, stated:

> The facilities are relatively spread out. There are times we saw with the Father's Day Storm a couple years ago, where some of the roads that connect into Hancock were simply impassable and wiped almost completely out.

Another interviewee raised concerns about the overall access to health facilities in the northern Western U.P., citing that road access in the region is tenuous and large infrastructural failures, such as the local lift bridge, would lead to mass rerouting to alternate hospitals, as the area's local hospitals can only be accessed via said bridge. Respondents shared fewer concerns regarding the impact of severe winter weather and snowstorms on health facility access, with multiple citing that the major roadways were usually open and clear even in severe conditions. Additional work that examines perceived risks of different disasters and its relationship to transportation infrastructure would be valuable in understanding how people relate perceived risks and perceived access to health facilities.

Respondents exhibited minimal confidence in their capacity to obtain resources from the state of Michigan, such as disaster relief or medical equipment. They highlighted the geographical distance between the Western UP and the resources located "below the bridge," a term often used by residents to refer to Michigan's lower peninsula due to its connection to the U.P. through the Mackinac Bridge. To even reach the bridge by car from Houghton (a city in the Western U.P.) takes upward of five hours. While parts of neighboring states, such as Wisconsin and Minnesota, are closer or just as close to the Western U.P. as downstate Michigan, the region must receive resources from their own state government. This is complicated by the separation of the two peninsulas by the Straits of Mackinac and the potential for the Mackinac Bridge to close in inclement weather, as well as cultural differences between the peninsulas. Respondents mentioned using what they had access to in the region, be it police cruisers, county vehicles, tribal cars, or even personal vehicles, to manage disasters and incidents, citing that it could be hours or days until they received state support. One respondent said:

> The ability to use what is existing [is because] people are used to it. Just because we don't have any other resources. By the time something came in from the outside… It's going to be hours and by then, we've got a big problem.We just have to make it work for now, and it's not always perfect [or] the most correct one, but it buys us time.We're biased about the U.P. because we have enough resources to probably deal. We will deal with it. It just depends on what level. We'll figure something out. It may not be exactly by the book or anything else, but we will.

It is unclear if specific historic incidents contribute to this lack of belief that state resources will arrive in time. Greater investigation into these potential incidents could contribute to improved understanding of how to support the Western U.P. in times of crisis in an effective and timely matter. Furthermore, understanding these incidents may provide insight into this idea that in the Western U.P. residents just need to find something that works for now in the hope that more help will come.

Respondents expressed a collective reliance on themselves and their community above their state or other resources. A respondent described how, after the flood event, numerous residents took the initiative to clean up their own properties before

aid groups could arrive at the scene, while some declined assistance altogether. The respondent shared:

> That's just kind of stubbornness in our community. There is kind of a mindset, maybe, that in a disaster, well, my injury isn't that bad, which makes me wonder how many other injuries [there were] … that were never reported because [people] did not think it was a big deal.

Other respondents conveyed worries about their capability to access community members in the event of a power outage. Multiple respondents said they had experienced difficulty in contacting or providing emergency services throughout the U.P. One respondent referred to challenges during the Father's Day Flood:

> We had houses where we couldn't get people out, and we couldn't get emergency services in.

Another respondent brought up that it is difficult to send out emergency bulletins in communities with limited cell phone coverage, aging populations, and variable methods of communication. Another mentioned that they felt there was no way to effectively spread news about things even as simple as a boil advisory without driving door to door. These barriers may be attributable to the relative isolation the Western U.P. experiences, not only from surrounding areas but even between its own residents, and would benefit from further investigation.

Respondents were asked to share any additional concerns they had regarding energy services and public health in the region. They referred to shortages in facility staffing, restricted availability of medical equipment, and insufficient capacity within health facilities. Repeatedly, respondents referenced the limited capacity of health care in the region, while other respondents brought up staffing concerns and equipment access issues. Overall respondents outlined that while energy security was important it is at times treated as secondary in the face of other more pressing public health challenges.

Discussion and Conclusions

The findings from the study contribute to the growing understanding that providing energy services, particularly electricity as an end-use energy service, is of prime importance for public health and rural community resilience (FEMA 2019; Tiwari et al. 2022). The unique geographical landscape of Michigan's Western U.P. leads to a distinct reliance on imported fuel like oil and natural gas, accompanied by vulnerabilities linked to the long-term storage necessary for delivering energy services. This research in line with growing literature on energy services underscores the importance of quantifying the electrical services of health facilities (Khan et al. 2020; Skarha et al. 2021). These facilities can offer energy service, especially in rural areas situated at the extremity of energy infrastructure, to ensure service availability during and post-disaster. Presently, in the Western U.P., there is insufficient understanding regarding the duration and types of services health facilities

can sustain and deliver to address community needs in the event of a prolonged disaster affecting the region.

The study further finds that the perception of self-reliance pervasive across the rural region promotes a collective preference to figure out a solution to problems rather than relying on outside resources (Greenberg, Dyen, and Elliott 2013). The finding further strengthens the understanding, where neighbors and community members are often the first responders and would provide support for energy service needs. This cultural self-perception could pose a challenge in the case of an unanticipated disaster, mainly because the region is at the tail end of the energy infrastructure, and extreme weather conditions risk energy service disruption in Western U.P. (Prehoda et al. 2019). Further, this perception of self-reliance also aligns with the literature that limits proactive planning (Greenberg et al. 2013). Professionals in the public health domain collectively expressed a sense that they could address needs as they arose by working together to respond. There is a growing concern for vulnerable community members; public health facilities in the region are in the early stages of conducting proactive planning to support community energy services needs during a disaster. The respondents working outside the public health facilities expressed skepticism that they could serve the role of improving energy services. These findings align with other early literature on the limited understanding of the role of energy services in public health resilience (Tiwari et al. 2023). Finding ways to promote proactive planning, including the quantification of preparedness and effort to enhance resilience, reduce identified vulnerabilities, and increase community self-reliance, may provide a way to connect with the culture of rural communities while working to address energy services to support public health.

For a rural region like the Western U.P., which is at risk of adverse disaster impacts, a prolonged absence of institutional memory of the impact on energy can lead to underemphasized proactive planning. Health facilities would do limited planning for the impacts of increased and exacerbating climate-induced disasters, projected to rise in the coming decades. Utilizing an energy service-based approach for the community's needs during and after a disaster can help prepare the region to enhance resilience to the disruption of services for public health due to climate-induced disasters.

Study Limitations and Future Research Direction

Through the study, we contacted representatives from health facilities, public health, and other local stakeholders. Potential future endeavors might involve broadening the survey distribution to encompass other healthcare facilities not initially included in the interviews, such as those situated beyond the Western U.P., long-term care facilities, or outpatient care centers. We understand that these facilities are crucial to the U.P.'s greater health system. However, they were not included in this study as we intended to focus on facilities that provided a degree of care to the community, such as hospitals and health departments, because of their central role in providing daily patient care. Hospitals and health departments are considered primary healthcare

providers in the rural service sector and are focal points for services during a disaster emergency.

Convergence research is increasingly used to study specific, compelling problems with deep interconnections between different disciplines. Through this case study, we established a relationship between energy services and public health with a focus on rural health, and future research work could further extend this relationship. A single case study focused on a geographic footprint of six counties cannot be statistically generalizable to the energy service needs of all the rural facilities in the United States (Small 2009; Sovacool, Axsen, and Sorrell 2018). Hence, we hope future research studies can build on the exploratory work and further explain the relationship between energy service needs, public health, and health facilities in the United States.

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Data Availability Statement. The data that support the findings of this study are available from the corresponding author upon reasonable request.

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