Communities without Bootstraps: Necessary Conditions for Community Energy Resilience Potential

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ABSTRACT

Community energy resilience, defined as a community's ability to anticipate, withstand, adapt to, and recover from energy disruptions, is a pivotal domain of overall community resilience. Despite a proliferation of assessment tools, their actionability is often undermined by capacity and governance deficits in small communities. This study investigates the fundamental qualities necessary for community energy resilience to be meaningful, measurable, and actionable, particularly for smaller localities. A Resilience Possibility Index, based on the physical presence of services needed during a prolonged power outage, was quantified for 15 Virginia localities. An Authority Index for the Public Health & Safety domain was also analyzed. Empirical analysis confirmed a strong positive correlation between population size and the Composite Resilience Possibility Index ($R^2 = .75$, $p < .0001$), a finding that aligns with urban scaling principles. While large, independent cities achieved high potential, many small towns displayed profound deficits and were constrained by a lack of jurisdictional control over essential services. These results confirm that smaller localities often function as resource-constrained subsystems of larger regional entities. We conclude that a diagnostic pre-assessment is appropriate to determine a community's readiness for complex resilience planning, thereby guiding resources toward foundational capacity-building where it is most needed.

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1. INTRODUCTION

The purpose of this project is to explore the necessary conditions that determine a community's potential to achieve energy resilience. As climate change and aging infrastructure make prolonged power outages more common (Roege et al., 2014), the concept of community energy resilience has become a focus for planners and policymakers (Roege et al., 2014; Nik et al., 2021). In response, a diverse and crowded landscape of assessment tools has developed to help communities benchmark their resilience capacities, with comprehensive reviews cataloging dozens of frameworks (Cutter, 2016; Loerzel & Dillard, 2021). However, the potential to operationalize these tools is not uniform across all localities.

A central challenge is that these assessment tools often implicitly assume a level of local capability that may not exist (Paterson et al., 2017). The frameworks often pose difficulties for smaller communities, like demands on financial and human capital and difficulty accessing or interpreting the data required for assessment (Paterson et al., 2017). Furthermore, the assessment methodologies themselves can present significant barriers; the operationalization of the concept of resilience is challenging (Tariq et al., 2021), and the sheer number of indicators and lack of consensus on application can overwhelm local practitioners (Gillespie-Marthaler et al., 2019). Top-down frameworks can overlook governance constraints, such as a community's lack of jurisdictional authority over essential services (Tariq et al., 2021). Consequently, the communities most vulnerable to disruptions may be those least equipped to conduct the assessments designed to help them.

This study posits that, before a community can usefully engage in complex resilience planning, it must first meet a baseline level of what we term "community energy resilience potential." To investigate the building blocks of community energy resilience potential, this study utilizes data from the pilot deployment of a novel Community Energy Resilience Workbook and Scoring Tool, developed as part of the Virginia Energy Resilience Study (VERS). VERS is a multi-phase research initiative designed and implemented by the Virginia Department of Energy and funded by the U.S. Department of Energy. The VERS tool was designed to help localities assess their capacity to withstand and recover from prolonged power outages across four discrete domains of vital energy services. Furthermore, it guided communities in developing actionable steps to improve energy resilience.

The VERS data offer a unique opportunity to systematically investigate the minimum qualities of population, services, infrastructure, and governance that make the concept of community energy resilience meaningful and its measurement actionable. To address this, a simple index to quantify resilience potential was constructed from and applied to the VERS data. In addition, jurisdictional control of public health and safety services was explored through an index of resilience authority.

This paper aims to answer the following research questions:

1. What capacities and characteristics must a community have for the concept of "community energy resilience" to be meaningful, measurable, and actionable?
2. How are these capacities and characteristics related to a community's measurable energy resilience potential?
3. Can a simple indicator that measures this intrinsic potential for energy resilience be constructed?

The paper begins by reviewing the theoretical background of community energy resilience and the literature on assessment practices. It then details the methodology for constructing the Resilience Possibility Index. After presenting the results, the paper concludes with a discussion of the implications for redirecting resilience planning toward more effective strategies.

2. BACKGROUND

This section establishes the theoretical basis for analyzing community vulnerability and resilience during long-term power outages. It begins with core concepts of resilience and community, narrows to the specific case of community energy resilience, and concludes by examining how population thresholds and governance structures shape a community's inherent potential to withstand such disruptions.

2.1. Concept of Resilience

The term resilience describes how a system responds to external impacts and maintains its core function (Gasser et al., 2021). There is no universal definition of resilience in an applied context, and interpretations vary by discipline. For example, engineers typically center recovery of built systems (e.g., restoring infrastructure post-disruption) (Gasser et al., 2021), while social scientists may prioritize equitable adaptation (e.g., policy that addresses social equity and climate resilience simultaneously) (Koliou et al., 2020). The systems perspective provides a unifying lens, defining resilience as the capacity of a dynamic system to adapt successfully to disturbances that threaten its function, survival, or development (Dragoicea et al., 2020). From this view, resilience is not a static asset but a system-level outcome that arises from dynamic interactions within a complex system.

This is central to social-ecological systems thinking, which frames resilience as the capacity to navigate change. A resilient system can absorb shocks, adapt incrementally, and, if necessary, transform its structure (Meerow et al., 2016). Resilience, in this view, is a system's demonstrated potential to persist through disruption (Dragoicea et al., 2020). This study adopts this systems perspective, focusing on the potential for resilience within community systems.

2.2. Community and Community Resilience

The concept of "community" is fluid and multifaceted, defined by both place-based geography and social networks (Cobigo et al., 2016; Wellman, 2001). While traditional definitions emphasized geographic proximity and shared identity, subsequent scholarship recognizes communities as complex, multi-dimensional constructs that can even transcend physical space (Brint, 2001; Wellman, 2001). These perspectives signify that the term "community" requires context-specific definitions to capture its dynamic role. For the purpose of measuring resilience to a stressor like a power outage, this study adopts a place-based, functional definition. We define a community by its municipal boundaries to analyze the vital energy services and governance within a specific geographic area.

Within this bounded system, community resilience is an outcome that arises from the interaction of a community's capacities and available resources (Faulkner et al., 2018). Frameworks of community resilience, such as the scoping review by van Kessel et al. (2025), identify four capacities as key among the abilities needed to manage crises and facilitate adaptation: absorptive (short-term buffering against external shock), coping (immediate response efforts), adaptive (long-term adjustments), and transformative (systemic change). The presence and interaction of these abilities determine a community's resilience potential, i.e., its inherent capability to manage crises (Faulkner et al., 2018; Norris et al., 2008). This study examines the potential for these capacities in the context of a specific stressor: a prolonged power outage. It therefore focuses on the subsystem of community energy resilience.

2.3. Community Energy Resilience and Capacity

Community energy resilience is a critical subsystem of community resilience and is concerned specifically with a community's ability to anticipate, withstand, adapt to, and recover from disruptions to its energy services (Roege et al., 2014). Given the interdependence of modern communications, water, emergency services, and other infrastructure, energy resilience is central to a community's overall functioning during a crisis.

Community energy resilience emerges from a socio-technical system, integrating tangible infrastructure (power lines, generators) with intangible human and organizational elements (utility crews, emergency protocols, social networks) (Nik et al., 2021). A community's potential for energy resilience is not merely the sum of its technical and social parts but the product of synergy between them (Roege et al., 2014).

In the U.S., the electric power grid infrastructure (the generation, transmission, and distribution grids) is largely owned and operated by investor-owned utilities, not by municipal governments. The resilience of this infrastructure is a subject of intense analysis and policy focus (Roege et al., 2014). This capstone project, however, does not assess the resilience of the power grid. Instead, it focuses on the community-level capacity to react to and manage the consequences of a power outage, irrespective of its cause.

2.4. Population Thresholds, Scale, and Resilience

From a systems perspective, a community's potential for resilience is contingent on its underlying complexity and connectivity. Population size serves as a powerful proxy for this potential, with the relationship being structured by economic and geographic factors.

Central place theory argues that the presence of goods and services depends on economic thresholds (i.e., the minimum market size for viability) and the range consumers will travel (Malczewski, 2009).This leads to a hierarchy where low-order services (e.g., a convenience store, a gas station) are widely available, and high-order services (e.g., a regional hospital) concentrate in fewer, larger central places. The hierarchy influences which services are within a community's boundaries, shaping its inherent resilience capacity (Shi et al., 2022; Wang et al., 2023).

Urban scaling theory quantifies these economic and geographic principles, modeling how city attributes change with population size via non-linear power-law relationships (Bettencourt et al., 2007). This reveals systematic advantages for larger communities. Specifically, infrastructure networks often exhibit economies of scale. Larger populations use infrastructure more efficiently (Bettencourt et al., 2007), creating a form of built-in redundancy that contributes to robust system performance (Roege et al., 2014). From the perspective of central place theory, achieving these economies relies on meeting the population threshold for infrastructure to be financially viable (Malczewski, 2009; Ribeiro & Rybski, 2021). Simultaneously, socio-economic outputs like wealth creation and crisis resolution (Wang et al., 2023) display increasing returns to scale in larger cities, where denser social interactions foster greater institutional flexibility (Bettencourt et al., 2007; Wang et al., 2023).

This scaling framework links population size to the components of resilience. The critical mass required for services concentration is functionally equivalent to the central place theory threshold. In essence, it is the prerequisite level of demand needed to sustain the services and institutions (Malczewski, 2009) upon which resilience depends. Larger cities therefore concentrate a higher density of the resources, redundant systems, and cooperative networks that constitute resilience capacity (Wang et al., 2023; Kharrazi et al., 2020).

Conversely, communities with smaller populations experience a relative deficit in agglomeration effects. A smaller population base may be below the threshold required to support high-order services, e.g., dedicated emergency management institutions (Wang et al., 2023). They often lack the dense networks that generate resourcefulness and rapid innovation, potentially limiting their ability to adapt during a crisis.

While the relationship between city size and resilience can be ambiguous due to unique large-city vulnerabilities and contextual factors (Lei et al., 2021; Wang et al., 2023), the theories collectively provide a compelling lens: *the presence of the essential services and capacities for resilience is structurally influenced by population-driven thresholds*. This implies that the central place theory threshold operationalizes the systems theory concept of a prerequisite level of complexity. Consequently, smaller communities would be expected to systematically possess fewer resilience-fostering services and have less capacity to manage them. This insight forms the basis for constructing and exploring an index of energy resilience potential, as population and service saturation are likely to be key determinants of a community's capacity to achieve energy resilience.

2.5. Community Resilience Assessment Tools

Community resilience assessment tools have proliferated since the early 2000s to measure the potential to prevent and mitigate the impacts of natural disasters on the built environment and human health (Gillespie-Marthaler et al., 2019; Sharifi, 2016). These tools are designed to quantify underlying capacities (e.g., institutional, infrastructural, social) from which resilience must be inferred (Gillespie-Marthaler et al., 2019).

A comprehensive inventory conducted by National Institute of Standards and Technology (NIST) researchers identified 56 frameworks and assessment tools (Loerzel & Dillard, 2021). This count, however, represents only a fraction of the total, which expands considerably if localized, private-sector, and specialized tools developed by states, cities, planning bodies, and academic institutions are considered.

Prominent frameworks in the U.S. include the NIST Community Resilience Planning Guide, which provides a six-step process for planning and implementation (NIST, 2016). The Federal Emergency Management Agency (FEMA) offers resources like the Resilience Analysis and Planning Tool to support planning and recovery (FEMA, 2025), and the U.S. Department of Energy (DOE) has supported the State Energy Resilience Framework to help states and utilities enhance energy system resilience (U.S. DOE, 2016). The National Oceanic and Atmospheric Administration (NOAA) also provides tools like the U.S. Climate Resilience Toolkit, a decision-support website (NOAA, n.d.). These tools integrate multiple dimensions of resilience, using proxies like resource diversity, social capital, and learning capacity to benchmark a community's underlying potential to handle disruptions (Gu et al., 2023; Koliou, et al., 2020).

The proliferation of tools presents two significant challenges for practitioners. First, the sheer number of indicators complicates practical application and places a high resource burden on communities (Gillespie-Marthaler et al., 2019). The second challenge is the implicit assumption in many top-down frameworks of "resilience as localism" – the idea that communities control the technical and governance levers of their systems (Paterson et al., 2017; Tariq et al., 2021). This often overlooks structural constraints, such as jurisdictional fragmentation and a lack of authority over essential services, that limit a community's ability to act (Paterson et al., 2017; Tariq et al., 2021).

For resource-constrained communities, these dual challenges of procedural complexity and flawed assumptions can undermine the utility of the assessment process. This situation suggests that a pre-assessment to evaluate resilience potential could direct resources more efficiently by identifying localities for which a full, complex assessment is premature.

2.6. Summary: Barriers to Action and the Prerequisite Threshold

The literature reveals a disconnect between the theoretical aims of resilience assessment and their implementation, rooted in a circularity: community resilience is dependent on a foundation of specific capacities and resources. Yet the process of conducting a complex, multi-indicator resilience assessment itself demands a significant investment of these same resources (Gillespie-Marthaler et al., 2019; Paterson et al., 2017). Consequently, a community's inability to provide the resources necessary to complete an assessment may itself indicate a deficit in the very resilience capacities the tool measures.

This contradiction is illuminated by the theoretical frameworks reviewed. From a complex adaptive systems perspective, a community must possess a threshold level of underlying complexity and connectivity for resilience to be an observable property. This "threshold" concept finds a quantitative basis in central place and urban scaling theories, which suggest that the concentration of the vital services and institutions upon which resilience depends is structurally influenced by population-driven thresholds (Bettencourt et al., 2007; Malczewski, 2009). This points to the existence of a de facto prerequisite threshold, i.e., a level of pre-existing capacity and autonomy that a community must possess for resilience to be measurable and actionable via the assessment process.

This concept of a prerequisite threshold provides a theoretical explanation for the observed gap between assessment tools and practice. Therefore, an approach that can identify a community's position relative to this threshold is warranted. This study seeks to bridge the gap between theory and practice by asking: What are the necessary preconditions for a community to express measurable resilience potential? And how can a simple indicator be constructed to measure this intrinsic potential for energy resilience?

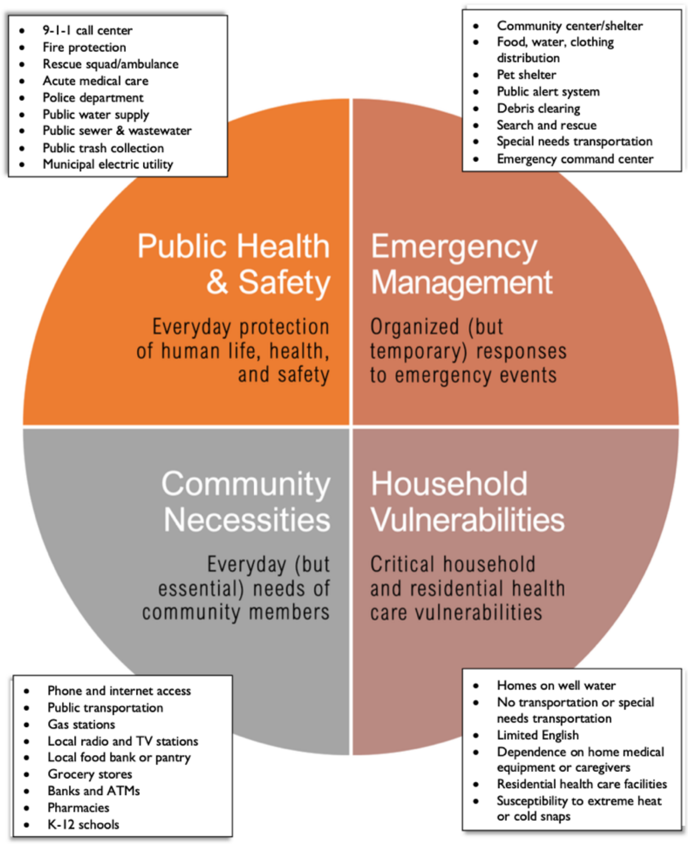
3. THE VIRGINIA ENERGY RESILIENCE STUDY AND SCORING TOOL

The data for this analysis were drawn from the Virginia Energy Resilience Study (VERS), the first phase of which developed a novel, modular scoring tool centered on energy services. This capstone project analyzes some of the VERS data to explore the concept of energy resilience potential and the necessary conditions that underlie a community's ability to be resilient in the face of a long-term power outage.

The VERS scoring tool was designed to help localities quantify their capacity to withstand and recover from prolonged power outages across four discrete domains of vital energy services: (1) Public Health and Safety (PH&S), (2) Emergency Management, (3) Community Necessities, and (4) Residential Vulnerabilities. This framework is presented in Figure 1 (from Virginia Community Energy Resilience Pilot Workbook and Scoring Tool, 2025; M. C. Papadakis, personal communication, September 25, 2025).

Figure 1

VERS Community Energy Resilience Framework



Note: Figure shows the four domains around which the VERS scoring tool is organized, representing the types of energy needs that are impacted by an outage. The vital energy services within each domain are identified in the bulleted lists. From Virginia Community Energy Resilience Pilot Workbook and Scoring Tool, by M. C. Papadakis, 2025. Unpublished instrument. Reprinted with permission of the author.

VERS identified a total of 34 vital energy services across the four domains (see Figure 1). As a concept, energy services focuses on what energy achieves in terms of meeting human needs rather than the security of energy supplies or energy infrastructure. In community resilience analysis, *vital* energy services are essential to human well-being and require continuity of access (Tiwari et al., 2022). More energy resilient communities have a greater ability to ensure that vital services are not interrupted by a long-term power outage.[1]

As the unit of analysis, "energy services" allows for identifying and addressing equity gaps because energy service requirements for resilience may vary greatly at the household level. Synthesizing the energy services outlook with established resilience principles yielded a holistic, simplified risk evaluation framework.

The application of this framework required consideration of jurisdictional boundaries in the design of the VERS workbook and scoring tool. The boundaries are defined by Virginia's unique system of government. The state empowers counties, independent cities, and incorporated towns (see Table 1). All three have elected governing bodies. However, independent cities are legally separate from and equivalent in authority to counties. Incorporated towns are municipalities that are subject to county authority except where Virginia has delegated specific voluntary authorities to the town (such as for law enforcement, water supply, emergency medical services, etc.).[2] Virginia has 95 counties, 38 independent cities, and 189 incorporated towns (as of 2022).

Furthermore, many significant communities are unincorporated, lacking their own governance (see Table 1). Unincorporated communities do not have a municipal government

[1] The Virginia Energy Resilience Study (VERS) operationalized power outages along a continuum of severity, categorizing them as Ordinary (minutes to hours), Major (1-3 days), Severe (several days to 2 weeks), and Catastrophic (more than 2 weeks) (M.C. Papadakis, personal communication, February 27, 2025). This framework connects outage duration to required levels of community resilience capacity, from coping to transformative. The "long-term power outage" aligns with the Major to Catastrophic categories, representing events where coping capacity is exhausted and planned, absorptive measures become critical. While this operationalization informed the overall design and scoring methodology of the VERS tool, the data utilized in this capstone project are derived solely from the presence or absence of vital services and social support plans. Consequently, the temporal aspects of the VERS outage framework do not affect the indexes calculated and analyzed herein.

[2] In this case, voluntary means that that the town has a right to provide a service or function, but it may choose not to.

and rely on the surrounding county to provide many of the services necessary for resilience during a power outage. Virginia has over 2,000 unincorporated communities.

Table 1

Summary of Virginia's Administrative Divisions and their Municipal Services

Characteristic	County	Independent city	Incorporated town	Unincorporated community
Legal status	Primary political subdivision of the state	Politically independent entity, separate from and legally equivalent to a county	Municipality within a county	A populated area within a county
Municipal government	Yes	Yes	Yes	No
Services provided	Full service provider: school system, law enforcement (sheriff/jail), social services.	Full service provider: school system, law enforcement (police), social services.	Limited service provider: e.g., police, trash, zoning, often supplementing county services. Does not operate a school system.	Relies on county for services.

Note: This table synthesizes characteristics of Virginia's administrative divisions. Adapted from *Virginia Government: Institutions and Policy* (Chapter 10), by L. Peaslee and N. J. Swartz, 2014, CQ Press.

To account for these differences, the VERS assessment tool was tailored into 2 versions: one for independent cities and incorporated towns, which both have municipal governments, and one for unincorporated communities, which do not have a local government and whose services are provided by the county.

Preliminary outcomes from the pilot study of the VERS tool revealed significant challenges. Despite extensive efforts, recruitment constraints yielded a smaller-than-anticipated sample that was absent unincorporated communities. Among participating communities, many struggled to complete the workbook, with some unable to finalize data collection (M.C. Papadakis, personal communication, February 27, 2025). This difficulty was attributed to three primary causes: (1) the workbook's time requirements, which disproportionately burden smaller communities; (2) the limited number of people willing or able to participate on behalf of the community, reflecting common social capacity challenges in less-resourced localities; and (3) a lack of interest in community energy resilience.

These challenges manifested the theoretical circularity described in the literature: the difficulties in completing the tool were symptomatic of a deficit in the capacities it was designed to measure. The lack of time, social capital, and interest points to a widespread absence of the basic requirements - or necessary conditions - for community energy resilience. This observation, consistent with the population-driven thresholds predicted by central place and urban scaling theories, prompted a critical reconsideration of the assumptions underlying quantitative resilience assessment tools.

Consequently, this study uses the VERS data to investigate this threshold. It constructs a series of indexes to quantify a community's energy resilience potential via the presence of essential services. The indexes are applied to empirically test whether a threshold can be identified that distinguishes a community as a potentially resilient system from a mere collection of households, and to examine the policy implications of such a threshold.

4. METHODOLOGY

4.1. Data Source and Preparation

Data for this capstone were drawn from the pilot phase of VERS during which, VERS researchers worked with volunteer community representatives – e.g., a town manager – to complete the self-assessment workbook and scoring tool. A sample of 15 communities was recruited via snowball sampling, social media announcements, and direct emails. The target population was communities that met the Virginia Department of Energy's "disadvantaged community" designation.[3] The response rate was 6.55% of the state's 229 incorporated towns and independent cities.

The sample included 4 independent cities and 11 incorporated towns with populations ranging from ~250 to 160,000. Geographic regions represented were Southwest Virginia (n = 7), the Eastern Shore (n = 4), Piedmont (n = 2), Northern Virginia, and the Shenandoah Valley (n = 1 each).

The VERS workbooks contain a total of 12 worksheets, three for each of the four domains. The worksheets for each domain were structured identically, enabling quantification of participant responses within and across each of the four types of services.

This study used the raw responses from the VERS pilot. For the Public Health and Safety (PH&S), Emergency Management, and Community Necessities domains, data were drawn from the first worksheet in each domain, which was a checklist of vital services physically present within the community's political boundaries (see Appendix A [PH&S], Appendix B [Emergency Management], and Appendix C [Community Necessities]). For the Residential Vulnerabilities domain, data were drawn from the second worksheet, which inventoried the community's social support systems for mitigating household-level risks (see Appendix D).

Three of the original 34 vital services were excluded from the analysis due to a near-total lack of applicability to the sampled communities: municipal electric utilities, support systems for households dependent on well water, and support systems for households with limited

[3] The "disadvantaged community" designation is a data-driven classification identifying census tracts experiencing significant cumulative environmental, health, and socioeconomic burdens (Virginia Department of Energy, 2024). This designation functions as a prioritization mechanism for state-led energy initiatives, directing funding and resources to advance environmental justice and equity goals. It operationalizes state policy by ensuring that vulnerable populations receive targeted investment to mitigate historical disparities and enhance community resilience.

English capability. Although services for well water dependence were excluded, the presence of a public water utility was a scored service. In the case where a community's water was provided by a private well system, this was considered both present and under local jurisdictional control for the purposes of the index calculation. The final dataset used for index construction consisted of 31 vital services across the four domains (see Table 2).

Table 2

Framework of Vital Energy Services by Domain and Characteristic

Domain	Vital energy services	Number of services in domain	System orientation	Temporal variation
Public Health & Safety	Presence of and authority over 911 call center, fire protection, rescue squad/ambulance, police department, acute medical care facility, public water, public sewer and wastewater treatment, and public trash collection[a]	8	Technical, public	Core, stable
Emergency Management	Presence of emergency command center, community centers/shelters, distribution of necessities, animal shelter, public communication and alerts, public works department debris clearing, search and rescue operations, special needs transportation	8	Technical, public	Reactive, temporary
Community Necessities	Presence of public space for accessing the internet/charging devices, public transportation, local TV/radio station, food bank/food pantry, grocery stores, gas station, bank/ATM, pharmacy, K-12 school	9	Technical, private	Core, stable
Residential Vulnerabilities	Ability to mitigate household vulnerabilities arising from lack of transportation, dependence on home health care equipment, dependence on home health caregivers, extreme heat, loss of home heating, and extreme cold[b]	6	Social, private	Reactive, temporary

Note: The services, domains, and characteristics listed in this table were derived from the Virginia Community Energy Resilience Pilot Workbook and Scoring Tool (Papadakis, 2025). Technical energy resilience = able to provide an alternative source (of power or other need) during outage. Social energy resilience = able to mitigate acute household vulnerability using public or private social services.

[a] Data regarding the presence of a municipal electric utility/electric department collected in the VERS pilot were omitted from the current analysis due to lack of applicability.

[b] Data regarding plans for mitigating residential vulnerabilities due to dependence on well water and limited English capability collected in the VERS pilot were omitted from the current analysis due to lack of applicability.

Responses from these checklists were systematically coded into quantitative variables. The physical presence of a service was coded as 1, and its absence was coded as 0. The strict use of political boundaries was a methodological constraint: services located immediately outside a community's limits were excluded from its index calculation.

For the Residential Vulnerabilities domain, worksheet responses were provided on an ordinal scale: 0 (no experience), 1 (informal/volunteer efforts), 2 (formal, untested service plans), and 3 (formal service experience that has been used in the past). For this analysis, "no experience" (the absence of a service) was scored as 0, and all other levels were scored as 1, as any level of organized response represents the presence of a social support service.

Finally, communities were assigned identifiers alphabetically by decreasing population, from the largest (A) to smallest (O). Communities A-D are the four independent cities in the sample, and Communities E-O are the 11 incorporated towns.

4.2. Index Calculation

The Resilience Possibility Index operationalizes the theoretical concept of *resilience potential* developed in the background section, providing a standardized quantitative measure of the degree to which vital energy services are present in a community. The fewer the number of services present in a community, the less potential (or opportunity) it has to be resilient if a long-term power outage occurs.

Following the VERS framework (see Figure 1), domain-specific Resilience Possibility Indexes were calculated for PH&S, Emergency Management, Community Necessities, and Residential Vulnerabilities based on the presence/absence of vital energy services in the community.

Indexes were calculated by summing the number of services in the given community, then dividing the sum by the total number of services in the domain. Using the example of the PH&S domain, if a community had an acute medical care facility, public water, public sewer/wastewater treatment, and public trash collection (each receiving a score of 1) but not a 911 call center, fire protection, rescue squad/ambulance, and police department (each receiving a score of 0), then it had a score of 4 out of 8 services. This yielded a PH&S Resilience Possibility Index of 4/8, or .50. Therefore, the Resilience Possibility Index represents the proportion of vital energy services per domain, and an index of 1.00 indicates that the community has all possible services. The Resilience Possibility Index represents a ratio variable/data. For interpretation, a threshold of .50 was adopted as a practical heuristic to distinguish communities with a majority of services present from those without.

Within the PH&S domain, a Resilience Authority index was also calculated. This index considered jurisdictional control over services, defined as ownership/operation by the municipality or a private entity (e.g., a store owner). Authority was assumed absent for county, state, or federally operated facilities. For example, a community might have a public water utility physically located within its boundaries (counted in the Resilience Possibility Index), but if that utility is owned and operated by the county, it would not be counted in the Authority Index. This index was developed to assess whether operational control is a critical factor in a community's resilience capacity. Consequently, for any given community, the PH&S Resilience Authority Index is either equal to or lower than its PH&S Resilience Possibility Index.

Finally, the Composite Resilience Possibility Index was calculated as the average of the four domain-specific indexes. The formula for a community is expressed as: (PH&S

Resilience Possibility Index + Emergency Management Resilience Possibility Index + Community Necessities Resilience Possibility Index + Residential Vulnerabilities Resilience Possibility Index) / 4. This provides a single, holistic measure of a community's overall energy resilience potential.

4.3. Mixed-Methods Index Analysis

A convergent mixed-methods approach was used in this study to provide insights from both quantitative and qualitative analysis.

Quantitative Analysis:

To evaluate the relationship between population size and both the Resilience Possibility Indexes and the Resilience Authority Index, least-squares regression was performed using Microsoft Excel for Mac, Version 16.101. Linear and logarithmic models were fitted and reported for the PH&S domain and a subanalysis of the nine smallest communities (G-O) in the Community Necessities domain. For all other domains and the Composite Resilience Possibility Index, only the logarithmic model is reported. Consistent with the PH&S analysis, the logarithmic model is the most appropriate and best-fit for the evident non-linear relationship between population and the resilience indexes.

Communities were stratified into large (≥ 44,826; n = 5), medium (≥ 900-≤ 8,300; n = 6), and small (≤ 519; n = 4) groups using natural breaks in the population distribution. Gaps between the groups exist where there were no communities in the sample with a population within that range. For example, no communities in the sample had a population of 519 to 900 people or 8,300 to 44,825 people. These natural breaks resulted in somewhat comparably sized groups for analysis (see Table 3).

Table 3

Community Stratification by Population Size

Population Group	Population Range	Communities in Group
Large	≥ 44,826	A, B, C, D, E
Medium	≥ 900- ≤ 8,300	F, G, H, I, J, K
Small	≤ 519	L, M, N, O

Fisher's Exact Tests (GraphPad Prism Version 10.6.1 (799)) were conducted to compare the three groups of communities based on the presence of specific vital energy services. The tests were also used in an exploratory subanalysis of the nine smallest communities (G-O) to investigate potential associations between their Community Necessities Index and other factors, such as geographic region. This exploratory analysis informed the subsequent qualitative, pattern-matching investigation.

Fisher's Exact Test was selected for its statistical accuracy when analyzing small, sparse contingency tables. For these tests, the ordinal variable (the population size groups) was treated as categorical groupings. This approach is methodologically sound for identifying associations but limits interpretation to the detection of distributional differences between these defined groups; it does not assess ordered trends across the original ordinal levels. It is important to note that the small sample size inherently limits the statistical power of the tests and the generalizability of the findings beyond this specific cohort.

To enable descriptive comparisons of service availability between population groups, the average service saturation was calculated for each domain and group. This statistic represents the mean number of vital services present per community within a group, expressed as a percentage of the total services in that domain. It was calculated by summing the total number of services present across all communities within a group, dividing by the number of communities in that group to get the average number of services per community, and then dividing by the total number of services in the domain. A higher average service saturation indicates that, as a group, communities possess a greater share of the vital services, providing a succinct metric for cross-group comparison.

Qualitative Analysis:

A pattern-matching analysis helped explain the quantitative findings, especially in domains where the link to population size was weak. This approach was applied to the Community Necessities and Residential Vulnerabilities domains, where the lower R^2 of the logarithmic regression models indicated that factors other than population affected the observed indexes.

For the Community Necessities domain, a subanalysis of the nine smallest communities (G-O) was conducted. Several contextual factors were examined, including geographic region, absolute land area, and poverty rate, to identify potential influences on the index beyond population size. This involved comparing communities that had similar population sizes. Data on past disaster declarations were also reviewed to assess the potential influence of historical hazard exposure, though these data were not included in the final reported results.

For the Residential Vulnerabilities domain, the qualitative analysis involved an examination of the raw, ordinal-scale data (0-3) underlying the binary “presence/absence” coding used for the index. The distribution of responses was examined to determine the prevalence of institutionalized preparedness versus reliance on informal measures to assess the scope of social services.

5. COMMUNITY ENERGY RESILIENCE POSSIBILITY INDEX

This section presents the results of the index calculations, organized by community domain. Community-level data were drawn from the self-assessment workbook responses, completed during the pilot phase of VERS through engagement between VERS researchers and volunteer community representatives. Results begin with the Public Health & Safety (PH&S) domain, which explores Resilience Possibility and Resilience Authority Indexes. This is followed by the Emergency Management, Community Necessities, and Residential Vulnerabilities domains. Domain-specific results are then synthesized into the Composite Resilience Possibility Index that provides a holistic view of resilience potential. The section finishes with a summary of the key statistical and thematic findings across all areas of analysis.

5.1. Public Health & Safety

Within the PH&S domain, most vital services were present, with the exceptions of 911 call centers and acute medical care facilities (see Table 4). This pattern reflected a robust baseline of the core energy services needed during an outage and suggests a high inherent potential for resilience in this domain.

Communities were stratified for analysis into small, medium, and large population groups by natural breaks in the sample population distribution (see Section 4.3 for details). The average service saturation (the mean proportion of vital energy services present within a community group) was 53% for small communities, 71% for medium, and 98% for large communities. This indicates that, even for the smallest set of towns, a consistent set of vital services was present.

Table 4

Physically Present Vital Services - PH&S Domain

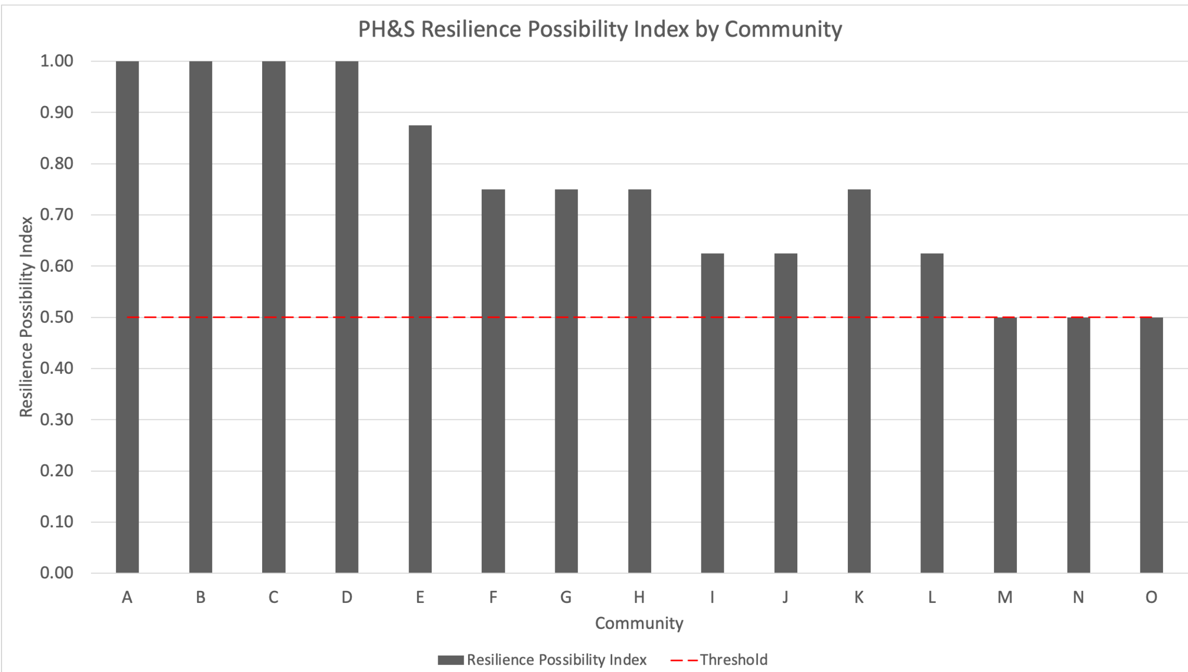
Vital service	Total number of communities with service in boundary (N = 15)	Large communities with service in boundary (pop. ≥ 44,826) (N = 5)	Medium communities with service in boundary (pop. 900-8,300) (N = 6)	Small communities with service in boundary (pop. ≤ 519) (N = 4)
911 call center	5[a]	4	0	1[a]
Fire protection	14	5	6	3
Rescue squad or ambulance	11	5	5	1
Police department/ law enforcement	13[b]	5	6	2[b]
Acute medical care facility	5	5	0	0
Public water utility	15[c]	5	6[c]	4[c]
Public sewer/wastewater treatment	15[d]	5	6[d]	4[d]
Public trash collection	12	5	5	2
Average service saturation[e]	75.00%	97.50%	70.83%	53.13%

[a] When authority is considered, 911 call centers were operated by four communities total and no small communities.
[b] When authority is considered, local law enforcement was operated by 12 communities total and by one small community.
[c] When authority is considered, public water utilities were operated by 12 communities total, four medium communities, and three small communities.
[d] When authority is considered, public sewer/wastewater treatment was operated by 11 communities total, five medium communities, and one small community.
[e] When authority is considered, average service saturation is 67.50% overall, 97.50% for large communities, 64.58% for medium communities, and 34.38% for small communities.

This high baseline of service presence was reflected in the PH&S Resilience Possibility Indexes. Using a threshold of .50 as a practical heuristic, a score at or above this level indicated that a majority of vital services were present within the community. All four large, independent cities (A-D) achieved the maximum index of 1.00, while most towns fell between .63 and .88 (see Figure 2). Even the three smallest communities maintained an index of .50, meaning they possessed half of these core municipal services.

Figure 2

PH&S Resilience Possibility Index by Community



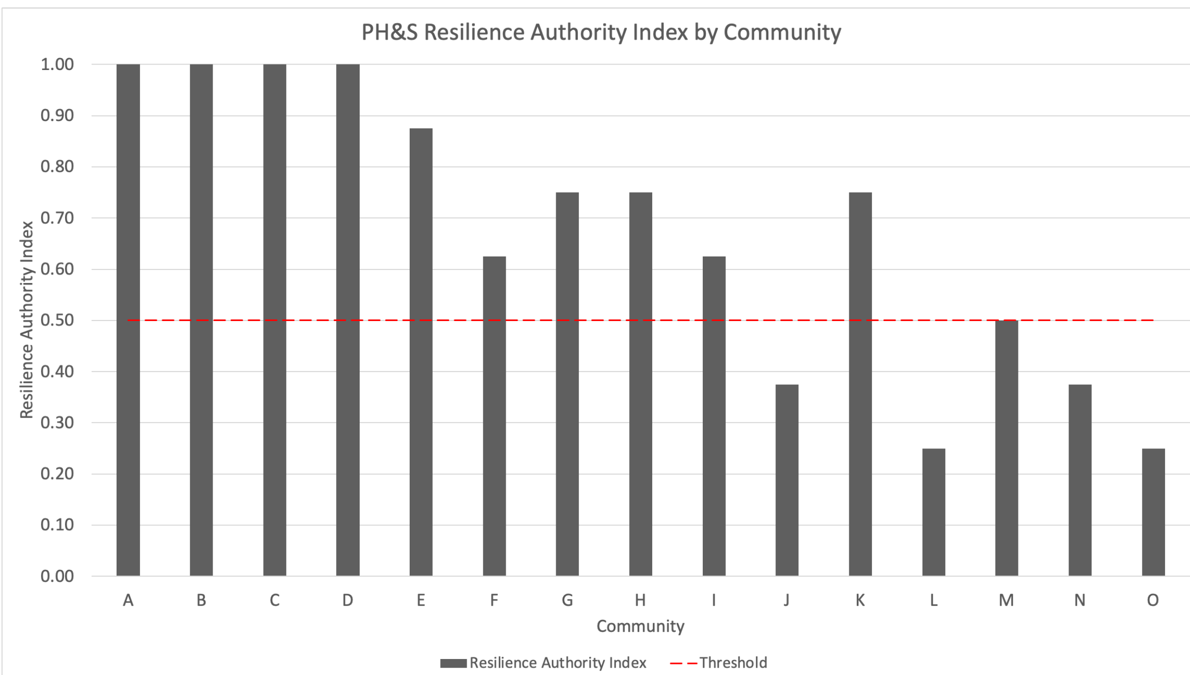
Note: Communities are sequenced from the largest (A) to smallest (O). The Resilience Possibility Index reflects the physical presence of vital energy services in the community. An index of .75 means that 75% of all the surveyed services are located in the community.

When jurisdictional control was considered, the Resilience Authority Indexes for three small and two medium communities declined, with all three small communities and one medium falling below the .50 threshold (see Figure 3). Indexes were unchanged for the five largest communities. This was expected, as four of the five are independent cities and thus have comprehensive jurisdictional control over municipal services. The average service saturation was therefore unchanged for the large community group but declined from 53% to 34% for small and from 71% to 65% for medium communities (see Table 4). This decline was most frequently caused by a lack of municipal authority over public water and sewer systems. In the most pronounced case, the authority gap extended to 911 call center and local law enforcement.

The gap between the presence of service and local control suggests that, although incorporated towns have the legal authority to operate such systems, they have opted to cede control to county-level or regional entities – a practical manifestation of central place theory. Consequently, their resilience is contingent on the performance and priorities of these external systems.

Figure 3

PH&S Resilience Authority Index by Community



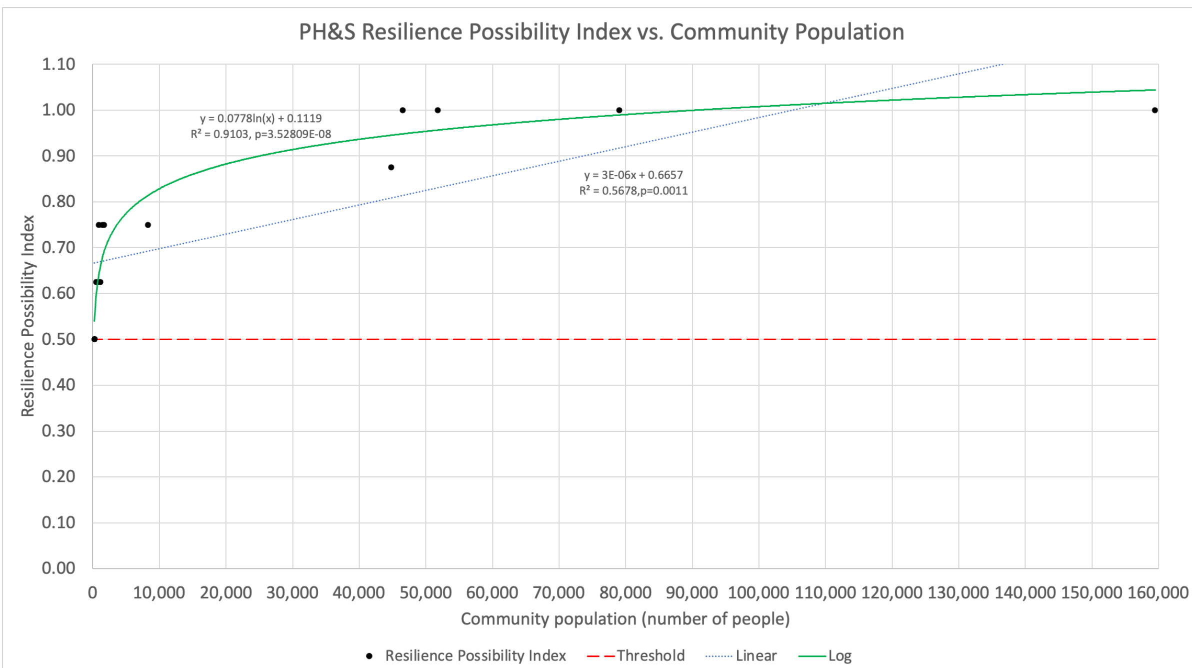
Note: Communities are sequenced from the largest (A) to smallest (O). The Resilience Authority Index reflects the governance capacity over the vital energy services that are present. An index of .75 means that 75% of all the surveyed services are owned and operated by either the municipal government or private owners.

The relationship between population size and the PH&S Resilience Possibility Index was analyzed using least squares regression (see Figure 4). The association was strong and best modeled logarithmically ($R^2 = .91$, $p < .0001$) compared to a linear fit ($R^2 = .57$, $p = .001$).

The log fit indicated that the largest marginal gains in resilience potential occurred as population increased at the lower end of the scale, with diminishing returns as population increased. A similar relationship exists for the Resilience Authority Index ($R^2 = .77$, $p < .0001$), demonstrating that population was a strong, but incomplete, indicator of a community's potential for resilience when operational control over its vital energy services was considered.

Figure 4

PH&S Resilience Possibility Index vs. Community Population



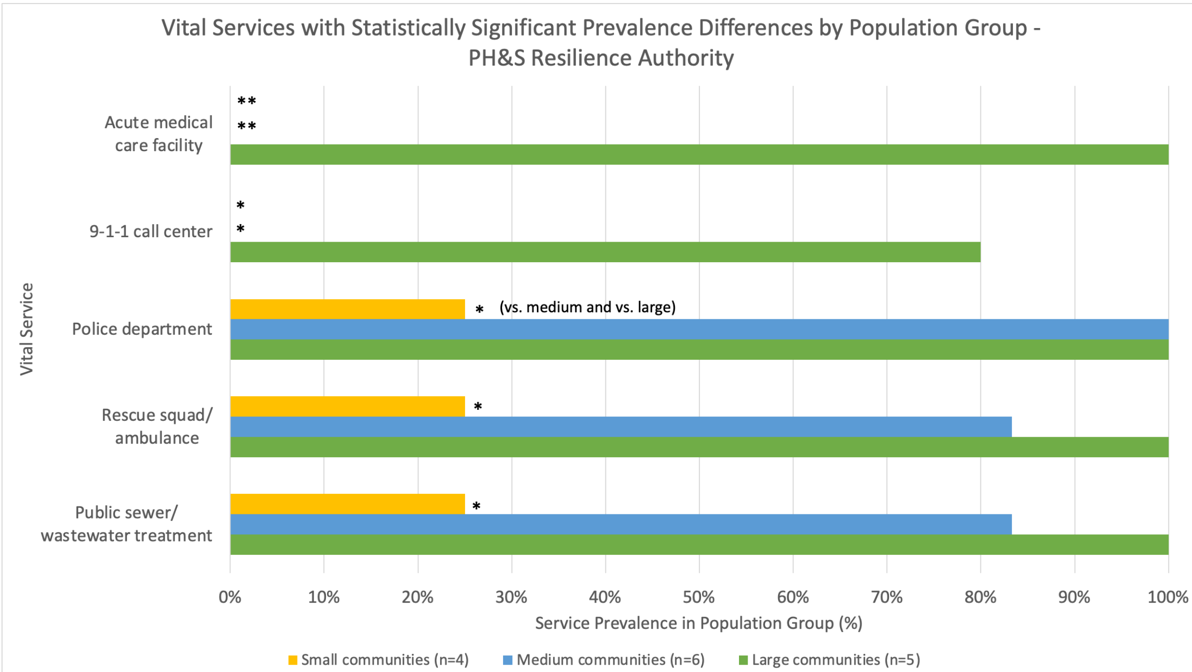
Note: The scatter plot displays the strong positive correlation between population size and the PH&S Resilience Possibility Index. The relationship is modeled with logarithmic and linear least-squares regression fits (logarithmic fit: $R^2 = .91$, $p < .0001$; linear fit: $R^2 = .57$, $p = .001$).

Fisher's Exact Tests identified services that distinguish groups of communities by size. The results showed a hierarchy in jurisdictional control aligned with central place theory. The most significant differentiators were the highest-order services: acute medical care facilities and 911 call centers (see Figure 5). Large communities were significantly more likely to provide or directly control these than both small and medium communities ($p \leq .01$ and $p \leq .05$, respectively), confirming their status as exclusive functions of the largest, autonomous jurisdictions.

The tests further revealed a tiered acquisition of authority. Large communities were significantly more likely to control public sewer/wastewater systems, police departments, and rescue squads than small communities (all $p \leq .05$; see Figure 5). The fact that medium-sized communities frequently demonstrated control over these services, unlike their smaller counterparts, indicates that jurisdictional authority is acquired incrementally and variably as population increases. Overall, small communities were statistically distinct from large ones for five of the eight vital services, while medium communities differed on only the two most specialized. This progression reinforces that the potential for resilience is closely tied to a community's position within an administrative and population hierarchy.

Figure 5

Vital Services with Statistically Significant Prevalence Differences by Population Group - PH&S Resilience Authority



Note: This figure identifies services for which a community's jurisdictional control differs significantly between groups of large, medium, and small communities. Services shown are those for which a Fisher's Exact Test found a statistically significant difference in prevalence between any two groups. Asterisks placed at the end of a bar denote the significance level of the difference between that group and the large communities group, except as noted for police department. $^*p \le .05$; $^{**}p \le .01$; $^{***}p \le .001$.

5.2. Emergency Management

The presence of vital services in the Emergency Management domain, which encompasses the reactive, temporary systems for crisis response, reflected a fragmented baseline for emergency management capacity, where the potential for a holistic response to an outage is strongly dependent on community size (see Table 5). There was a profound deficit for small communities, which had 22% average service saturation, contrasting with 40% for medium and 88% for large communities. This meant that the typical small and medium community in the sample had less than half of the vital energy services needed to mount an organized response to an outage.

Table 5

Physically Present Vital Services - Emergency Management Domain

Vital service	Total number of communities with service in boundary (N = 15)	Large communities with service in boundary (pop. ≥ 44,826) (N = 5)	Medium communities with service in boundary (pop. 900-8,300) (N = 6)	Small communities with service in boundary (pop. ≤ 519) (N = 4)
Emergency command center	7	5	2	0
Community centers or shelters	8	4	2	2
Distribution of necessities	6	3	1	2
Animal shelter	6	5	1	0
Public communication and alerts	10	5	4	1
Public works department / debris clearing	11	5	5	1
Search and rescue operations	8	4	3	1
Special needs transportation	5	4	1	0
Average service saturation	50.83%	87.50%	39.58%	21.88%

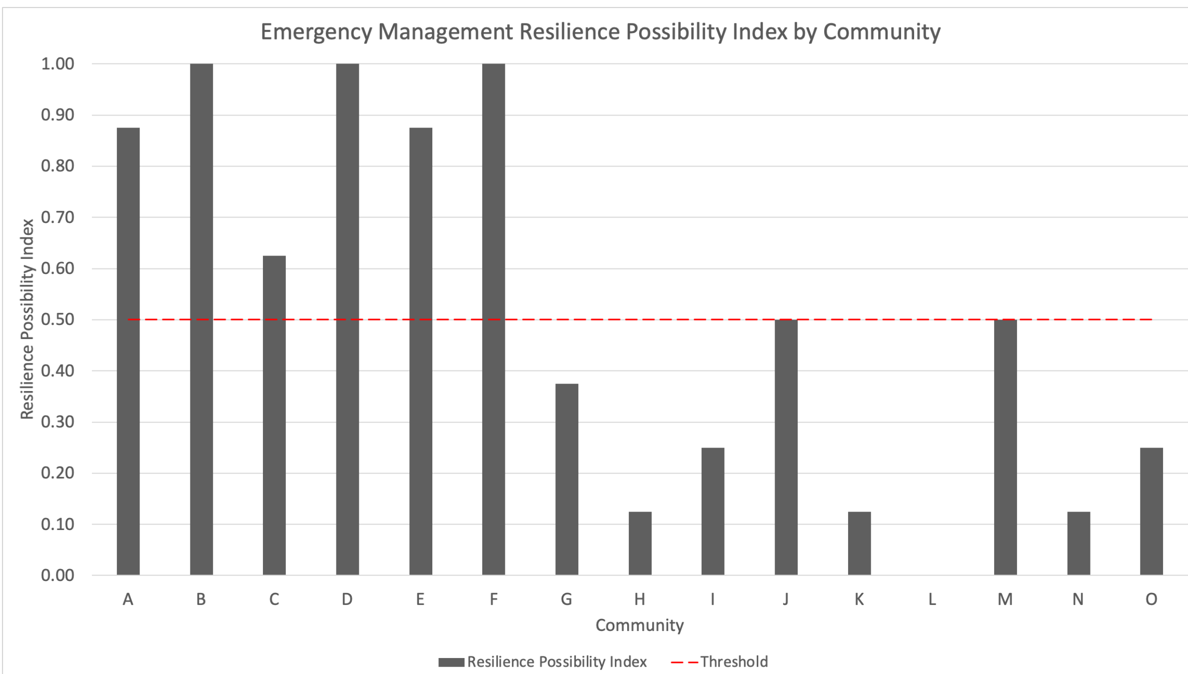
The data showed a step-change in services at the level of large communities, where the population base provided a critical mass to sustain the specialized personnel and institutional capacity required for a comprehensive emergency response. This was reflected in the lower and less consistent Resilience Possibility Indexes for small and medium towns (see Figure 6).

All five large communities (A-E) and the largest medium-sized community, Community F, recorded indexes at or above .63. Importantly, Community F was its county seat and largest town in the county. The community's role appeared to concentrate high-order emergency services, functioning as a central place that provided these resource-intensive capabilities for the wider region.

In contrast, six of the remaining nine small and medium communities recorded indexes of .25 or lower. This indicates that a community's potential to mobilize reactive crisis response resources coalesces around a higher order of population and administrative function.

Figure 6

Emergency Management Resilience Possibility Index by Community

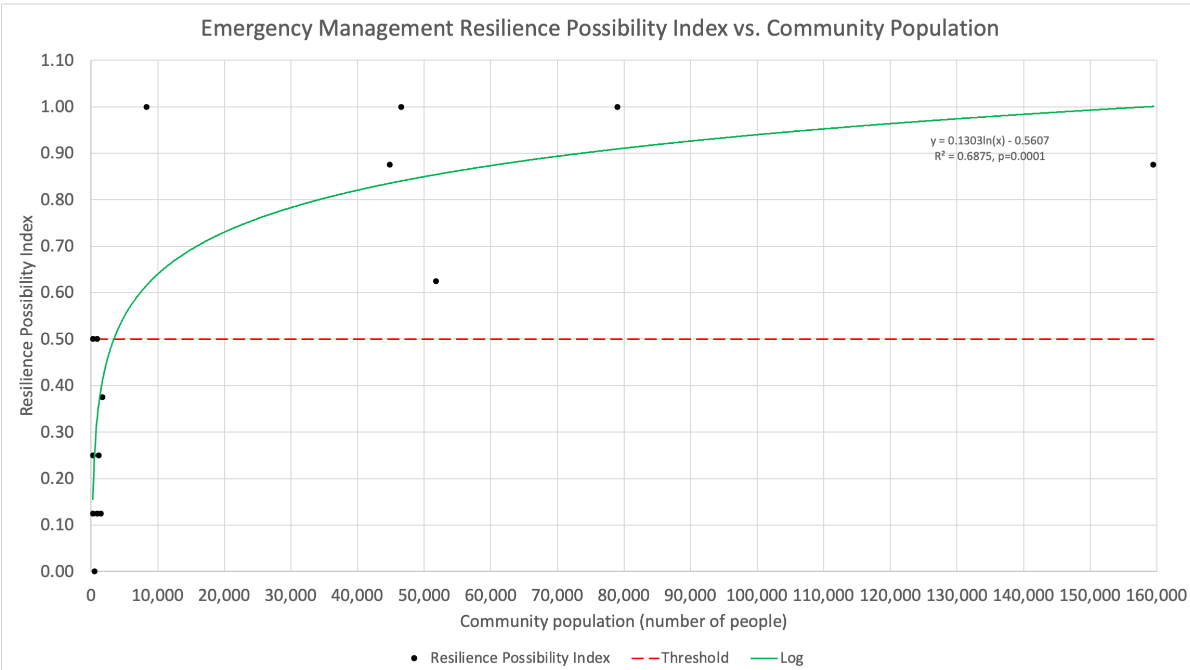


Note: Communities are sequenced from the largest (A) to smallest (O). The Resilience Possibility Index reflects the physical presence of vital energy services in the community. An index of .75 means that 75% of all the surveyed services are located in the community.

The strong, significant logarithmic relationship between population size and the Resilience Possibility Index ($R^2 = .69$, $p < .001$; see Figure 7) highlighted that the potential for resilient emergency response, which requires redundant systems and specialized mobilization, was concentrated in communities with larger populations. Notably, Community F's index of 1.00 was substantially higher than predicted by its population size, likely due to its role as county seat and population center.

Figure 7

Emergency Management Resilience Possibility Index vs. Community Population

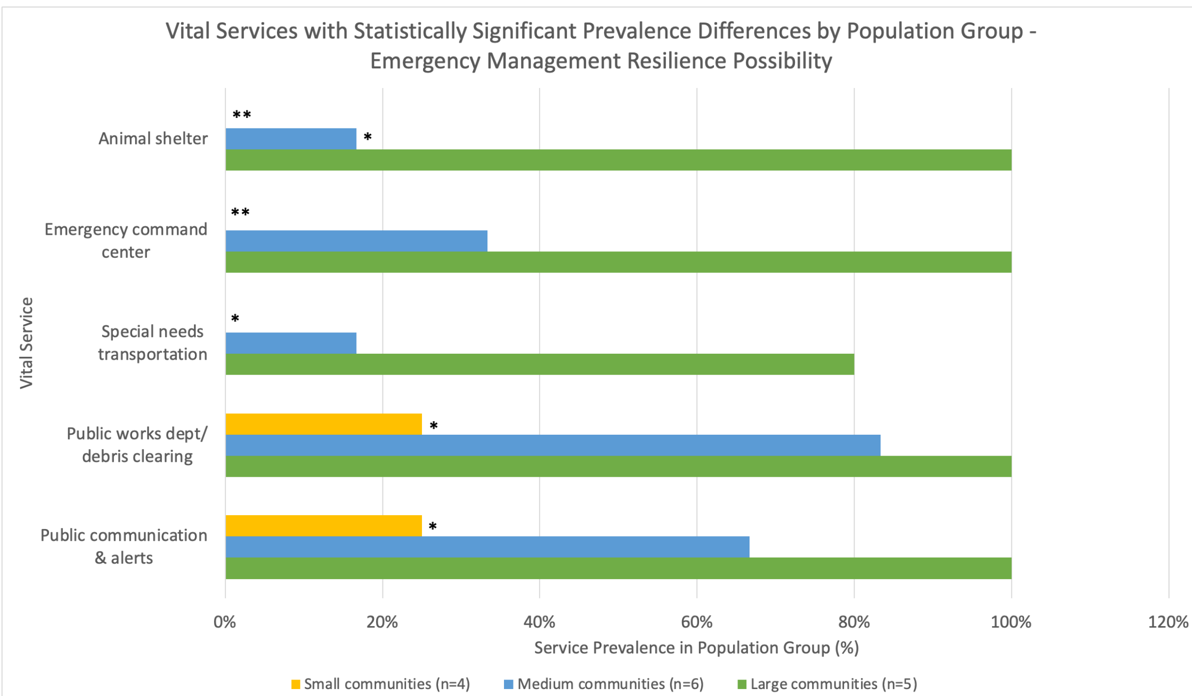


Note: The scatter plot displays the strong positive correlation between population size and the Emergency Management Resilience Possibility Index. The relationship is modeled with a logarithmic least-squares regression fit ($R^2 = .69$, $p < .001$).

Consistent with these results, large communities were significantly more likely than small communities to possess five of eight vital services in this domain (see Figure 8). As expected, high-order, resource-intensive services like emergency command centers ($p \leq .01$) and animal shelters ($p \leq .01$) were almost exclusively found in the large communities. The disparity extended to services often categorized as low order. Large communities were more likely to have special needs transportation ($p \leq .05$), public works departments for debris clearing ($p \leq .05$), and organized public communication and alert systems ($p \leq .05$). Crucially, the VERS instrument specifically queried the deployment of these services during an emergency (e.g., providing transportation for vulnerable populations relocating to safety; see Appendix B for the data collection worksheet). This shows that the capability for emergency response was disproportionately concentrated in larger communities, transcending the services' classifications under normal conditions.

Figure 8

Vital Services with Statistically Significant Prevalence Differences by Population Group - Emergency Management Resilience Possibility



Note: This figure identifies services whose availability differs between groups of large, medium, and small communities. Services shown are those for which a Fisher's Exact Test found a statistically significant difference in prevalence between any two groups. Asterisks placed at the end of a bar denote the significance level of difference between that group and the large communities group. *$p \leq .05$; **$p \leq .01$; ***$p \leq .001$.

5.3. Community Necessities

The pattern of service availability in the Community Necessities domain, which encompasses the stable provisions for daily life, revealed a general hierarchy of service presence, with population size acting as a structuring influence. Large communities achieved complete

(100%) service saturation (see Table 6), a manifestation of the systematic advantages described by urban scaling theory. This contrasts with an average saturation of 44% for small communities and 70% for medium communities. Distinct population thresholds were observed, from low-order necessities like gas stations and banks/ATMs that were nearly universal, to medium-threshold services like grocery stores and pharmacies that were scarce in small communities. However, this gradient of services was coupled with a wide range of profiles among the small and medium communities, indicating the influence of local context.

Table 6

Physically Present Vital Services - Community Necessities Domain

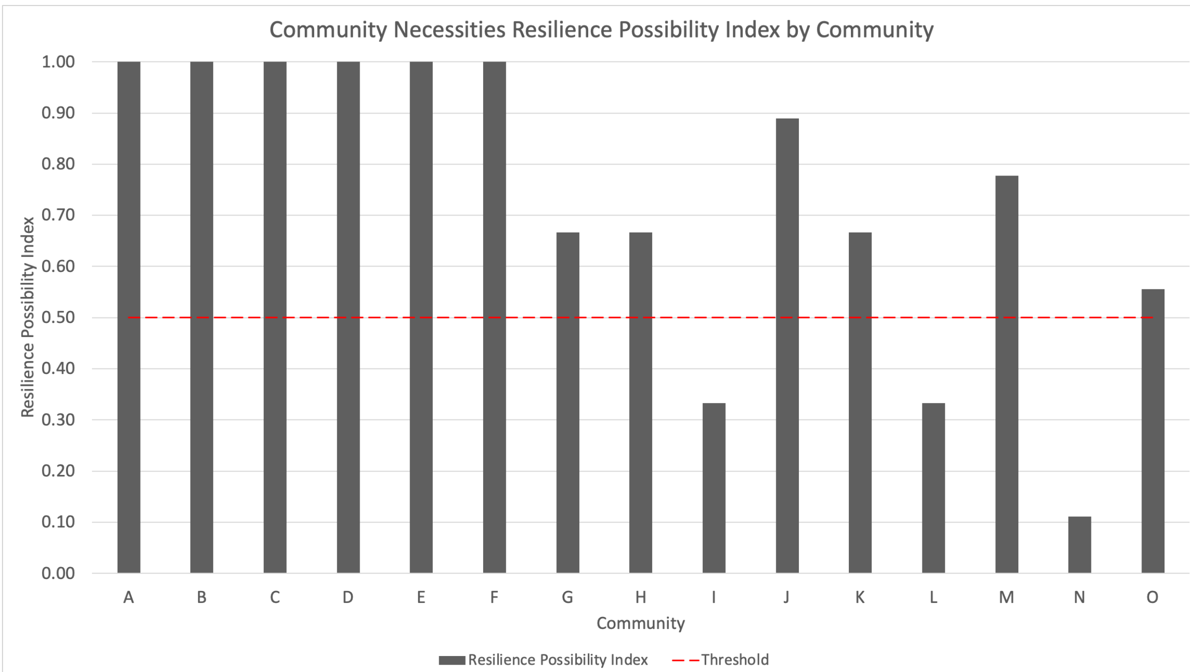
Vital service	Total number of communities with service in boundary (N = 15)	Large communities with service in boundary (pop. ≥ 44,826) (N = 5)	Medium communities with service in boundary (pop. 900-8,300) (N = 6)	Small communities with service in boundary (pop. ≤ 519) (N = 4)
Phone and internet access[a]	8	5	2	1
Public transportation	11	5	3	3
Local TV/radio station	10	5	3	2
Local food bank/pantry	10	5	3	2
Grocery store(s)	11	5	5	1
Gas station(s)	14	5	6	3
Bank(s)/ATM(s)	13	5	6	2
Pharmacy(ies)	11	5	5	1
K-12 schools	11	5	5	1
Average service saturation	73.33%	100%	70.37%	44.44%

[a] This refers to a public space for accessing the internet and charging phones or other devices.

The pattern of Resilience Possibility Indexes confirmed this observation (see Figure 9). All five large communities and the largest medium-sized community, Community F (the county seat and largest town in its county), achieved an index of 1.00. Indexes ranged from .33 to .89 for the other medium communities and from .11 to .78 for small communities.

Figure 9

Community Necessities Resilience Possibility Index by Community

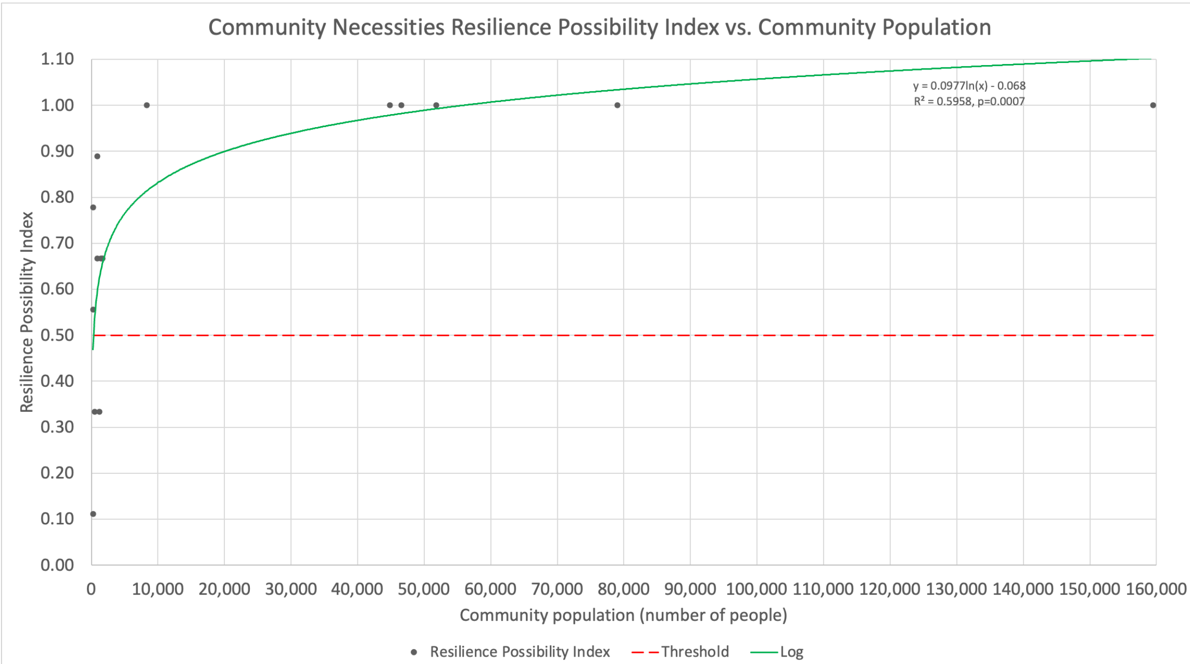


Note: Communities are sequenced from the largest (A) to smallest (O). The Resilience Possibility Index reflects the physical presence of vital energy services in the community. An index of .75 means that 75% of all the surveyed services are located in the community.

A moderate logarithmic relationship between population and the Resilience Possibility Index was observed ($R^2 = .60$, $p < .001$; see Figure 10). This finding aligns with the expectations of urban scaling and central place theory, while the moderate strength of the fit points to the influence of local context, as exemplified by Communities J and M. Despite their small populations, these communities achieved high indexes of .89 and .78, respectively, substantially surpassing the model's predictions. This deviation demonstrates that local contextual factors can concentrate these essential goods and services, independently of population size.

Figure 10

Community Necessities Resilience Possibility Index vs. Community Population

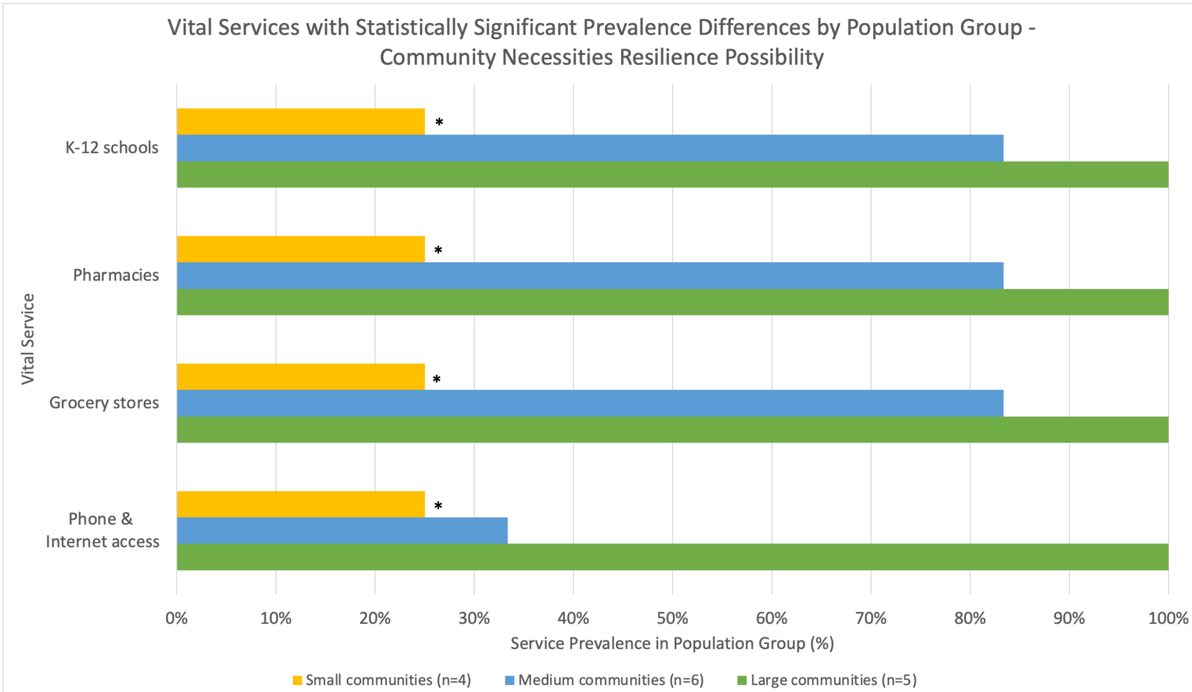


Note: The scatter plot displays the moderate positive correlation between population size and the Community Necessities Resilience Possibility Index. The relationship is modeled with a logarithmic least-squares regression fit ($R^2 = .60$, $p < .001$).

Fisher's Exact Test identified the services for which presence differed significantly between population groups (see Figure 11). Small communities were significantly less likely than their large counterparts to have a K-12 school, a pharmacy, a grocery store, or a public space for internet access and device charging (all $p \leq 05$). The consistent absence of these services in small communities – particularly those considered moderate-threshold necessities like pharmacies and grocery stores – indicates that their populations fell below the critical level required to sustain even the basic services for daily functioning.

Figure 11

Vital Services with Statistically Significant Prevalence Differences by Population Group - Community Necessities Resilience Possibility

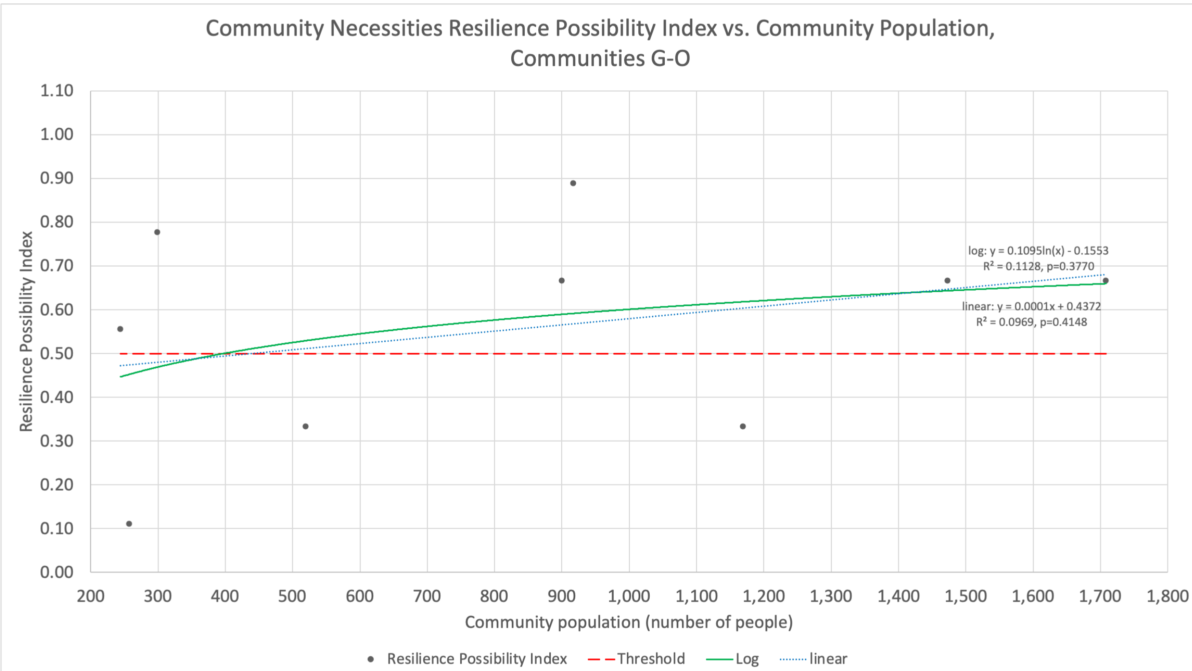


Note: This figure identifies services whose availability differs between groups of large, medium, and small communities. Services shown are those for which a Fisher's Exact Test found a statistically significant difference in prevalence between any two groups. Asterisks placed at the end of a bar denote the significance level of the difference between that group and the large communities group. *$p \leq .05$; **$p \leq .01$; ***$p \leq .001$. "Phone and internet access" refers to a public space for accessing the internet and charging phones or other devices.

The considerable variability in indexes among the nine smallest communities (G-O) prompted a specific analysis to determine if population size remained a significant predictor within this restricted range. The value of population size as an indicator diminished markedly among these communities, and no statistically significant relationship with the Resilience Possibility Index was found (logarithmic fit: $R^2 = .11$, $p = .38$; linear fit: $R^2 = .10$, $p = .41$; see Figure 12). This finding prompted an investigation into the local factors influencing the presence of vital services for meeting basic needs.

Figure 12

Community Necessities Resilience Possibility Index vs. Community Population, Communities G-O



Note: The scatter plot and regression analysis show no statistically significant relationship between population size and the Community Necessities Resilience Possibility Index in Communities G-O (population < ~1,700; logarithmic fit: $R^2 = .11$, $p = .38$; linear fit: $R^2 = .10$, $p = .41$).

To identify factors other than population size that could explain the variability in resilience potential, this study examined regional geography, poverty rates, and land area. A matrix was constructed for these data (see Table 7), and a pattern-matching analysis was applied. The analysis indicated that local context was multifaceted. For instance, a Fisher's Exact Test revealed a significant regional disparity in the presence of food banks. Communities in Southwest Virginia were significantly more likely to have a food bank than those on the Eastern Shore ($p = .048$). As a mid-order service, food banks would be expected to scale with local population; their uneven distribution across these communities (all population < ~1,700) suggests that strong regional factors, rather than local population size alone, influenced their presence. An examination of poverty rates showed no clear deterministic pattern. The poverty rates range from 27% to 60% in the Southwest communities and 3% to 26% in the Eastern Shore communities. However, Community G, which had the highest poverty rate in the sample (59.5%), lacked a food bank, indicating that poverty rate alone was not a sufficient predictor of this service's presence.

Regional geography and economic connectivity emerged as potential factors explaining the observed variability. The Eastern Shore's peninsular isolation could constrain supply chains and reinforce a reliance on transient disaster aid, particularly given its acute hurricane risk. In contrast, Southwest towns' proximity to an interstate highway corridor likely facilitates greater integration into regional transportation and supply networks. This enhanced connectivity may effectively expand their functional economic area, enabling the support of a broader suite of local services. Additionally, the rugged terrain of Southwest Virginia suggests a potential for more prolonged outages, which could incentivize the establishment of permanent local resources despite a smaller residential population.

Collectively, these observations suggest that small communities may be informally categorized by their regional economic role. Some, like Communities J and M, appear to function as "service hubs," concentrating community necessities by drawing from a wider catchment area and achieving agglomeration effects. Others, particularly on the Eastern Shore, demonstrate that when both population and regional connectivity are low, the key elements of a resilient community are often absent.

Table 7

Contextual Factors and Selected Service Presence for Low-Population Communities (G-O) - Community Necessities Domain

Community	Region	Absolute land area (sq mi)	% of population living under the poverty line	Population	Public transpor-tation	Local TV/radio station	Local food bank or food pantry	Grocery store	Pharmacy	K-12 school	Community Necessities Resilience Possibility Index
J	SW	2.6	27.1	917	--	X	X	X	X	X	.89
M	SW	0.4	50.8	299	X	--	X	--	X	X	.78
G	SW	1.7	59.5	1,708	--	X	--	X	X	X	.67
H	E. SHORE	2.6	25.3	1,473	X	--	--	X	X	X	.67
K	SW	1.4	33.4	900	--	--	X	X	X	X	.67
O	SW	2.8	31.8	244	X	X	X	X	--	--	.56
L	E. SHORE	0.4	13.2	519	X	X	--	--	--	--	.33
I	E. SHORE	1.0	25.7	1,169	X	--	--	--	--	--	.33
N	E. SHORE	0.2	2.8	257	--	--	--	--	--	--	.11

Note: This subanalysis focuses on services with mid-range prevalence (present in 4 to 7 of the 9 communities) to best identify differentiating factors. Services with very high saturation (gas stations, banks/ATMs) or very low saturation (public space for accessing the internet and charging phones or other devices) in this cohort were omitted. An “X” indicates that the service is present within the community’s boundary. Eastern Shore communities are shaded in blue to distinguish the regional grouping. Geographic and demographic data are from the U.S. Census Bureau (2022) American Community Survey 5-year estimates. Data were retrieved and compiled via the Census Reporter tool (censusreporter.org).

5.4. Residential Vulnerabilities

The Residential Vulnerabilities domain assesses a community's reactive, temporary ability to protect households that are at-risk and especially vulnerable during power outages. This domain evaluates the presence of social and institutional capabilities – from informal, volunteer efforts to formal service experience – for mitigating specific household-level risks (see Appendix D for data collection worksheet). As described in the methodology section, communities that indicated any level of response to address a vulnerability were scored as 1 for that vulnerability, while those indicating no capability were scored as 0 (see Section 4.2 for details).

The presence of services in this domain yielded a similar average service saturation for small (46%), medium (53%), and large (57%) communities (see Table 8). No single service was universally present. The most common capability was in addressing a lack of transportation during an extended power outage (12 of 15 communities), suggesting that this is an integral element of local response. A notable pattern emerged for services addressing extreme temperatures: large communities reported a higher prevalence of cooling and warming centers than their smaller counterparts. This aligns with the greater resources often required to establish and maintain dedicated shelter infrastructure.

Table 8

Vital Services for Mitigating Residential Vulnerabilities - Residential Vulnerabilities Domain

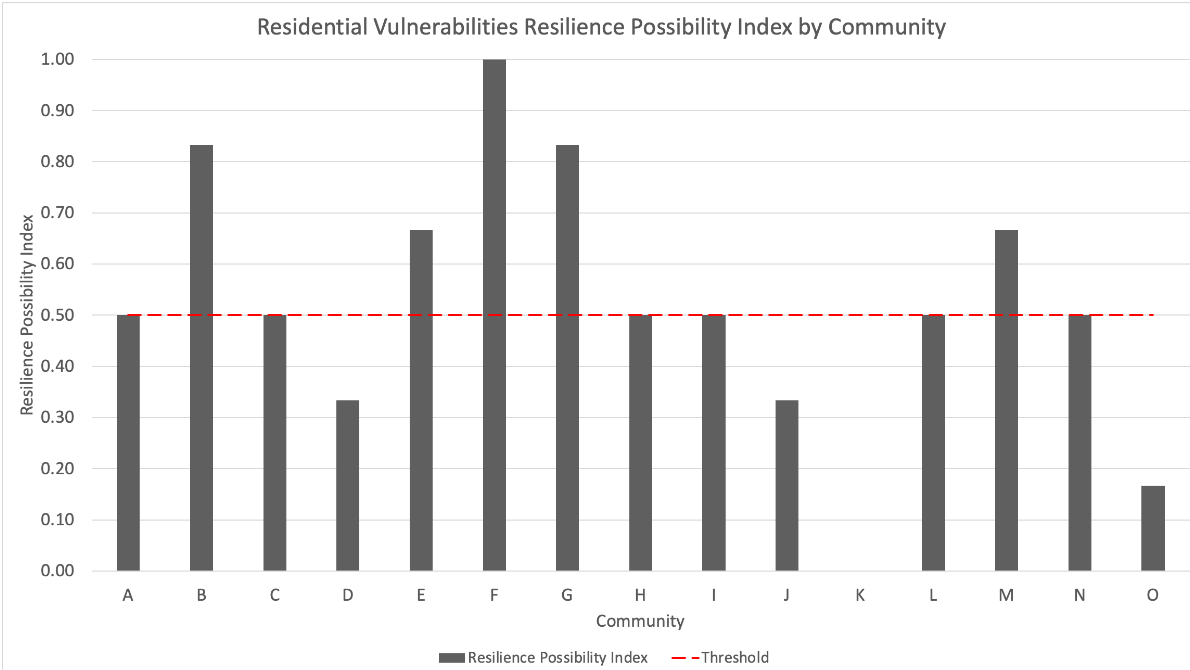
Vital service	Total number of communities with service in boundary (N = 15)	Large communities with service in boundary (pop. ≥ 44,826) (N = 5)	Medium communities with service in boundary (pop. 900-8,300) (N = 6)	Small communities with service in boundary (pop. ≤ 519) (N = 4)
Lack of transportation	12	3	5	4
Dependence on home health care equipment	6	2	3	1
Dependence on home health caregivers	7	1	5	1
Susceptible to extreme heat	7	4	2	1
Loss of home heating	7	3	2	2
Vulnerability to extreme cold	8	4	2	2
Average service saturation	52.22%	56.67%	52.78%	45.83%

Note: The vital services listed correspond to social support services to mitigate the named household vulnerability. For example, "lack of transportation" represents the capability to "identify households without transportation and relocate them to a safer place" during a prolonged outage. See the VERS data collection worksheet (Appendix D) for details on the services. A service was coded as present for any level of organized response, from informal volunteer efforts to formal service experience that has been used in the past.

Unlike other domains, the Residential Vulnerability Resilience Possibility Index showed a distinct lack of pattern (see Figure 13). Some small and medium communities (e.g., F = 1.00, G = .83) matched or exceeded the indexes of the largest localities, while others (e.g., K = .00, O = .17) fell far short.

Figure 13

Residential Vulnerabilities Resilience Possibility Index by Community

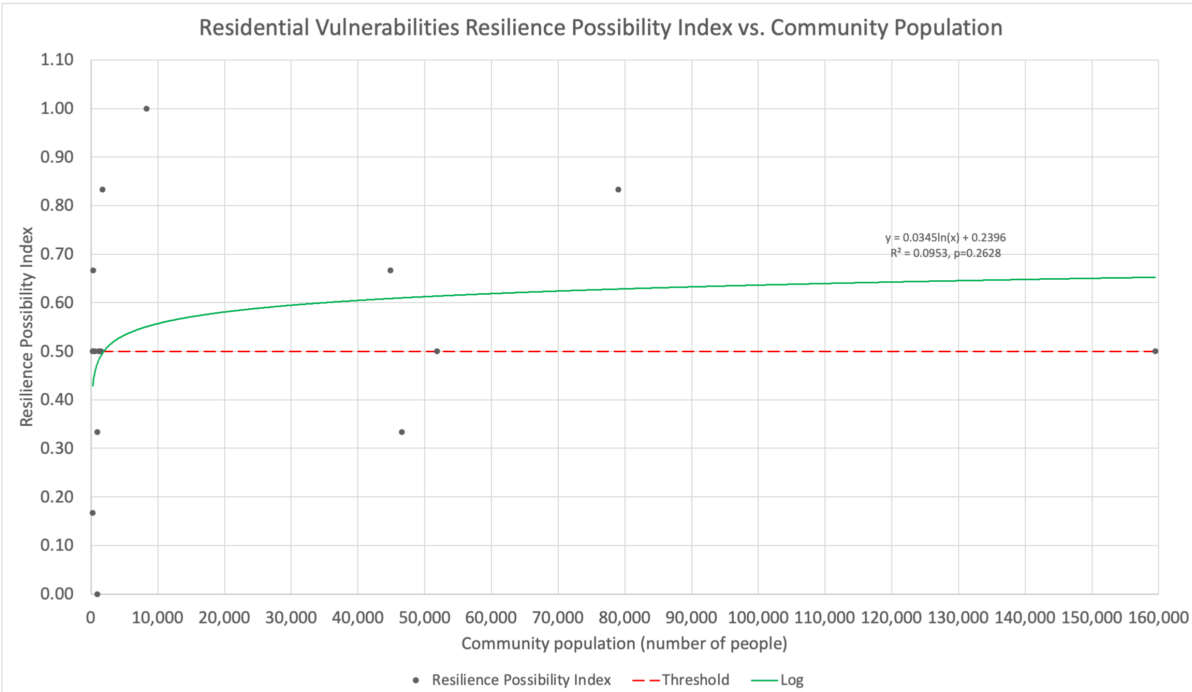


Note: Communities are sequenced from the largest (A) to smallest (O). The Resilience Possibility Index reflects the physical presence of vital energy services in the community. An index of .75 means that 75% of all the surveyed services are located in the community.

The lack of a pattern was reinforced by the regression analysis and Fisher's Exact Test. The logarithmic regression analysis found no significant relationship between population and the Resilience Possibility Index in this domain ($R^2 = .10$, $p = .26$; see Figure 14). The Fisher's Exact Tests found no significant differences between community groups and the presence of any specific service. This suggests that the presence of organized response capabilities for mitigating residential vulnerabilities was determined by factors other than population size.

Figure 14

Residential Vulnerabilities Resilience Possibility Index vs. Community Population



Note: The scatter plot and regression analysis show no statistically significant relationship between population size and the Residential Vulnerabilities Resilience Possibility Index (logarithmic least-squares regression fit: $R^2 = 10$, $p =.26$).

As described previously, communities provided scaled responses indicating their level of experience addressing household-level risks, ranging from no experience at all (0) to formal, applied service experience (3). Examination of the underlying ordinal data revealed a clear distinction in how communities maintained these vital social capabilities. Formal, applied experience was rare and narrowly focused, existing exclusively for managing extreme temperatures through designated warming and cooling centers. Only four communities (A, B, D, N) reported this level of institutionalized preparedness. In contrast, the capacity to act was more widespread, primarily sustained through informal volunteerism and social networks. This was especially true for small- and medium-sized communities; among the ten communities F-O, only Community N reported any formal service planning or experience. The results demonstrate that the social capital necessary to support vulnerable households was present across the spectrum of community sizes. Ultimately, the data revealed a contrast in resources: smaller communities relied on widespread informal social networks, whereas formal, applied service experience was a capacity concentrated primarily in the largest cities.

5.5. The Composite Resilience Possibility Index

The Composite Resilience Possibility Index provides a holistic measure of a community's overall potential by averaging its indexes across all four domains. It is the average of the four domain-specific indexes. This aggregate metric summarizes the landscape of a community's resilience possibilities, revealing systemic patterns of strength and vulnerability.

Composite Indexes showed a clear, hierarchical pattern strongly associated with population size (see Table 9 and Figure 15). The five large communities formed a high-scoring cohort (.78-.96), a finding consistent with the systemic advantages for larger populations outlined by urban scaling theory. The six medium-sized communities displayed considerable variability (.39-.94). Community F, a medium-sized town, achieved a notably high Composite Resilience Possibility Index of .94, rivaling larger cities. Its strength, distributed across all domains, shows how a community's administrative and demographic role – in this case, as a county seat and largest town in the county – can concentrate services and social capital to overcome the typical limitations of its population size.

The remaining medium-sized communities show a range of outcomes (.39-.83), and the four small communities are clustered at the lower end of the spectrum (.31-.61). Community M's Composite Resilience Possibility Index of .61, however, demonstrates that strong contextual factors can elevate a small community's resilience potential. Its profile was that of a localized "service hub," providing a core suite of Community Necessities (index = .78) that supported its surrounding area. It also possessed basic emergency response capabilities, such as public communication systems and search and rescue operations, that were absent in its small-community peers. This combination suggests a level of organized, albeit limited, institutional capacity. Yet its lack of high-order services like an acute medical care facility and an emergency command center reflects a persistent divide: local context can fortify a community's daily and reactive resilience, but the threshold for complex, resource-intensive emergency management remains structurally tied to a larger population base.

Table 9

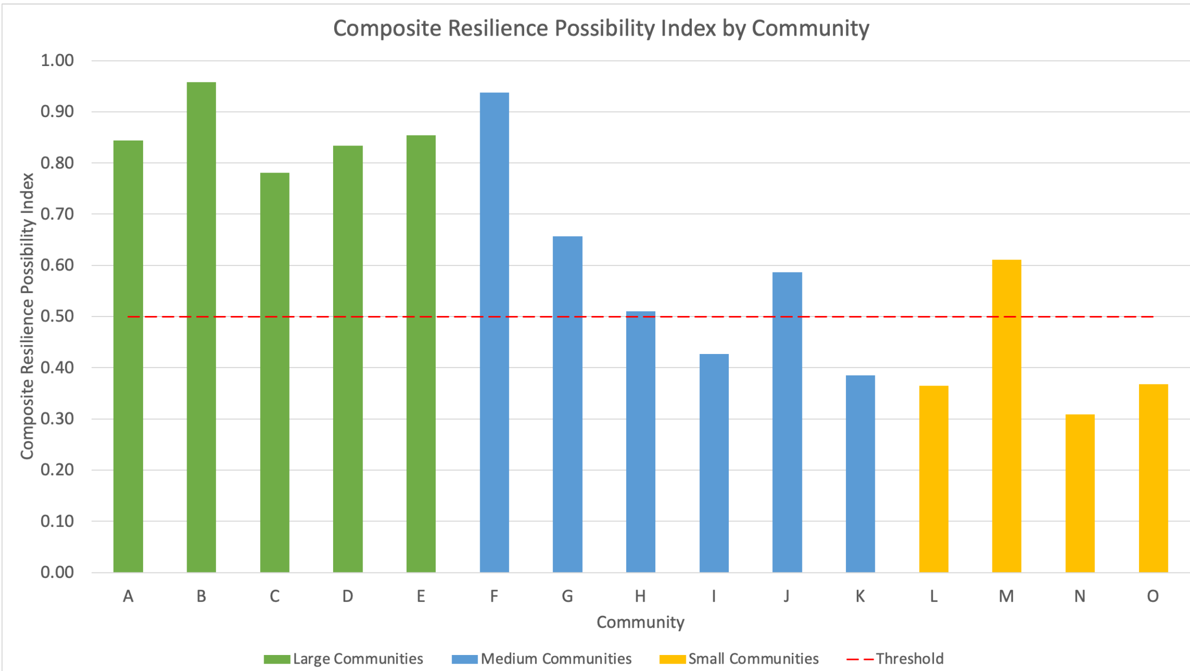
Domain and Composite Resilience Possibility Indexes

Community	PH&S Resilience Possibility Index	Emergency Management Resilience Possibility Index	Community Necessities Resilience Possibility Index	Residential Vulnerabilities Resilience Possibility Index	Composite Resilience Possibility Index
Large communities (population ≥ 44,826)					
A	1.00	.88	1.00	.50	.84
B	1.00	1.00	1.00	.83	.96
C	1.00	.63	1.00	.50	.78
D	1.00	1.00	1.00	.33	.83
E	.88	.88	1.00	.67	.85
Medium communities (population ≥ 900- ≤ 8,300)					
F	.75	1.00	1.00	1.00	.94
G	.75	.38	.67	.83	.66
H	.75	.13	.67	.50	.51
I	.63	.25	.33	.50	.43
J	.63	.50	.89	.33	.59
K	.75	.13	.67	.00	.39
Small communities (population ≤ 519)					
L	.63	.00	.33	.50	.36
M	.50	.50	.78	.67	.61
N	.50	.13	.11	.50	.31
O	.50	.25	.56	.17	.37

Note: Communities are shaded to distinguish the population groups used in the analysis.

Figure 15

Composite Resilience Possibility Index by Community

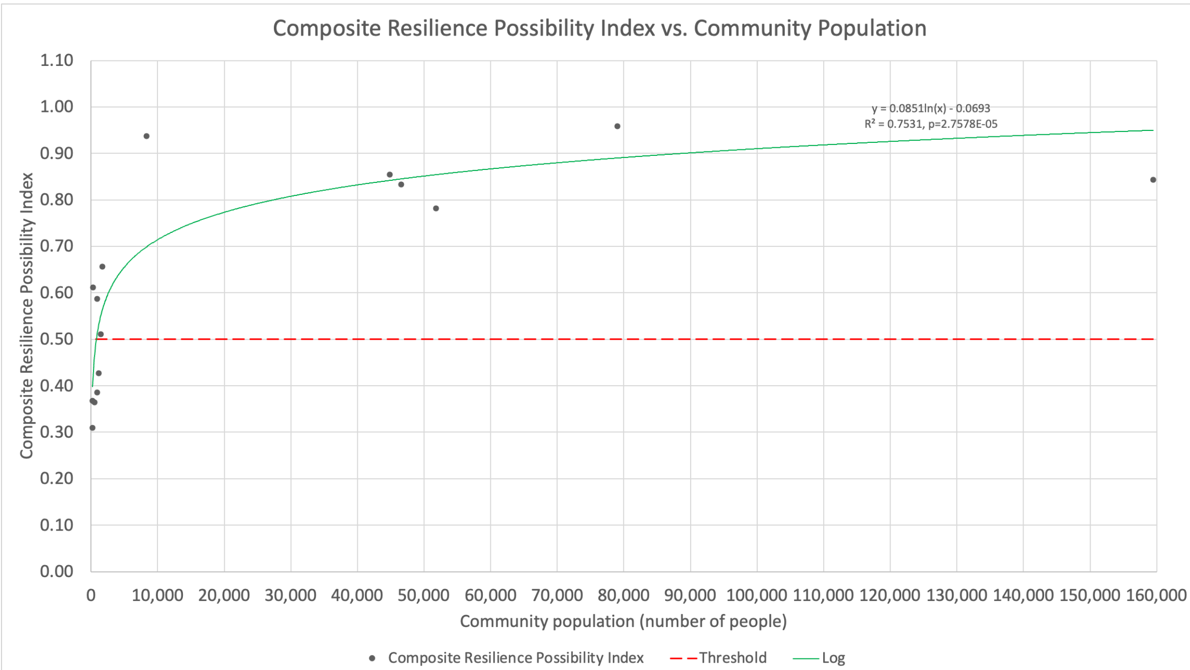


Note: Communities are sequenced from the largest (A) to smallest (O). The Composite Resilience Possibility Index averages a community's Resilience Possibility Indexes across all four domains. An index of .75 means that 75% of all the aggregated vital energy services across the four domains are located in the community.

A strong logarithmic regression fit ($R^2 = .75$, $p < .0001$; see Figure 16) confirmed a significant positive association between population size and the Composite Resilience Possibility Index. This finding aligns with the resource-concentrating effects predicted by urban scaling theory. The logarithmic nature of the relationship indicates that the most substantial gains in resilience potential occur at smaller population scales, with diminishing marginal returns as communities grow larger. The strength of this composite relationship arises from the compounding differences observed across individual domains; smaller communities systematically lack not just isolated services, but a full portfolio of the vital energy services necessary to anticipate, withstand, and recover from a prolonged outage. Consequently, population size serves as a powerful proxy for a community's overall energy resilience potential.

Figure 16

Composite Resilience Possibility Index vs. Community Population



Note: The scatter plot displays the strong positive correlation between population size and the Composite Resilience Possibility Index. The relationship is modeled with a logarithmic least-squares regression fit ($R^2 = .75$, $p < .0001$).

5.6. Major Findings

This analysis of 15 Virginia communities revealed that the communities' potential for energy resilience was fundamentally structured by its population size, yet also shaped by regional roles, social capital, and jurisdictional authority.

A strong, logarithmic relationship was found between population size and resilience potential. This was most pronounced in domains reliant on technical and institutional capacity. In the Public Health & Safety domain, the relationship was exceptionally strong

($R^2 = .91$, $p < .0001$). Small communities maintained a sound baseline of services (53% average service saturation) but systematically lacked high-order functions, illustrating a hierarchy of core service provision.

The data underlying a strong relationship in the Emergency Management domain ($R^2 = .69$, $p < .001$), however, revealed a severe deficit. Small communities exhibited an absence of the reactive systems needed for crisis response, with only 22% average service saturation. This indicates that smaller communities lack not just high-order services, but the organizational capacity to manage an outage. The largest communities, in contrast, consistently possessed a high baseline of services, suggesting they met a prerequisite level of energy resilience potential.

The analysis further uncovered a gap in jurisdictional control. In the Public Health & Safety domain, shifting from measuring service presence to operational authority caused indexes for several small and medium communities to fall below a practical threshold (index = .50). This authority gap demonstrates that the local power to manage essential services during an outage is a potentially necessary condition for actionable response, one that eludes many smaller localities.

In the Residential Vulnerabilities domain, the link to community population size dissipated. Here, the capacity to protect at-risk households during a disruption was predominantly based on informal volunteerism and social networks. Informal social services were a critical and widely distributed resource, especially in smaller communities. This indicates that social capital can provide an integral response capability, independent of the formal, infrastructure-dependent systems concentrated in larger cities.

Finally, the consistent performance of the Composite Resilience Possibility Index demonstrated the feasibility of a simple tool to stratify communities by their intrinsic energy resilience potential. The variability among small communities showed that the index was sensitive to identifying outliers where strong local factors partially compensate for a small population base.

Collectively, these findings challenge the assumption of uniform fitness for assessment. They indicate that a community's readiness for complex energy resilience planning is preconditioned on its position within a population-driven hierarchy of services and authority for managing power outages.

6. IMPLICATIONS FOR COMMUNITY ENERGY RESILIENCE PLANNING

This study's findings challenge the current approach to community energy resilience planning that assumes all self-identified communities are suitable candidates for complex resilience assessment. The hierarchy of resilience potential, stratified by population size, necessitates a more strategic allocation of resources. The findings point toward a bifurcated framework that aligns assessment and intervention strategies with a community's inherent potential. Furthermore, the findings provoke rethinking of the "community" as the default system for energy resilience assessment.

6.1. A Tiered Approach to Community Energy Resilience Planning

The Resilience Possibility Index developed in this study offers a practical mechanism for a diagnostic pre-screening of community energy resilience potential. Its strong correlation with population size reveals a de facto prerequisite threshold. Rather than uniformly applying comprehensive assessment tools, a diagnostic application of this index can triage communities into distinct planning pathways.

Communities with an index above a defined threshold (e.g., ≥ .50) possess sufficient service saturation to make sophisticated, multi-capacity resilience assessment a meaningful exercise. For these communities, the focus can justifiably remain on optimizing existing systems and enhancing adaptive and transformative capacities. This approach identifies outliers, such as high-performing small communities, ensuring resources are allocated based on demonstrated capacity.

Conversely, communities not meeting the threshold would be directed toward a "capacity building track." Here, the focus must be strategic. The resilience potential of these communities is often structurally constrained, making complex, high-cost investments inefficient. Instead, the goal is to strengthen the dynamic, non-material attributes of existing community assets. A three-pronged strategy – focusing on social capital, regional collaboration, and strategic external investment – is well-suited to this task, as it can achieve significant gains through targeted enhancements.

The first prong involves the deliberate cultivation of social capital and local agency. This intervention focuses on strengthening and better organizing the extant informal social networks and volunteerism identified in this study. This inherent strength can be leveraged by, for example, creating a community-managed registry of residents with specific skills (e.g., medical training) and resources (e.g., generators) to be activated during an outage and establishing networks for sharing resources. Funding workshops where community members interact to collectively share the knowledge needed to manage power outages would build local problem-solving skills and offer the opportunity for social learning. This approach builds resilience by leveraging the social capital that exists independently of population size.

The second prong entails rethinking governance structures and information flows to overcome the inherent limitations of a small population base, including a limited tax base, a lack of economies of scale, and constrained jurisdictional authority. The promotion of shared-service and regional models, such as inter-municipal agreements, is necessary. These models pool resources across communities to achieve the economies of scale needed for high-order services, while also providing a formal mechanism to overcome fragmented jurisdictional authority. This creates multiple, substitutable pathways for accessing essential support. Furthermore, ensuring robust and equitable communication through diverse channels is imperative for the timely mobilization of resources and dissemination of alerts during a disruption.

The third prong consists of strategic external investment designed to sustain the community-led and collaborative efforts of the first two prongs. Grants should be directed toward high-impact projects that provide the tools and stability for these approaches to succeed during a power outage. This could include funding for backup power at facilities identified by the community, programs for the rapid procurement of emergency supplies, and incentives that help retain essential services like pharmacies and grocery stores.

This strategy represents a pragmatic and structurally aligned approach to building resilience where traditional, autonomous development is constrained. For communities with low intrinsic potential, these targeted actions enhance the dynamic capacities that enable them to anticipate, withstand, and recover from a prolonged power outage.

6.2. Re-defining System Boundaries

The data from this study demonstrate that for many communities, the functional system for energy resilience does not align with municipal boundaries. From a complex adaptive systems perspective, a community lacking core services and jurisdictional authority is more accurately classified as a subsystem of a larger regional socio-technical system. Its energy resilience is a function of this encompassing system, not solely of its own bounded entity. These findings empirically validate the theoretical critique of resilience as localism, revealing that the assumption of local autonomy is often structurally unsound for small communities. Consequently, the default system boundary for energy resilience assessment must be re-evaluated to reflect these functional, cross-scale relationships.

This reality demands a shift in planning interventions, which must target the appropriate levels of the nested system. Interventions directed "down" a level strengthen the community subsystem by building capacity among its individual actors and social networks, fostering local agency and resourcefulness. This is achieved through the cultivation of social capital and social learning, as outlined in the capacity-building track, which empowers households and neighborhoods to build resilience from the ground up. However, there is a limit to how much a community can do on its own to deal with shocks. Communities below the prerequisite threshold require sustained support from higher-level systems. Therefore, interventions must also be directed "up" a level to focus on the county or regional tier. This approach, embodied by the promotion of shared-service models and strategic external investment, directly addresses cross-scale dynamics by pooling resources to overcome the economic and jurisdictional thresholds that individual communities cannot meet.

By aligning practice with the reality of nested systems, resilience planning can begin to move beyond the paradigm of localism. This perspective acknowledges that for many communities, energy resilience is not about achieving autonomy but about strategically strengthening interdependence. This redefinition implies that not every self-identified municipality constitutes a coherent "system" for energy resilience assessment. The default approach must shift from assuming municipal suitability to rigorously defining functional system boundaries by analyzing the actual flow of resources, services, and authority. A systems-thinking approach, therefore, requires that the first step in any resilience assessment is to determine the appropriate scale of the system being assessed, rather than uncritically adopting political borders.

6.3. Limitations of the research

While this study provides insights into the prerequisites for community energy resilience, several limitations must be acknowledged to contextualize the findings.

The most significant limitation is the small sample size (N = 15) and its geographically bounded nature (Virginia, USA). This reduces the statistical power of the analyses and limits the generalizability of the results. The findings reflect patterns within this specific sample and may not be transferable to other regions with different governance structures, geographies, or economic bases. Furthermore, the sample did not include very large metropolitan areas, which may face unique scalability challenges that could alter the observed relationship between population and resilience potential. Methodologically, the use of multiple comparisons through numerous Fisher's Exact tests increases the risk of Type I errors (false positives).

The uneven distribution of community sizes in the sample limits the population-resilience relationship modeling findings. A large gap exists between the largest medium-sized community (population 8,300) and the smallest large community (population 44,826). This absence of data for mid-sized towns means the logarithmic model represents a "best-fit" interpolation across this gap. Therefore, the trajectory of the relationship between small and large population clusters remains uncertain.

The data were collected during the pilot phase of the VERS tool. While rigorous coding procedures were applied, the potential for inconsistencies in how communities self-reported against the workbook criteria remains a source of potential measurement error.

Finally, this study focused on socio-institutional and service-based metrics. It did not incorporate spatial or geometric analyses of the communities, such as density, topography, or the physical distribution of infrastructure. These factors could significantly modulate a community's actual resilience during an outage and are an important avenue for future research.

7. CONCLUSIONS

This study was motivated by the gap between the proliferation of community energy resilience assessments and the practical readiness of communities, particularly smaller ones, to implement them. It therefore investigated the necessary preconditions that make the concept of community energy resilience meaningful, measurable, and actionable. Analysis of 15 Virginia communities moves beyond assessing resilience as a realized outcome to diagnosing the potential that enables its attainment. The analysis confirms the existence of a prerequisite threshold, operationalized through the Resilience Possibility Index, which stratifies communities into those capable of autonomous planning and those that function as interdependent subsystems of larger regional entities.

The primary empirical contribution is the quantification of a strong, logarithmic relationship between community population size and resilience potential. This finding demonstrates that the critical mass required for the resource density and complex interactions underpinning systemic energy resilience is not uniformly distributed. Furthermore, the concentration of high-order services, such as acute medical care facilities and emergency command centers, in the largest localities empirically supports the hierarchical organization of services predicted by central place theory.

Theoretically, this work strengthens the critique of "resilience as localism" by providing evidence of the limitations of this paradigm. The divergence between the Resilience Possibility and Resilience Authority Indexes within a single domain highlights jurisdictional control as a critical, yet often unmeasured, component of resilience. This suggests that a community's potential is constrained not only by the services within its borders but also by its operational control over them, a relationship that warrants systematic investigation across all community service domains.

Future research should build on these findings in three key directions. First, the diagnostic approach developed here requires validation in other geographic and governance contexts to test its generalizability. Second, research should move from identifying a community's status as a subsystem to defining and modeling the functional regional systems of which they are a part. Finally, integrating spatial and infrastructural data would provide a more complete picture of vulnerability and resilience.

In sum, this study argues that the concept of "community" in energy resilience planning must be functionally defined. For many small towns, the path to resilience lies in strategically strengthening their role within a nested system, rather than in pursuing autonomy. By acknowledging this reality, policymakers and planners can shift from a paradigm of flawed localism to one of effective, nested-systems governance, ensuring that efforts to build resilience are not only well-intentioned but are aligned with a community's inherent potential.

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Appendix A: Public Health and Safety Checklist

Step 1: Identify Areas of Potential Impact

The *Public Health and Safety Checklist* identifies the vital facilities and services that are affected by a power outage. Your team should be able to tick through the checklist in just a few minutes. A quick phone call, email, or text message to someone who would know will take care of anything you are unsure about. If your community has ***more than one*** facility or service—like a rescue squad station—simply make a note of that.

Step 1. Public Health & Safety Checklist

✓ Check the box if the service or facility ***is physically present*** in your town, city, or Census tract.

Facility or Service	Explanation
☐ 9-1-1 call center	A 9-1-1 call center is operated in your town, city, or Census tract.
☐ Fire protection	A fire station and fire protection are located in your town, city, or Census tract.
☐ Rescue squad or ambulance	A rescue squad or ambulance service is located in your town, city, or Census tract.
☐ Police department	A police department or a police station is located in your town, city, or Census tract.
☐ Acute medical care facility	An acute medical care facility is located in your town, city, or Census tract. (Acute medical care is when someone receives immediate, short-term treatment for a sudden major injury, illness, or medical condition. This care is usually provided at hospitals or urgent care clinics.)
☐ Public water	Your city or town operates a municipal water supply. (Does not apply to a Census tract assessment.)
☐ Public sewer and wastewater treatment	Your city or town operates a public sewer and wastewater treatment system. (Does not apply to a Census tract assessment.)
☐ Public trash collection	Your city or town operates a public waste management system. (Does not apply to a Census tract assessment.)
☐ Municipal electric utility or electric department	If your city or town has its own electric utility or electric department, you will not evaluate its resilience here. We will work with you on that.

Appendix B: Emergency Management Checklist

Step 1: Identify Areas of Potential Impact

The *Emergency Management Checklist* identifies emergency responses that are often provided during an emergency event, disaster, or significant power outage.

Your team should be able to go through the checklist in fairly quickly. A brief phone call, email, or text message to someone who would know will take care of anything you are unsure about. If your community operates ***more than one*** emergency response service—like shelters or distribution centers for necessities—make a note of each.

Step 1. Emergency Management Checklist

✓ Check the box if an emergency response is provided by and within your community. You are not limited to local *government* capabilities. If local non-governmental organizations your community have planned emergency responses, you should include them.

Facility or Service	Explanation
☐ Emergency command center	Your city or town sets up a command center for its emergency management and coordination. (Does not apply to a Census tract assessment.)
☐ Community centers or shelters	Your city or town has designated community shelters that are open to the public during an emergency. Or, a center/shelter is provided in your Census tract.
☐ Distribution of necessities—food, water, clothing, etc.	Your city or town offers groceries, prepared meals, water, clothing, personal hygiene products, baby products, or other basic provisions during an emergency. Or, there is distribution point for these necessities in your Census tract.
☐ Animal shelter	Your city or town provides an emergency shelter for household pets. Or, an emergency animal shelter is provided within your Census tract. (Some folks will not relocate during an emergency if they are concerned about their pets.)
☐ Public communication and alerts (texts, social media, etc.)	Your city or town provides information about the emergency through public communication such as phone and text alerts or social media. (Does not apply to a Census tract assessment.)
☐ Public works department (debris clearing)	Your city or town has a public works department that helps clear debris created by an emergency event. (Does not apply to a Census tract assessment.)
☐ Search and rescue operations	Your city or town mobilizes search and rescue in an emergency. (Does not apply to a Census tract assessment.)
☐ Special needs transportation	Your city or town provides transportation to people who need assistance relocating to a safer place during an emergency. Or, such transportation is provided in your Census tract. Examples include people with physical disabilities, households without personal vehicles, and the homeless.

Appendix C: Community Necessities Checklist

Step 1: Identify Areas of Potential Impact

The *Community Necessities Checklist* identifies the critical necessities that are required during a long-term power outage. You will evaluate only what is physically located in your community. You might have many of one kind of establishment, such as several gas stations or grocery stories. The instructions for Step 2 explain how to handle that in your assessment. Your team should be able to tick through the checklist in just a few minutes. A quick phone call, email, or text message to someone who would know will take care of anything you are unsure about.

Step 1. Community Necessities Checklist

✓ Check the box if a facility or service is located within your community.

Facility or Service	Explanation
☐ Phone and Internet access	There is a public space for accessing the Internet and charging phones or other devices in your city, town, or Census tract. Note that having back-up power for a public alert system will not be effective in a long-term outage if people cannot charge their phones or get online.
☐ Public transportation	Your city or town provides public transportation or transportation is provided in your Census tract. This is typically a bus system or transportation services for the elderly and people with disabilities. These services might be offered by the local government or by non-profit organizations.
☐ Local TV or radio station	There is a local TV or radio station in your city, town, or Census tract. Local TV and radio can be critical trusted sources of news and information during a major power outage or emergency event.
☐ Local food bank or food pantry	There is a food bank or food pantry in your city, town, or Census tract. Some residents may regularly depend on a food bank or pantry to meet their basic needs.
☐ Grocery stores	There a grocery store or other source of groceries in your city, town, or Census tract. The longer the power is out, the more likely it is that people will need to buy or replace groceries and other necessities.
☐ Gas stations	There is a gas station in your city, town, or Census tract. The longer the power is out, the more likely it is that people will need to refuel their vehicles. Note that most gas stations typically have a 2-to-4 day supply of gasoline under *normal* circumstances.
☐ Banks and ATMs	There is a bank, credit union, or ATM location in your city, town, or Census tract. The longer the power is out, the more likely it is that people will need cash to pay for basic necessities.
☐ Pharmacies	There is a pharmacy in your city, town, or Census tract. People who rely on prescription medications may need to refill their prescriptions during an extended power outage.
☐ K-12 schools	There is a K-12 school in your city, town, or Census tract. Schools enable children to maintain a sense of routine and normalcy. They may also receive meals during school hours. In an extended power outage, parents may need to be outside the home for many reasons. Access to schools during such a time helps both children and parents.

Appendix D: Residential Vulnerabilities Support Worksheet

Step 2. Residential Vulnerabilities Support Worksheet					
✓ Check the box ***that best matches*** the ***existing*** social capability of your community.					
Vulnerability	**Energy resilience question**	**We have nothing like this at all**	**We have some experience with this through informal and volunteer activity**	**We have formal plans in place but have not yet needed to use them**	**We have formal plans in place and have used them in the past**
Lack of transportation	For a power outage longer than 1 day, is your community able to identify households without transportation and relocating them to a safer place?	❑	❑	❑	❑
Dependence on well water	For a power outage longer than 1 day, is your community able to provide potable water for homes on wells?	❑	❑	❑	❑
Limited English capability	Does your community have a public alert system that allows people with limited English to understand what is happening during an emergency or that warns people of a possible emergency like a bad storm?	❑	❑	❑	❑
Dependence on home health care equipment	For a power outage longer than 1 day, is your community able to identify households dependent on home health care equipment and provide them with a source of electricity for their equipment?	❑	❑	❑	❑
Dependence on home health caregivers	For a power outage longer than 1 day, is your community able to identify households dependent on home health caregivers, doing a wellness check, and then acting on any needs?	❑	❑	❑	❑
Susceptible to extreme heat	Does your community have a cooling center or other way of providing shelter where people susceptible to extreme heat can relocate during a heat wave?	❑	❑	❑	❑
Loss of home heating	For a power outage during the winter that is longer than 4 hours, does your community have a warming center where people without heat can relocate?	❑	❑	❑	❑
Vulnerability to extreme cold	Does your community have a warming center or other way of providing shelter that people who cannot afford to fully heat their homes can go during extremely cold weather?	❑	❑	❑	❑