



From Metrics to Action: A Framework for Identifying Limiting Factors, Key Causes, and Possible Solutions in Food-Energy-Water Security

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Food, energy, and water (FEW) security require adequate quantities and forms of each resource, conditions that are threatened by climate change and other factors. Assessing FEW security is important, and needs to be understood in the context of multiple factors. Existing frameworks make it hard to disentangle the contributors to FEW insecurity and to determine where best to expend efforts on short- and long-term solutions. We identified four consistent components of FEW security (availability, access, preference, quality). This framework provides detailed and nuanced insights into factors that limit or bolster security in each of the three sectors. The integrated framework identifies proximate and ultimate underlying causes of deficiencies in each security component providing opportunities to identify short- and long-term solutions.

Keywords: sustainability, resilience, environmental justice (EJ), Alaska (USA), security, food, energy, water

INTRODUCTION

Food, energy, and water (FEW) are essential for life. FEW security can be defined as having reliable access to suitable sources of food, energy, and water (e.g., FAO, 2008). A lack of FEW security creates hardship, stress, and other undesirable outcomes for society and the environment (Greaves, 2016; Staupe-Delgado, 2020). Thus, considerable attention has been given to defining and evaluating FEW security, treating the three domains separately and together. Various methods for qualitative and quantitative assessment of FEW security, allowing evaluations at different scales and in different contexts. Having secure FEW sources is not the same as making use of those resources (e.g., Mortreux et al., 2020), but questions of individual choice are beyond the scope of this paper.

FEW security is typically complex, involving many interacting components, so much work has been done to identify those components and the ways they interact (FAO, 2008; Hoff, 2011; Sovacool and Mukherjee, 2011; Biggs et al., 2015; Willis et al., 2016; D'Odorico et al., 2018; Newell et al., 2019; UNESCO, 2019). The concept of the FEW Nexus has been developed to understand the potential for tradeoffs and synergies among the three domains (Hoff, 2011; Loring et al., 2013). Doing so can avoid inadvertent harm and take advantage of opportunities that might otherwise be missed. These connections also mean that food, energy, and water security should not be treated separately, since actions that alter security in one domain may affect security in another, for better or for worse.

Evaluating FEW security and FEW Nexus connections can help show where disparities and problems occur. Among the challenges threatening FEW security and creating disparities is climate change (the focus of this special issue), which has the potential to affect all three sectors or individually with repercussions for other components (Loring and Gerlach, 2009; Rasul and Sharma, 2016; Yildiz, 2019). More work is needed, however, to determine the causes of those problems and thus the actions that can be taken to address them. Here, we draw on the available literature and recent research in rural Alaska to illustrate how a consistent approach can be used to identify proximate and underlying causes of FEW insecurity, pointing to short- and long-term solutions.

Components of FEW Security, Interactions, and Policy

We conducted a literature search using the Web of Science (WoS) with the keywords of food, energy, water, nexus, and framework ($n = 386$) and then examined each result for either the creation of novel frameworks to assess FEW security or references to established frameworks that were not produced by our search. To ensure that we did not miss any frameworks developed specifically for food, energy, or water in the Arctic; we also searched the WoS with the keywords food or energy or water security and Arctic. This allowed us to find articles and frameworks relevant to our study area, which often included cultural and preference components. Our search was not meant to be exhaustive, but rather to capture the variability and consistency among different approaches to assessing FEW security. The goal was to develop an approach grounded in previous research efforts to independently assess FEW security, but also identify commonalities among these efforts by using a detailed and consistent security assessment within and among FEW. A total of 25 papers met our criteria in that they identified components of food, energy, or water systems that can be used to assess security (Supplementary Table S1). Major themes emerged from these papers including availability, access, preference, quality, environmental stewardship, and decision making, policy, or power (Supplementary Table S1). The first four were the most consistent across the papers examined. We used this same set of literature to identify drivers, indicators, and outcomes found in other regions which were then tested during our own fieldwork in rural Alaska (Supplementary Table S2). This approach will enhance the ability to identify policies that could affect multiple components and identify trade-offs and synergies.

The four components we used are availability, access, preference, and quality (Schmidt et al., 2022). All can be assessed qualitatively and quantitatively, as data and other resources are available (Huntington et al., 2021). *Availability* asks whether the resource exists in adequate and sufficiently stable supply to meet individual or community needs. Availability can often be assessed with readily available data. *Access* asks whether people can obtain a resource that is available in adequate supply. Access can be measured directly through interviews and surveys and indirectly through measures such as purchasing power or infrastructure

inventories. *Preference* asks whether the resources available and accessible are in fact what people actually want. Preference is most readily measured through interviews and surveys, though some indication can be obtained by comparing how communities make use of different forms of each commodity. *Quality* asks whether the resources that are available, accessible, and preferred are in the right condition. Like preference, quality is most readily assessed through interviews and surveys.

As the descriptions indicate, the four components interact to some degree, or are at least nested within one another. If food, energy, or water is unavailable, then access, preference, and quality are moot. In times of scarcity, people may be willing to accept items that they would ordinarily not prefer or whose quality they would otherwise find unacceptable. While such interactions are important to keep in mind, the four components are nonetheless useful for diagnosing specific shortcomings to FEW systems. We also note that the four components we identify are hardly the only way to break FEW systems down. Other approaches may work just as well, and even better, than ours for identifying the causes of insecurity. The main idea is not to find the ideal set of components, but to use a reasonable set of components to move from problems to causes.

A similar comment can be made about the details of FEW Nexus interactions. They are important considerations and justify treating food, energy, and water together as we do here. For this paper, however, the details are less important than the simple acknowledgment that there are connections. Using a common approach allows us to identify common causes of insecurity and distinguish where different causes produce different problems. Designing solutions to insecurity must take into account FEW synergies and tradeoffs, but those are often highly context dependent and thus beyond the scope of this paper.

POLICY OPTIONS AND IMPLICATIONS

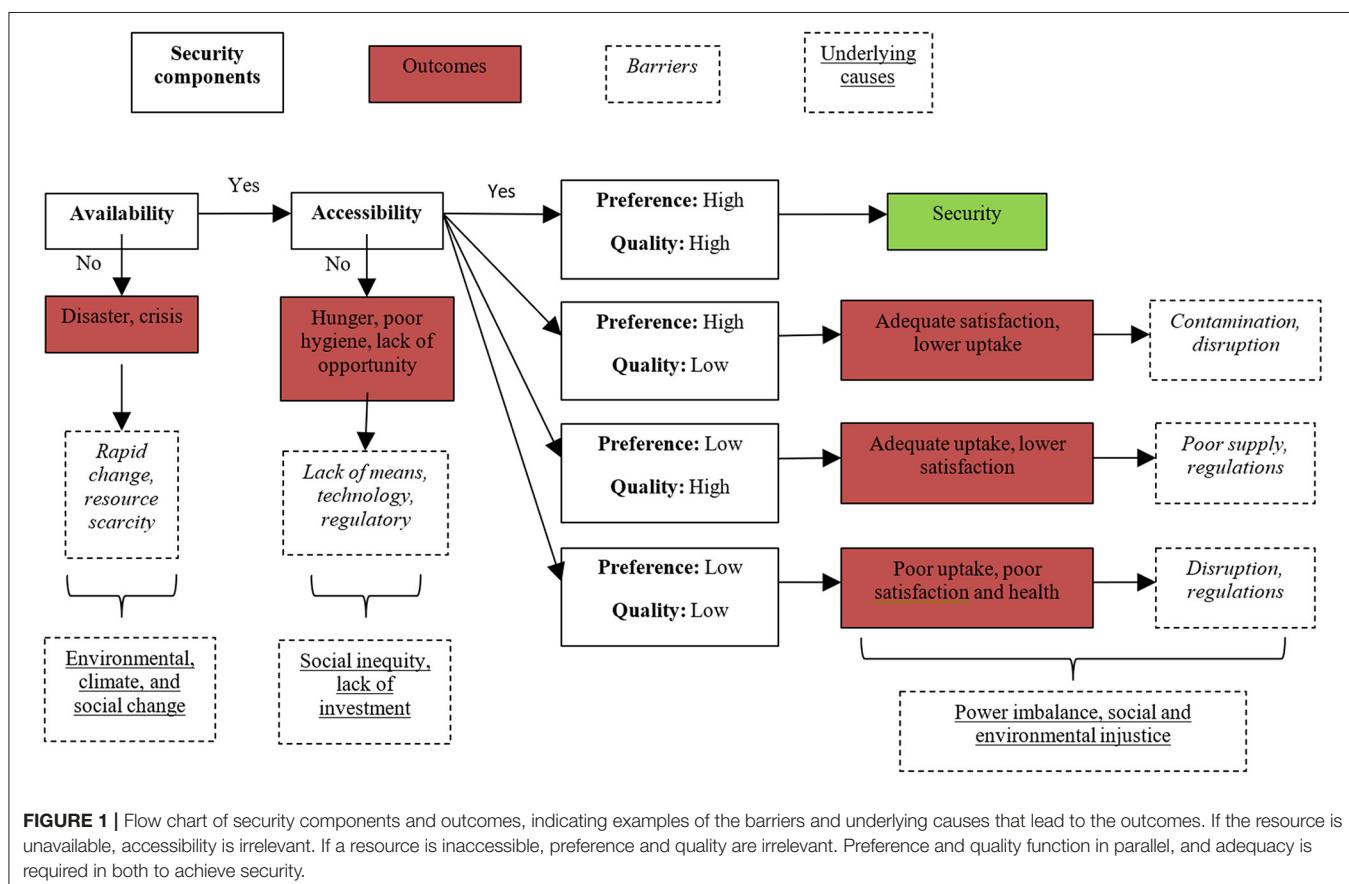
Identifying Causes of FEW Insecurity

The four components of FEW security can be assessed to determine where specific deficiencies occur. The next step is to identify the underlying cause or causes of the problem, which can then lead to solutions. As a starting point, we suggest a qualitative, descriptive system based on the primary barriers to FEW security (Table 1; Figure 1):

- Lack of availability indicates resource scarcity and usually indicates a disaster or crisis (FAO, 2008; Hoff, 2011; World Economic Forum, 2012). For example, a drought may make water unavailable in the short term, and climate change may make water unavailable more permanently.
- Lack of access indicates inadequate socio-economic means or technology and usually indicates major societal inequities or political power (Sen, 1999; Grey and Sadoff, 2007; Ritter et al., 2014; Willis et al., 2016; Aboelnga et al., 2018; Eichelberger, 2018; Hameed et al., 2019; Sharma and Kumar, 2020; Eichelberger et al., 2021). For example, lack of access to energy may reflect poverty or inadequate infrastructure.

TABLE 1 | Components, outcomes, barriers, and causes of FEW security.

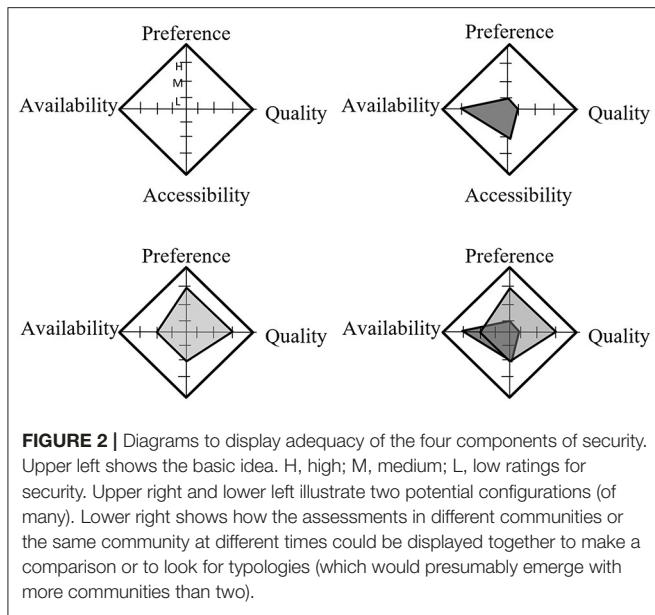
FEW security component	Outcome(s) of inadequacy	Short-term barrier(s) to security	Long-term barrier(s) to security	Underlying problem(s)
Availability	Disaster, crisis	Temporary resource scarcity	Persistent resource scarcity	Environmental or social change
Access	Hunger, poor hygiene, lack of opportunities	Shortage of cash Infrastructure failure	Inadequate socio-economic means Lack of adequate infrastructure, technology	Poverty and other societal inequities Lack of investment in infrastructure
Preference	Lower satisfaction, lower sense of agency	Inadequate supply of preferred good/service	Market failure Regulatory restrictions	Power imbalance
Quality	Lower uptake, poor health	Pollution/contamination event Transportation disruption	Degraded environments Lack of equitable infrastructure or transportation	Environmental injustice Social injustice

**FIGURE 1** | Flow chart of security components and outcomes, indicating examples of the barriers and underlying causes that lead to the outcomes. If the resource is unavailable, accessibility is irrelevant. If a resource is inaccessible, preference and quality are irrelevant. Preference and quality function in parallel, and adequacy is required in both to achieve security.

- Lack of preferred goods or services indicates a regulatory barrier and usually indicates a power imbalance (FAO, 2003; Penn et al., 2017; Wright et al., 2018; AKDEC, 2021a). For example, regulations may prohibit the harvesting or consumption of preferred foods, especially by groups whose preferences are not reflected in mainstream practices and who lack the power to effect regulatory change.
- Lack of quality may indicate various shortcomings, often related to social and environmental injustice (Grey and Sadoff, 2007; Vahabi and Damba, 2013; McOliver et al.,

2015; Wright et al., 2018). For example, poor water quality may result from pollution and lack of adequate treatment, conditions more likely to be found in poor and marginalized communities (Eichelberger et al., 2021).

Using this approach to identifying the causes of FEW insecurity, an individual, household, community, or region could be described by the combination of barriers to security in each of the FEW domains. Since the purpose of our paper is to showcase how this approach can be used, we provide examples



from a variety of drivers, however, one could focus specifically on social justice or climate related issues. Action could then be focused on addressing the proximate and ultimate causes specific to each case. The assessment framework can also be used to evaluate which components may be contributing to insecurity and identify topologies common among communities (Figure 2) or common shortcomings among food, energy, and water in a given community. Thereby the goal would not be to compare communities, but to identify common adequacies or inadequacies to determine if there is a common solution that would improve security for several communities. We note that the way each barrier manifests itself is likely to vary depending on the scale being considered, in addition to the specific context of each case. For example, household poverty may be related to community poverty, but the two are not the same. A poor household in an affluent community likely has access to infrastructure that is simply unavailable in a poor community, though in the affluent community that infrastructure may entail a high cost. Regarding climate, lack of rainfall related to a drought might create water insecurity at the community level, but insecurity may vary among households that harvest rainwater for drinking or gardening vs. those who can purchase non-local sources of water and food. We also note that security may be reduced by a combination of barriers, requiring more than one action to address more than one cause. The approach can still help identify priorities as well as the need for multiple actions, creating more realistic expectations for the outcome of any single action.

ACTIONABLE RECOMMENDATIONS

Examples From Rural Alaska

To illustrate these ideas, we present selected real-world examples from household interviews and discussions with community

leaders in four communities in rural Alaska (Schmidt et al., 2022) and published sources (Table 2). The examples are intended to illustrate a range of barriers to FEW security and the underlying causes of those barriers. For the sake of simplicity, we have avoided examples where the different sectors are intertwined (e.g., high power costs raising the price of treated water). We note, however, that the use of consistent components for evaluating security helps identify common underlying causes, such as the social and environmental injustices that perpetuate rural poverty and thus affect food, energy, water, and more in rural Alaska communities.

In Table 2 we illustrate how climate change can be a cause for inadequate FEW security and its effects on all four components of security. Given the enormity of climate change, using the framework proposed here helps communities and those in governance to identify what underlying problem changes in climate are creating and among those which are having the most widespread effects on FEW security. We also take it to the next level and identify short and long-term solutions which, if they arise frequently, can highlight efficient and impactful actions to take toward reducing the negative effects of climate change on FEW security and widening disparities.

The examples in Table 2 illustrate limitations to FEW security. Conversely, one could provide examples of conditions that support FEW security. For example, healthy ecosystems make food available, robust supply lines make energy available, and rivers that run year-round make water available. A high rating for the preference component of food security would suggest a conducive market and regulatory system that accommodates what people want in the ways they want it. Identifying these supporting conditions is also important to long-term FEW security, to make sure that such factors are recognized and protected, alongside efforts to remove barriers.

CONCLUSIONS

FEW security is a global concern (Hoff, 2011) and a major component of sustainability (United Nations, 2019). The approach we present here provides a consistent means of assessing problems and identifying causes, thus pointing toward solutions. Without such an approach, the various contributors to FEW insecurity are hard to disentangle, and determining where best to expend effort on short- and long-term solutions is likewise difficult. The four components of FEW security we use here form a rough hierarchy of need and urgency. Those without food are less likely to be concerned with having choices than they are with simply obtaining food of some kind. Urgency and importance, however, are not synonymous. Addressing only what is urgent will not achieve long-term security, and so all components of FEW security deserve attention.

Further work, for example using visualization of the four components (Figure 1), can allow us to view changes over time and identify typologies associated with FEW securities or insecurities. For example, one type of community might typically have available but unaffordable FEW resources, creating a different pattern and pointing to different solutions than

TABLE 2 | Examples from rural Alaska of limiting factors, causes, and solutions based on literature and our research.

Limiting factor	Cause	Short-term solution	Long-term solution	Underlying problem(s)
Availability (food)	Ice conditions prevent walrus harvest on St. Lawrence Island (Huntington et al., 2013)	Emergency declaration and emergency food shipments	Diversification of food sources (may require regulatory change)	Environmental change, disrupting traditional patterns (Slats et al., 2019)
Availability (energy)	Low river water levels limit driftwood availability (Jones et al., 2015)	Use more heating oil, barter for wood	Create a community wood storage facility to increase supply of seasoned, dry wood	Climate change, disproportionate burdens on those who do not travel across land for wood
Availability (water)	Water treatment plant burns down (Williams, 2021)	Fly water into the community, boil local water	Re-build water treatment plant and maintain access to clean local water sources	Disaster, lower diversity of resources
Access (food)	No or limited access to land for hunting (Meter and Phillips, 2014)	Temporary permits, move harvests elsewhere	Negotiate access rights	Social inequities and lack of political power of subsistence-dependent communities
Access (energy)	Cancellation of state subsidy program causes spike in electricity prices in rural communities (Kitchenman, 2019)	Reduction of household electricity use	Alleviate rural poverty, provide cheaper renewable energy	Poverty, creating hardship for poor households
Access (water)	Water utility bill is too expensive	Use the washeteria (centralized community facility) or nearby natural water sources	Install renewable energy to lower the overall operating cost of the water treatment plant	Poverty, lack of wage-earning opportunities
Preference (food)	Reduced king salmon run, regulatory closures for harvest (Brown et al., 2016)	Switch to utilizing chum salmon instead of preferred king salmon	Regulatory change for commercial fishing bycatch, international treaty negotiation, strengthened sharing networks	Climate change, lower diversity of resources
Preference (energy)	Diesel power generation generating air pollution and risk of fuel spill (AKDEC, 2021b)	Reduction in energy use, reliance on local sources (e.g., driftwood)	Switch to renewable energy sources such as wind, hydro, or solar power	Social injustice resulting in lack of investment in sustainable rural infrastructure
Preference (water)	Over-chlorination of municipal water to meet national water regulations or due to improper operation (Ritter et al., 2014)	Use alternative sources of water (with higher risk of pathogens)	Regulatory change, use of alternative treatment systems, improved training	Power imbalance, with regulations that do not meet the needs of remote communities or lack of resources for training and maintenance in rural areas
Quality (food)	Perishable foods go bad in transit through lengthy supply chain (Meter and Phillips, 2014)	Increased reliance on non-perishable foods or local gardens	Improved delivery service, increased capacity for local food production	Social injustice leading to lack of resources for secure food delivery to small, rural communities
Quality (energy)	Changes in water or wind reduce production of efficient and reliable renewable energy (Mellor et al., 2017; Basu and Walsh, 2018; Geck et al., 2021)	Continued reliance on diesel powered generators	Diversification of renewable energy sources	Increased temperatures and highly variable rain alter water run-off, increased storms, and wind cause wind turbines to be turned off
Quality (water)	Pollution of traditional (non-municipal) sources (Eichelberger, 2018)	Boil or filter water (which may not remove some pollutants)	Reduce pollution, protect key water sources	Environmental injustice, placing disproportionate burdens on marginalized communities especially in relation to limited capacity

a community typified by FEW shortages or one typified by shortcomings in preference or quality. Through the identification of typologies, we can focus efforts to improve FEW security for multiple communities. The four components also move from the objective (is there water in the river?) to the subjective (do I like the taste of the water?). Objective measures are easier to make in some respects, for example remote sensing can be used to assess water availability. Subjective measures require more intensive effort, such as questionnaires or interviews administered on a household or individual basis. Outcomes and choices, however, depend on both objective and subjective factors. All four components are needed to understand the degree to which people feel FEW secure.

It is also useful to consider the respective merits of quantitative and qualitative assessments. A qualitative approach is a useful and feasible first step and can be sufficient in some cases (Huntington et al., 2021). Quantitative assessments can be carried out later if the extra effort, time, and expense are warranted. While quantification is possible in theory and at times in practice (e.g., Laspidou et al., 2020), a practical challenge is obtaining sufficiently reliable data to provide confidence that a numerical measure actually means something. In addition, using numbers will inevitably lead to comparisons from community to community and region to region (Chen et al., 2015; Willis et al., 2016; Fall and Kotstick, 2018). Again, this is possible in theory, but only if the data are truly comparable and if the different circumstances of each case are documented in sufficient detail to allow accurate interpretation of the FEW data. With or without such reliability in data and interpretation, simple and simplistic comparisons run the risk of being used to create rankings, which in turn can create stigma for those lower on the list, and otherwise lead to undesirable if unintended outcomes.

The allocation of limited resources among many communities requires identifying priority needs. Measures of security within a community likely reflect local circumstances and expectations as well as perceptions that can be affected by recent changes as noted earlier, making cross-community comparisons difficult. For example, in rural Alaska, the loss of ferry service to Cordova in 2019 caused an understandable reduction in perceived food security, as supplies had to be flown in at greater cost (Huntington et al., 2021; Schmidt et al., 2022). This does not mean, however, that Cordova's food security was objectively

worse than another community that had always had to rely on air cargo and was simply inured to the inherent costs and uncertainties. Our approach is useful for identifying the causes of the changes within Cordova but should not be used on its own to compare Cordova's needs with those of another community.

Our approach emphasizes where FEW security shortcomings lie and points to the underlying causes of those shortcomings. The approach can also be used to identify strengths of current systems that should be retained. Finding solutions to shortcomings or ways of retaining strengths is another step, beyond the scope of a research project, and best carried out by community leaders and other practitioners engaged in FEW services. Researchers can still help, but we do not wish to over-promise what a research project can achieve, nor to tread on the responsibilities and initiative of community leaders to address their own community's needs. The approach proposed here is intended to provide a practical way to systematically evaluate FEW security in small communities. While it may lack the appeal of a numerical rating, it offers instead a pragmatic way to move from problems to causes and then to context-specific, long-term solutions for sustainability and resilience.

AUTHOR CONTRIBUTIONS

JS and HH conceived and wrote the paper. EW, DH, RW, and SA contributed to editing and writing. All authors approved the manuscript for submission.

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SUPPLEMENTARY MATERIAL

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