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A framework for assessing food-energy-water security: A FEW case studies from rural Alaska

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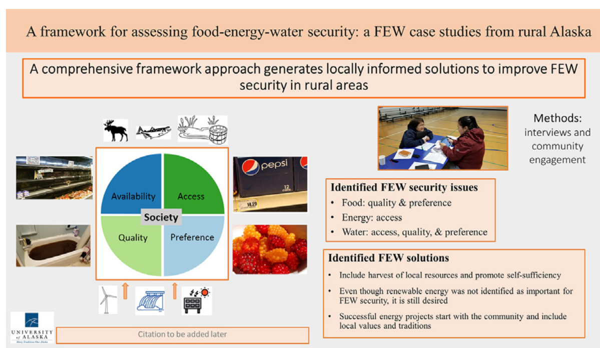
HIGHLIGHTS

- Based on interviews in rural Alaska, FEW security is high among study communities.
- Quality and preference relate to food and water insecurity; access effects energy.
- Community perspectives and expectations influence reported FEW security.
- Subsistence foods boost food security above what purchased foods provide.
- Links between RE and FEW security are minimal, but communication is key.

GRAPHICAL ABSTRACT



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ABSTRACT

Food, energy, and water (FEW) are basic needs for well-being and quality of life. Assessing FEW security allows residents, communities, and policy makers to make informed decisions about how to sustain and improve well-being. We have developed a FEW security assessment framework that examines four components of security: availability, access, quality, and preference. With the help of local community members, we interviewed 114 households in three rural Alaska communities to assess FEW security, drivers and outcomes of FEW security, and potential interactions among FEW components and with renewable energy (RE) developments. While FEW security was high overall, preference and quality, especially for food, was lower. Food harvested from the local environment (i.e. subsistence) was necessary to include in security assessments given that 24% of participants reported insecurity when asked about contemporary sources (i.e. purchased) versus 5% reporting insecurity for subsistence food sources (i.e., harvested). The major influences on FEW security tended to originate from outside the community, including factors such as transportation, income, fuel prices, and weather. One internal factor, health, was both a driver and an outcome of FEW security. Satisfaction with RE varied (42%–68%) with dissatisfaction due to unreliability, uncertainty of the economic benefit, desire for other types of RE, or wanting more RE ($n = 6$). Communication about RE projects was key to managing expectations, promoting knowledge, and identifying benefits for residents. Participants did not identify linkages between RE and FEW security. Our assessment tool can be used by communities and policy makers to contextualize FEW security into more insightful and specific components, allowing for identification of attainable actions to improve FEW security and thus individual and community well-being.

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1. Introduction

Food, energy, and water (FEW) security are a fundamental human right, with insecurity linked to negative impacts on quality of life, well-being, environment, and sustainable development (Biggs et al., 2015; Greaves, 2016; Staupe-Delgado, 2020). However, FEW security is becoming more challenging to maintain due to human population growth, urbanization, consumerism, and economic development (de Amorim et al., 2018; EIA, 2021; United Nations, 2012; United Nations, 2017). These factors place increased demands on limited FEW resources which are also being reduced or shifted due to climate change (Hoff, 2011; IPCC, 2013; WEF, 2011). Determining ways to maintain or improve security is becoming increasingly important and key to sustainable development, environmental security, and the well-being of future generations (Biggs et al., 2015; FAO, 2009; Gjorv, 2017; Molajou et al., 2021; Molotoks et al., 2021; United Nations, 2019).

An interconnected and holistic nexus approach is necessary to assess FEW security because food, energy, and water are all necessary for sustainable development (Afshar et al., 2021; Biggs et al., 2015; Rasul, 2016; Simpson and Jewitt, 2019; United Nations, 2018). We define the nexus as an approach that can highlight the linkages and feedbacks among FEW and related factors which can focus on the system rather than isolated sectors (Hoff, 2011). This approach identifies interdependencies and subsystems which can drive meaningful actions needed to increase FEW security in the context of sustainability (Bazilian et al., 2011; Biggs et al., 2015; Pahl-Wostl, 2019; WEF, 2011). While the FEW nexus approach has been used around the globe (Albrecht et al., 2018; Newell et al., 2019; Schlör et al., 2021), it is still relatively unexplored in Alaska and the Arctic (Huntington et al., 2021; Natcher and Ingram, 2021; Whitney et al., 2019). The information gathered from interviews and presented here contributes towards the movement from theory to application in improving sustainability and FEW security (Shannak et al., 2018; Zhou et al., 2021).

Many FEW frameworks focus on national or regional level assessments (FAO et al., 2020; Natcher and Ingram, 2021; Siddiqi and Anadon, 2011), which are useful for identifying large-scale factors like global policies and geography, international trade, and higher-level governance. However, these types of assessments often fail to capture community variation and trade-offs experienced locally (Aboelnga et al., 2019; Loring et al., 2013). This is especially true for countries with urban and rural populations that exhibit large variations in socio-economic conditions and environmental gradients. There is a need for more detailed information on FEW security and variability at the community level and knowledge about the roles that community and individual choices and preferences play in FEW security (Biggs et al., 2015; Itayi et al., 2021; Loring et al., 2013). For example, local governance, which is informed by community residents, is important for FEW security (Kiparsky et al., 2017; Slade and Carter, 2017). At the community level, the FEW framework is holistic and thus better able to capture complex systems facing individuals. Individuals do not make decisions in isolation but rather incorporate many related factors.

Much of the existing FEW nexus work has also focused on agricultural systems and urban areas outside of the Arctic (Albrecht et al., 2018; Biggs et al., 2015; D'Odorico et al., 2018; Zhang et al., 2019). Our research focuses on FEW security among three small communities in rural Alaska that vary in socio-economic characteristics, remoteness, culture, and integration of renewable energy. It is important to better understand FEW security in remote places because nearly 46 million people in the United States and 44% of the world's population live in rural areas (i.e. < 79 people/km^2) (Parker et al., 2018; World Bank Group, 2020). Like many rural residents, members of the communities in our study depend on local resources (Hogeboom et al., 2021; ICC, 2015; ICC Canada, 2012). In addition, communities in rural, remote locations in Alaska frequently depend on islanded microgrids for electricity, making many of them solely dependent on local power plants which are typically fueled by diesel that must be transported at high cost from elsewhere (Holdmann et al., 2019). Therefore, these communities also provide an excellent opportunity to explore the effects of renewable energy on FEW security in a relatively simple and isolated setting.

Our framework for assessing FEW security was developed based on four components of FEW security frequently found in the literature but never before combined into a combined framework: availability, access, preference, and quality (CCA, 2014; Goldhar et al., 2013; Hossain et al., 2016; Penn et al., 2017; Sovacool and Mukherjee, 2011; Walch et al., 2018). By using these four components, others have determined different and individual sources of insecurity, and previous research on FEW security in Alaska has been largely limited to independent exploration of the sectors (i.e., food, energy, or water) (Fall and Kotstick, 2018; Holdmann et al., 2019; Penn et al., 2017; Walch et al., 2018). For example, Walch et al., 2018 found that access to traditional food tended to be lower, but quality was high. Meanwhile availability of water might be high (Poppel et al., 2015), but access low (Instanes et al., 2016; Wright et al., 2018). Combining the four components into one assessment such as our proposed framework allows for a more complete picture of potential insecurity and robust solutions.

Additionally, our research explicitly includes both traditional and contemporary sources of food, energy, and water and compares them using food security as an example, which allows for insights into their respective contributions. Contemporary sources include food purchased at the store, tap water, and power from power plants. Traditional sources are subsistence foods or water and fuel collected from the local environment (i.e., rivers, ice, firewood, etc.). Inclusion of traditional sources is important because, without them, FEW security may be inaccurately assessed given that many rural households harvest large quantities of local wild foods and water to offset high prices, to augment poor selection or quality at the store, for personal preference, and to practice cultural traditions (Loring and Gerlach, 2015; Smith et al., 2008). These local or traditional resources are equally, if not more, important than contemporary ones in both cultural and security contexts (ADF & G, 2014; Alix and Brewster, 2004; Eichelberger, 2010; Harder and Wenzel, 2012). Little research collects information on both traditional and contemporary FEW resources, and none has quantified the relative importance of their respective contributions to security (Eichelberger, 2017; Fall and Kotstick, 2018; Natcher et al., 2016). Our applied research uses a mix of quantitative and qualitative methods to provide in-depth information (Johnson and Onwuegbuzie, 2004; Simonovich, 2017) on FEW security that provides a holistic picture to move beyond theory and political debates to actionable information for improving FEW security. This approach is currently lacking from much of the FEW nexus work (Al-Saidi and Elagib, 2017).

In order to identify areas of strengths and weaknesses which can be used to increase or maintain security and sustainability, and based on our literature review and our previous knowledge about rural Alaska communities, we developed three hypotheses concerning FEW security. Specifically, we sought to examine variability in FEW security within and among communities, the reasons for any such variability, the factors that influence FEW security, and how assessment of FEW security can contribute to understanding and to action to improve FEW security. Our hypotheses were:

Hypothesis 1. The status of security components differs among FEW sectors and across communities, and these differences are important for understanding FEW security and identifying ways to improve or maintain security.

Hypothesis 2. FEW connections and trade-offs exist, but additional factors such as transportation, employment, health, etc. will have equal or greater influences on FEW security.

Hypothesis 3. An integrated framework that allows for simultaneous assessment of FEW sectors and components provides a more in-depth understanding of security and the identification of strengths and weaknesses among communities.

Here we present results from our interviews on FEW security with residents of three rural Alaska communities from January through March

2019. First, we present overall FEW security by community and within the three FEW sectors. Then we illustrate how FEW security varies by the four components (availability, access, preference, and quality) in our framework. Finally, we combine the three sectors (food, energy, and water) and four components (availability, access, preference, and quality) to look at how security varies in detail. This holistic assessment of FEW security is critical to understanding the extent to which countries and communities are sustainably meeting their FEW needs. With this approach we identify specific impediments to improving FEW security as well as key aspects of FEW security that should be sustained.

2. Materials and methods

2.1. Background and study areas

The FEW framework was tested in three rural Alaska communities: Cordova, Kongiganak, and Igiugig (Fig. 1). These communities, like many rural communities in the world, depend mainly on local sources of food, energy, and water, and provide a semi-closed system in which to study the FEW nexus and security. These communities were chosen because they have different types of renewable energy projects, reflect variation among rural Alaska communities, and were interested in participating. Cordova has over 2200 residents, Kongiganak has 439 residents, and Igiugig has 50 year-round residents. The populations of Kongiganak and Igiugig are primarily Indigenous with most residents identifying as Yup'ik. In Cordova, only 4% of households are Indigenous. All three communities are off the road system (Fig. 1). Igiugig and Kongiganak are accessible by plane year-round and by barge in the summer. Historically, Cordova has historically been more accessible as it is served by the state-operated year-round ferry service which connects Cordova to Alaska's road system. But in the fall of 2019 the state halted the ferry service for the winter, which meant Cordova was only accessible by plane (Boots, 2019) or private boat.

Table 1 shows selected socio-economic characteristics of the three communities. Employment and income opportunities are limited in rural Alaska and transfer payments account for a significant percentage of household's disposable income (Goldsmith, 2008). Cordova has the highest employment rate with a local fish processor and opportunities for commercial fishing. Cordova and Igiugig have higher incomes and employment levels than Kongiganak, which correspond to lower rates of SNAP assistance. In all three communities, residents harvest wild foods to various extents, relying on their largely undisturbed environments for high quality fish and game, and use nearby water sources or rainfall to supplement their water supply. Subsistence is important in all three communities with a per capita harvest much larger than in urban Alaska (where the harvest is 8 kg per capita, (Fall, 2018)). Although comprehensive subsistence surveys have not been conducted in Kongiganak, the community prides itself on having a strong subsistence culture (LKSD, 2020). Kongiganak lacks piped water so most residents haul their drinking water from a local washeteria, which is a community facility attached to the water plant, or natural sources like rivers and lakes.

All three communities also have different experience with renewable energy technologies. Cordova has a large hydropower system (3500 MWh/yr) that provides 60% of the power for Cordova including fish

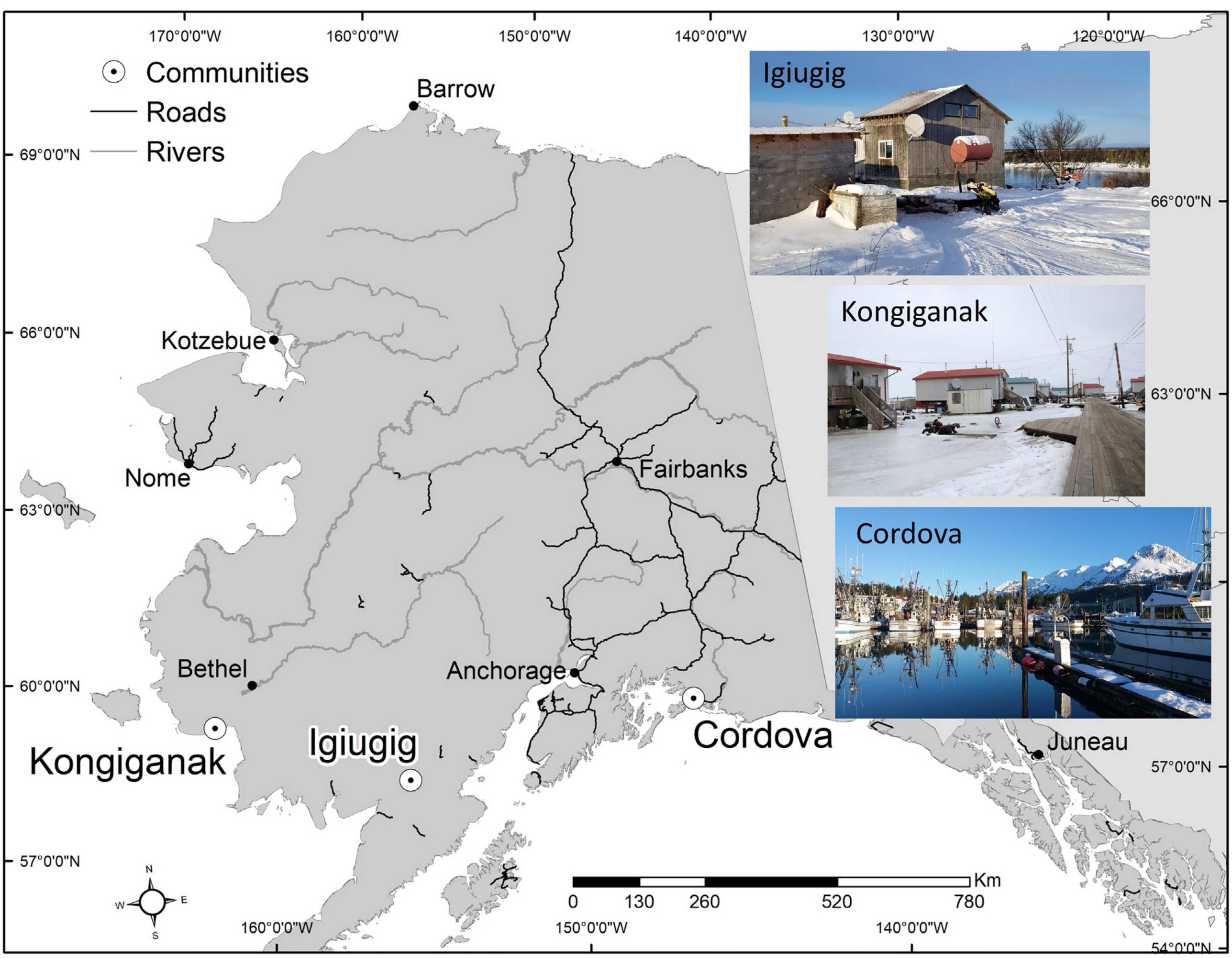

Fig. 1. Rural Alaska communities that participated in FEW assessment interviews conducted between January and March 2019.

Table 1
Socio-economic characteristics of three communities in rural Alaska that participated in FEW interviews in January through March 2019.

Characteristics	Cordova	Igiugig	Kongiganak
Population size[a]	2221	50	439
Number of households (HH)[a]	1110	19	109
Average HH size	3.5	4.4	5.1
% female population[c]	45%	55%	41%
% Indigenous HH[c]	4%	88%	95%
Median age[c]	38	31	25
Median HH income[c]	$94,625	$61,250	$50,313
% working 35 h > week	75%	52%	32%
Per capita harvest (kg)[b]	53	246	NA
% SNAP[c,d]	3%	6%	61%
% without complete plumbing[c]	0%	6%	97%

[a] (US Census Bureau, 2010).
[b] Alaska Department of Fish and Game Division of Subsistence ((ADF & G, 2021) Cordova 2014, Igiugig 2005).
[c] 2019 ACS 5-year estimate selected economic characteristics.
[d] Numbers are an underestimate due to ACS methodology that removes households that are eligible under the more lenient rules established for Alaska (ACS, 2019).

processing plants (ACEP, 2015). The electric company is cooperative, and members see cost savings due to hydropower on their bills. This system has been operating for over a decade. Igiugig has the most diverse use of renewable energy including solar, wind turbines, and a new run-of-river hydrokinetic power system (Ross, 2019). The goal is to eventually provide 90% of the power with this new system (Deedy, 2021). Kongiganak has five 95 kW wind turbines that were installed in 2008 (Chaninik Wind Group, 2013). In the last few years electric thermal stoves had been added to some houses to help provide heat when excess energy is created from wind (Byrd, 2021).

2.2. FEW framework

We began by examining a range of security frameworks developed for FEW sectors independently (Fig. 2) (FAO, 2013; Goldhar et al., 2013; Walch et al., 2018). Among the common features of these frameworks is the idea that a FEW security framework needs to reflect social, cultural, bio-physical, and economic conditions (de Grenade et al., 2016; Lawford et al., 2013; Loring and Gerlach, 2009). Based on the aims and experiences of existing frameworks, as well as our own experience working in rural Alaska, we identified four aspects of FEW security that we believe are important to distinguish and essential for understanding the nuances of security and its causes: availability, access, quality, and preference (Hussien et al., 2018; Itayi et al., 2021; Loring et al., 2013; Walch et al., 2018; Westengen and Banik, 2016).

- *Availability* means having adequate quantities available when it is needed, and it includes stability which indicates that the resource is consistently available (FAO, 2014).
- *Access* is defined separately because FEW may be available, but this may not always be accessible due to affordability issues or, in the case of subsistence foods, fish and game populations may be scarce, regulations may prevent harvests, or socio-environmental factors may prevent traveling to harvest resources (Brinkman et al., 2016; Chapin et al., 2016).
- *Quality* is the condition of the FEW resources available and the extent to which FEW can be utilized to meet the needs of individuals. Fruit and vegetables may be available in the local store, but they may be already starting to decompose or tap water could be available but contains a heavy sediment load.
- *Preference* refers to whether FEW that is available and accessible is what people want and individuals may differ in their preference due to individual, cultural, or social factors. People may be forced to use non-preferred options because they are limited in their choice of FEW resources. If fuel oil is the only option for heat, then a resident is forced to use this source since going without heat during an Arctic winter is not feasible.

2.3. Interview design

An interview guide was developed with a mix of closed and open questions (Bernard, 1988) and the goal of learning more about local perceptions of FEW security, testing the relevance of our four components of FEW security, and discovering linkages and trade-offs among FEW components

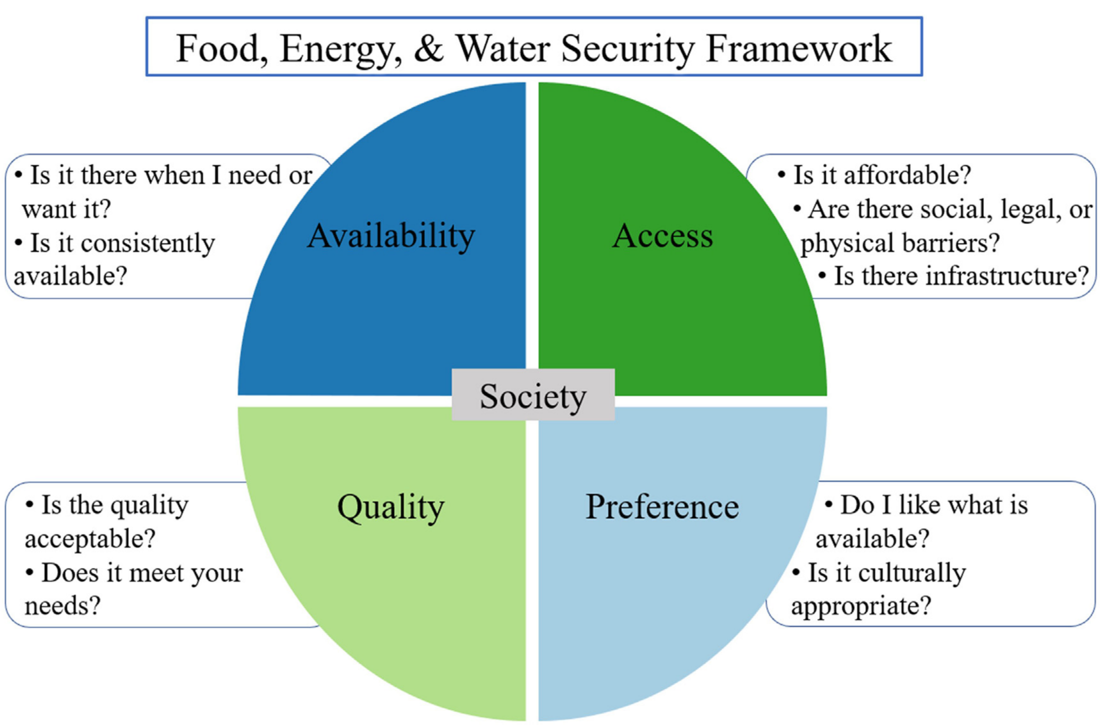

Fig. 2. FEW security framework.

(Appendix 1). The questions used to assess security were developed based on previous survey instruments and research (Bickel et al., 2000; Brinkman et al., 2014; Eichelberger, 2010; Fall and Kotstick, 2018; Ford and Berrang-Ford, 2009; ICC, 2015; ICC Canada, 2012; Kruse et al., 2009; Loring and Gerlach, 2015). The framework was assessed through the development of 35 statements (Appendix 1 and Appendix 2). These statements reflected each FEW sector and, within each sector, statements addressed each of the four components of our framework. The statements reflected contemporary and traditional sources of FEW such as store bought and subsistence foods, tap water and natural sources, and powerplants (i.e., diesel) and firewood. Surveys were pre-tested with 10 residents in Anchorage who had previously lived in rural Alaska to assess questions for content, language, and length. The desired length of the interview was 20 to 40 min. The final interview guide was approved by the University of Alaska Fairbanks Institutional Review Board (# 1093666), responsible for ethical conduct of research involving humans.

2.4. Data collection

Data were collected with the assistance of local researchers, who received human subjects training as certified by the Institutional Review Board. Quota sampling was used with a goal to interview at least 50 households in each of the communities of Cordova and Kongiganak and as many as possible in the smaller community of Igiugig (Lavrakas, 2008; Sousa et al., 2004). Participants were selected with the help of the local researchers with the goal of representing the composition of the community (i.e. race, household size, sex, and age; Table 1). This non-probabilistic approach is often used to gain valuable exploratory information about populations and can identify groups that may need more focus in the future (Halm and Bakas, 2007; Lunsford and Lunsford, 1995; Sousa et al., 2004). We compared our survey sample distribution (i.e., sex, ethnicity, and age) with official demographic information to confirm that our sample under normal approximation was within 95% of the target population (Cochran, 1977; Sousa et al., 2004) (Appendix 3). At the end of the interview participants were compensated on a US$50/h rate, up to US$50 total.

2.5. Data analysis

Basic statistics were used to identify security among FEW components and specifically how the four different components of availability, access, quality, and preference affected overall FEW security. Likert statements allow the interviewee to evaluate the level of agreement with a statement and make quantitative comparisons. The statements were written to reflect higher security when participants agreed (i.e. strongly agree = high security, agree = secure), lower security when they disagreed (i.e. strongly disagree = low security, disagree = insecure), and neutral (i.e. no opinion; Appendix 2). The statements also reflected the different components of FEW security mentioned above as well as conventional (i.e. store and piped water) and traditional (i.e. wildfoods and local water sources). A Wilcoxon sign-ranked test was used to assess whether Likert (i.e., ordinal) responses to the FEW security statements were different from neutral. A Kruskal-Wallis one-way ANOVA ($\alpha = 0.05$) test was used to determine if communities differed in their responses to the statements (Agresti, 2010). If differences were detected among communities then a Dunn-test was performed to identify which communities were similar (Dunn, 1964). The R statistical program and the MASS, FSA, and Likert packages were used to perform all statistical analyses (Bryer and Speerschneider, 2016; Ogle et al., 2020; Rozzi, 2020; Venables and Ripley, 2002).

Qualitative data provided an enriched understanding of FEW security and connections with other aspects of life. The two researchers who conducted interviews in all three communities inductively coded the open ended questions, meaning that the codes developed were based on main themes observed in the data, and consensus building was used to finalize the codes (LeCompte and Schensul, 2013). One initially developed the themes and codes, and the second reviewed the data, themes, and codes to achieve a consensus. Word clouds were used to explore what items people tended to purchase from the local stores.

3. Results

3.1. Participation

We interviewed 50, 51, and 13 households in Cordova, Kongiganak and Igiugig, respectively. We aimed for a sample of 50 households in the larger communities and interviewed all households present at the time of the interviews in Igiugig. Median age of participants and household size were comparable to ACS data in Table 1 (Cordova = age 36, HH size = 3.0; Igiugig = 29, 4.1; Kongiganak = 24, 6.8). Demographic characteristics of our survey population mimicked that of our target population except for Cordova where we slightly over-sampled Indigenous households (Appendix 3).

3.2. FEW security

Prior to assessing FEW security with Likert statements and examining the components of security, we asked in very broad terms whether participants were most secure among food, energy, or water in each of their communities. Security was highest for food and water, which are items that can be harvested from the surrounding environment and have multiple sources (Table 2). Water was generally the most secure except for Kongiganak which has no piped water supply. In Kongiganak, more residents reported being secure in food. All three communities reported being least secure in energy (Cordova 70%; Igiugig 69%, Kongiganak 57%).

3.3. FEW assessment

3.3.1. FEW sectors

Nearly all (95%) of the statements regarding FEW security were significantly different from neutral ($p < 0.01$) meaning they reflected either security or insecurity (Appendix 2). Overall, most residents (79%) agreed with our FEW security framework statements indicating high security (Fig. 3). Among FEW sectors in aggregate across the three communities, food had the lowest security largely due to lower scores from Cordova (63%), which had just lost ferry service, and Kongiganak (64%), a very remote community. The ferry service provides the most affordable mode of transportation in and out of Cordova. In Kongiganak, which lacks piped water in households, more than twice as many people rated water security as "very low" (i.e. high insecurity) than was the case for any other sector among all three communities. Based on our FEW assessment statements, energy security was overall high (79% agreed or strongly agreed), but slightly lower in Kongiganak (72%) than in the other two communities. Statistical examination of the responses among communities indicated a large amount of variation among the responses to the FEW statements. Twenty-six of the 35 statements had significant pairwise differences ($p < 0.05$; Appendix 2) indicating that, even though security appears to be high, communities in rural Alaska are heterogenous in their FEW security.

Table 2
Number and percentage of participants that indicated which FEW sector was the most secure in their community. This is the initial assessment of FEW security prior to the Likert statements among three communities in rural Alaska based on interviews in March 2019.

	Cordova		Igiugig		Kongiganak		Total	
Community	n	%	n	%	n	%	n	%
Food	9	18	2	15	25	49	36	32
Energy	5	12	0	0	8	16	13	12
Water	35	70	11	85	18	38	64	57

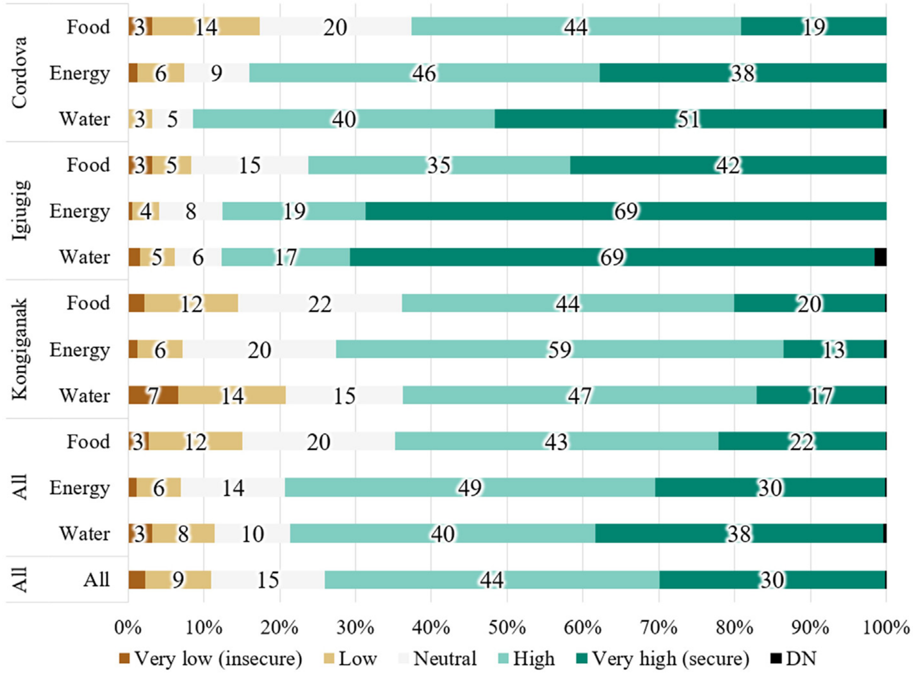

Fig. 3. Security among FEW sectors in three communities in rural Alaska based on interviews done January through March 2019. Percentages less than three are not labeled.

3.3.2. Components of security

Fig. 4 illustrates the differences among components of FEW security, with availability ranked as the most secure with participants agreeing with most of our statements (82%) followed by quality (72%) and finally access (67%) and preference (66%). The two most remote communities, Igiugig and Kongiganak, indicated access was the biggest driver of insecurity while preference was the issue in Cordova (Fig. 4). However, preference was nearly equal to access in Igiugig, and the second issue identified in Kongiganak. Questions related to subsistence foods such as access either through personal harvest or sharing (91% agreement) and quality (91%) tended to have more support indicating higher security. The main issue raised by residents across all three communities was that local store-bought food is expensive, especially with respect to quality. In Igiugig and Kongiganak, which are more remote and smaller communities, a common concern was that readily available food in the store was "*junk food.*" To deal with the lack of high-quality food and costs, Igiugig residents started

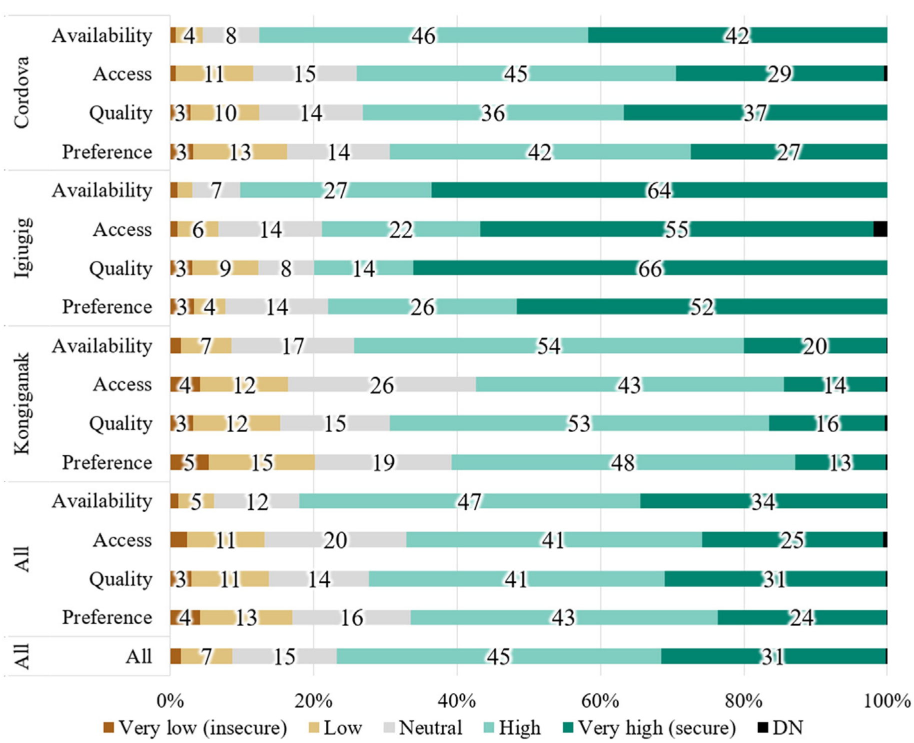

Fig. 4. Security among four components of FEW sectors in three communities in rural Alaska based on interviews conducted from January through March 2019. Percentages less than three are not labeled.

a program that provides free eggs for elders from locally raised chickens and have an active greenhouse that makes fresh produce available to residents. In the smaller communities of Igiugig and Kongiganak, people typically purchase junk food and other staples such as rice, sugar, flour, and milk from the local store. Purchasing from online retailers has also become a common practice with people purchasing canned goods, meat, coffee, produce/veggies, and other bulk items, typically to be delivered via mail, which is subsidized and thus more affordable than standard air cargo.

3.3.3. FEW sectors and components

Breaking down FEW sectors into their four components of availability, access, quality, and preference highlighted the complexities of FEW security as well as the differences among each FEW sector. Availability in all three sectors was quite high with nearly 80% or more of these statements garnering support (i.e., agree or highly agree; Table 3). However, the food and water available was not what is preferred. Nearly 50% of participants indicated the quality of the store food was poor (48%) or not what they want (46%, Appendix 4). Water preference and quality were rated lower among security components (Table 3). Reasons for lower quality from treatment plants included the smell or taste of chlorine used in the treatment process (Kongiganak R7, R10; Cordova C5, C8, J11, JS7) or unappealing color (Kongiganak J10), while others simply preferred natural sources for cultural or personal reasons. "*I want to be able to get untreated spring water.*" (Cordova C5).

Among the twelve potential situations (3 sectors × 4 components) in Table 3, energy was identified as the most secure with residents indicating 80% "high" or "very high" agreement with statements about security for three of the four components. Availability of energy is high, but access, mostly driven by affordability issues, is a challenge for many with 17% and 12% of participants indicating they cannot afford gas or to heat their house, respectively (Appendix 4). Several people mentioned the expensive costs of fuel and actions taken to reduce costs such as "*[I] had to retrofit the house with Toyo [a brand of oil-fired heater] and heat-conserving curtains. Everyone sleeps upstairs [where it is warmer]. We are making adjustments to make it [heat] affordable*" (Igiugig 1). The price of fuel also limited peoples' activities, including subsistence, gathering groceries, and driving children to school and events. "*If gas was more affordable, we wouldn't have so much logistics planning to make with driving with as few trips as possible*" (Cordova 9).

3.3.4. Food security: contemporary versus subsistence

Food security associated with contemporary sources such as the local store or mail orders was much lower than security provided by subsistence resources (Fig. 5, Kruskal-Wallis chi-square = 236, df = 1, $p < 0.001$). Almost a quarter of responses indicated low food security (24%) with respect to contemporary food sources and 5% of participants indicated severe insecurity. Meanwhile no responses indicated severe food insecurity from subsistence resources (Fig. 5). All four components were rated as more secure for subsistence resources than contemporary resources with only 28% and 35% of the responses indicating acceptable quality and utility and desired preference, respectively for, contemporary resources.

Overall, the differences among the three communities illustrated the complexity of FEW security. Kongiganak was least secure in water with preference (33%) and access (25%) as the main points of insecurity. Food also tended to be less secure than energy for all four components save for availability and stability. Igiugig generally had high security, but if there were two areas to improve security, they were the quality and utility of food and water (Fig. 5). Like Igiugig, Cordova had overall high security, but statements indicated all components of food security could be improved upon, especially preference and quality (Fig. 5).

3.4. Renewable energy and FEW insecurity

Satisfaction with renewable energy (RE) programs varied among our communities (Cordova 68%, Igiugig 42%, Kongiganak 67%). Dissatisfaction largely arose due to unreliability ($n = 11$), followed by uncertainty of the economic benefit ($n = 7$), desire for other types of RE ($n = 6$) or more RE (n = 6). In Igiugig a brand new RivGen system was installed, but there were still issues with power generation. Unreliability often related to misconceptions about when and how much power should be produced by RE. Even so, 22% of participants indicated the desire for more renewable energy to help offset the costs that was identified as a point of FEW insecurity. Reasons for not wanting more RE varied widely with residents stating they were not aware of the projects, projects did not directly benefit them, and needing more knowledge about RE before making a statement. Among the 22% who said they would like more RE, solar was identified as the most desirable RE (54%) followed by wind (24%), and tidal (17%). To facilitate the development of RE projects four main themes emerged: incorporating Indigenous values into the planning process and formalizing it to be "understood by westerners", having a vision and strong sense of community, willingness to change, and human capital. In Cordova and Kongiganak 40% and 92% of residents, respectively, indicated that if the RE system in their community stopped working they would be affected. Affects in Cordova include increased costs for residents and business (100%) and increase oil dependence (13%). Meanwhile the lower impact on residents in Kongiganak was due to residents not directly benefiting from RE (19%), not working well (13%), and not knowing about them (10%). It is notable that when asked what effects FEW security no respondent mentioned their RE programs.

Table 3
Assessed security among FEW and their four components based on interviews done January through March 2019 within three communities in rural Alaska. Percentage of responses within each Likert category from 1 (very low security) to 5 (very high security) from the FEW framework statements. The average indicates the average score from 1 to 5. Light green indicates 0–10% or 3.0–3.4, medium green indicates (11–49% or 3.5–3.9), and light teal indicates (50–79% or 4.0–4.4).

Sector	Component	n	Very low (insecure)	Low	Neutral	High	Very high (secure)	DN	Ave.
Food	Access	153	2%	14%	22%	39%	23%	0%	3.6
	Availability	204	0%	5%	16%	55%	23%	0%	4.0
	Preference	153	5%	17%	25%	40%	13%	0%	3.4
	Quality	102	5%	16%	19%	29%	31%	0%	3.6
Energy	Access	153	1%	10%	20%	46%	23%	0%	3.6
	Availability	306	1%	3%	13%	48%	35%	0%	3.8
	Preference	102	2%	8%	9%	52%	29%	0%	3.8
	Quality	102	1%	5%	11%	53%	30%	0%	3.8
Water	Access	102	5%	7%	16%	39%	33%	2%	3.2
	Availability	255	2%	7%	7%	41%	43%	0%	3.8
	Preference	102	5%	11%	11%	39%	33%	0%	3.2
	Quality	51	3%	11%	10%	44%	32%	0%	3.6

3.5. Outside factors affecting FEW insecurity

When asked what factors affected FEW security, costs were the most mentioned issue, particularly fuel costs (Table 4). Residents also mentioned many other drivers of FEW insecurity, such as transportation. Residents mentioned the challenge of getting goods and supplies into rural Alaska in a timely manner and with acceptable quality. When a desired good does arrive in the community its supply is often quickly depleted. "*Everyone runs and grabs good produce when it shows up. [It is] delivered once a week instead of twice a week*" (Cordova 10). While Cordova used to be served by two airlines, one had recently cancelled its service, which resulted in a decrease in deliveries. In addition to the reduction in air cargo, the ferry service was suspended just before this research commenced (Duncan, 2020). Nearly all

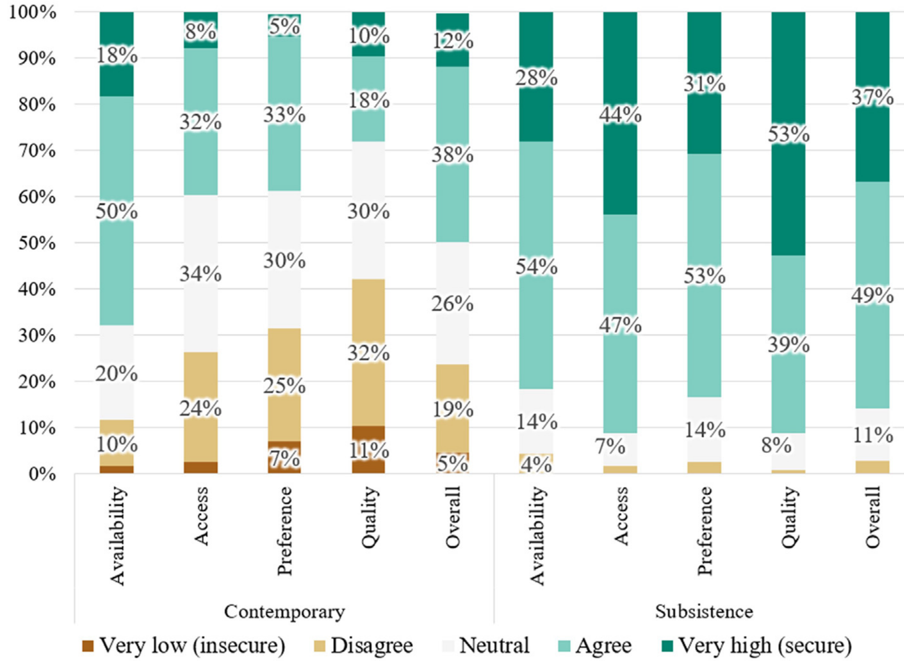

Fig. 5. FEW security based on contemporary (i.e. e.g. store, online shopping, etc.) versus subsistence sources among three communities in rural Alaska based on interviews done January through March 2019.

Cordova participants (94%) indicated they were affected by the ferry cutbacks with two-thirds mentioning impacts to food security or finances (68%). Residents of Igiugig did not mention supply chain issues, perhaps because they have adopted a strategy to overcome this by maintaining a direct flight to Anchorage where residents can call 'transporters' in Anchorage to pick up supplies in a timely manner from stores with more selection and lower prices. Overall, this highlights the substantial and at times precarious role transportation plays in food security.

In addition to transportation, seasonality and weather were also important. "*Depending on when the barge comes in it impacts whether food, veggies are received. [We] may not receive them for a week or two depending on delay. In summer it's a lot easier and there is the ferry*" (Cordova 13). In Kongiganak, residents and store owners mentioned increased rain events in winter, resulting in flight cancellations and delays for mail orders. These delays result in empty store shelves and food rotting out before arrival. Subsistence is also a highly seasonal activity with the types and amounts of resources changing throughout the year. On a longer timescale, concerns were expressed about climate change and the effect on salmon runs of a recent drought in Cordova. Other factors that influenced people's ability to practice subsistence were regulations, availability of personal free time, knowledge/health, fuel costs, and proximity to the resource. Income and disposable income were the second most common comment with participants mentioning the high cost of living which reduced their ability to purchase gas, and transportation options. It is clear there are many outside factors that influence FEW security, but changes to a few key factors such as transportation issues and improvements in health preservation could have large effects on FEW security.

Table 4
Factors affecting FEW security as reported by people interviewed January through March 2019.

	Cordova		Igiugig		Kongiganak		Total	
Factors	n	%	N	%	n	%	n	%
Costs	46	46%	4	44%	47	49%	97	47%
Transportation	13	13%	0	0%	17	18%	30	15%
Weather and seasonal variation	11	11%	2	22%	5	5%	18	9%
Fuel costs	9	9%	1	11%	7	7%	17	8%
Income and disposable income	8	8%	0	0%	8	8%	16	8%
Ability to do subsistence	6	6%	2	22%	4	4%	12	6%
Health	5	5%	0	0%	6	6%	11	5%
Access to markets	3	3%	0	0%	2	2%	5	2%

3.6. Outcomes of FEW insecurity on residents

Most participants indicated FEW affects other aspects of their household (50%) though a number indicated no effect (15%) while the remaining were unsure (35%). Of those who indicated FEW security affected them, most mentioned quality of life issues such as physical and mental health (46%), being uncomfortable (39%), and additional stress (11%). Health is a driver and outcome of FEW insecurity in that 91% of participants indicated that when they have access to nutritious foods their health is better and 63% said their health affects their ability to get the food they want (i.e. subsistence foods). Health is important for maintaining access to nutritious foods including subsistence foods. "*My health affects my ability to get some of the things we need*" (Kongiganak 8). Several residents noted that having healthier food makes them mentally and physically happier (Kongiganak $n = 7$, Cordova $n = 11$). Other impacts were financial hardship ($n = 10$) caused by an increase in FEW prices which forced households to cut back in other areas, and additional time ($n = 4$) that could be needed if people had to travel further for water or subsistence foods, leaving less time for other activities.

4. Discussion

Food and water have long been acknowledged as a basic right (United Nations, 1948), and energy is increasingly being viewed in the same light (Eichelberger, 2010). Yet, around the world many communities continue to experience FEW insecurity. Our framework was effective at identifying specific, detailed, and nuanced ways in which communities are or are not FEW secure. Understanding community level FEW security is necessary to guide decision at any level of governance. We also illustrate that a carefully structured assessment can identify insecurities overlooked with a broad question. For example, when asked in general which of the three sectors residents thought they were most secure in, energy was the lowest. But when we assessed how often people lacked common components of security (i.e., access, availability, quality, preference) energy was relatively secure compared with water and especially food. The difference in results is likely due to the role that self-sufficiency plays. Many of the comments indicated that vulnerability informed residents' responses because energy, unlike food and water, for the most part cannot be harvested from the local environment, and people are dependent on power plants and fuel delivered from outside the community.

"Self-sufficiency", such as harvest of local resources, is associated with higher levels of FEW security (Elgert et al., 2016; Hossain et al., 2016; Smith et al., 2019). Our findings also indicate that self-sufficiency may explain the higher reported food security reported for subsistence foods versus contemporary sources. Not only were preference and quality higher than contemporary sources, as might be expected for locally produced and culturally valued foods, but access and availability were also regarded as higher despite considerable variability in fish and wildlife populations (Chapin et al., 2014) and the level of skill and work required to harvest local foods. Connections to the local environment, strong sharing networks, and passing down of culture and traditional values provide a sense of pride and empowerment for residents when faced with food limitations, especially in contrast to expensive, limited store options (Heeringa et al., 2019). The ability to sustain harvests is likely to become increasingly challenging as seen with the recent collapse of the salmon runs along the Yukon River that has had devastating effects on communities (Hughes, 2021a; Hughes, 2021b). In order to maintain FEW security, flexible and forward-thinking management is needed of our natural resources.

The role of perception is also likely in the finding that food security in Cordova was slightly lower or on par with more remote and smaller communities (Fig. 3). This surprising result stresses the importance of context and expectations. Cordova has two large grocery stores, has regular large plane service, and typically people can bring in food on the ferry from urban areas. Just prior to our survey, however, Cordova had recently lost ferry service which many stores and residents used to access higher quality foods from urban areas. So, expectations for food quality and access were high, higher than most places in rural Alaska, and thus at the time of this survey residents indicated their food preferences were not being met because quality was falling short compared with what they were used to. Our results highlight how topical events, such as the cancellation of ferry service, can influence perceived security. This example also illustrates how FEW security is dynamic and contextualized, and perspectives and expectations matter when assessing FEW security. This result also illustrates the perils of comparing results from different communities, as reported FEW security may not align with an objective comparison of conditions from one community to the next. In other words, Cordova residents' disappointment over the effect of losing ferry service do not necessarily mean their food security should be a higher priority than a more remote community that is simply inured to poor food options.

Cultural context is also important to keep in mind when assessing attitudes and opinions. Even though food and energy prices are much higher in remote Alaska (Goldsmith, 2010) and there are often issues with water treatment and power plants (Eichelberger et al., 2021; Holdmann et al., 2019) participants still for the most part declined to report dissatisfaction (i.e. lower security). Some Indigenous cultures in Alaska tend to avoid conflicts, including talking poorly about people and events, (Burch, 2006; Kingston, 2008; Morrow, 1990) or talking about negative events for fear of increasing the likelihood of occurrence (Huntington et al., 2006). So, speaking poorly about service or discussions about poor service or power outages might be underrepresented in our results. Customs such as preference for non-piped water or certain foods also affect perceptions and comparisons of security. While it is important to acknowledge local expectations, customs, and goals for FEW security, these considerations can also make comparisons across communities difficult. More research is needed into how local culture and context affect assessments of security and comparability across regions and time, as well as ways to identify shortcomings in FEW security without violating cultural norms of avoiding negative speech.

As mentioned, energy security was rated quite high despite publications indicating energy security is a critical issue in the Arctic (de Witt et al., 2021) All three of the communities involved in this research have renewable energy programs which may have resulted in energy security being above normal for rural Arctic areas, as well as a perception of local agency instead of dependency. This provides the opportunity to learn from these communities and provide evidence based suggestions. For example, even though security was high among our communities their satisfaction varied. Cordova and Kongiganak had higher satisfaction levels which we believe is due to communication and community engagement. In Cordova cost-savings due to hydroelectric energy generation are printed on customers' monthly energy bills, which many residents commented on seeing, and thus economic impacts were readily apparent and one of the main concerns should the hydroelectric facility stop functioning. In Kongiganak even though not all residents have electric thermal stoves, the EV program is structured to provide benefits beyond energy (i.e. local jobs and training) (Chaninik Wind Group, 2013).

The importance of community engagement is even further strengthened by the lessons learned from Igiugig. To have an active renewable energy program means that the community has a vision, capacity, and is motivated. Integrating and maintaining modern technology within archaic diesel-powered grid systems is challenging, and creating systems that benefit customers directly is even more difficult given the high fixed costs of operating power plants in remote locations. State policies such as the power cost equalization program can work against renewable energy if local gains are offset by reduced subsidies (Fay et al., 2010; Hossain et al., 2016). Igiugig is on the forefront of energy exploration with the only Arctic in-river hydro generation system as well as smaller solar and wind systems. Residents of this small, tight-knit community pride themselves on relying on their Yup'ik values of hard work, cooperation, respect, and humility (ANKN, 2012). However, this community has found a way to overcome the disconnect between Indigenous and local cultures and those responsible for making energy decisions which have been identified as a barrier towards energy security (MacKay et al., 2021). They use this knowledge to make progress towards independence and self-sufficiency which can involve taking risks with new technologies. Kongiganak also pushes the boundaries of technology, as seen in their use of thermal stoves to convert wind energy into relatively cheap heat for households (Chaninik Wind Group, 2013; Schwoerer, 2011), a major boon given that heating expenses can make up a large portion of the household budget (Schmidt et al., 2021).

The difference in security among contemporary versus subsistence foods is stark and highlights the need to evaluate both when assessing food security. According to the USDA, 10% of households in Alaska were food insecure (2017–2019) (Coleman-Jensen et al., 2020); we estimated 15% when both 'contemporary' and subsistence foods were included. When subsistence foods were the resource, low security was only an issue among 3% of the responses and no one reported being very insecure, in contrast to 'contemporary' sources where 5% reported high levels of insecurity (Fig. 5). Our results are similar to other Indigenous Arctic regions with greater food insecurity associated with reliance on store-bought resources (Ford and Berrang-Ford, 2009). In some studies, lower consumption levels of traditional foods have been associated with higher rates of food insecurity among Canadian Inuit (Huet et al., 2012; Rosol et al., 2011; Rosol et al., 2016). As with food, many residents indicated natural sources of water had higher quality and were preferred. Harvesting water from the local environmental has cultural benefits (Eichelberger, 2017) and our results show that maintaining this ability is important for water security. As for energy, affordability was a main driver of insecurity and in many rural communities harvest of firewood is important to provide heat and deal with unreliability from local power plants (Jones et al., 2015; Schmidt et al., 2021). Identifying insecurities among the resources used by residents is important because each is driven by a different set of factors and thus insecurity in each category needs to be addressed differently. Store-bought foods are affected by price and availability of imported foods and transportation (First Nations Development Institute, 2018; Martin et al., 2008), whereas subsistence foods can be affected by fuel prices, climate change, demographics, regulations, and other factors (Brinkman et al., 2014; White et al., 2007).

The results from our examination of the components of FEW security relate closely to the self-reported drivers of FEW security. Unlike researchers who have conceptualized drivers of FEW security, we asked residents to self-identify drivers of FEW security (FAO, 2014; Itayi et al., 2021; Loring et al., 2013; Wong, 2020). Drivers identified by residents overlapped with those thought to influence FEW security such as health, transportation, income, and costs, but some of the more common drivers identified in the literature that were mentioned less frequently in our interviews include climate change, education, and demographics. Residents largely identified more immediate drivers (e.g., weather versus climate) and local drivers rather than global ones (e.g., fuel costs versus global oil prices). However, local issues relate to global scale issues but identifying how they are linked and what trickle-down factor is important can help identify how large-scale change might affect FEW security. Health was key since it was recognized as both a driver of FEW security and an outcome. Health disparities are widely acknowledged among Indigenous and rural residents (Hartley, 2004; Sarche and Spicer, 2008; Service IH, 2019) and our research indicates that improvements in FEW security could help reduce this disparity while improving FEW security from within communities.

FEW security is complicated and varies among communities in rural Alaska (Fall and Kotstick, 2018; Huntington et al., 2021). There are also big differences from community to community, reflecting local circumstances (e.g., whether there is a piped water system or whether ferry service was cut). It is important to not disengage FEWs interpretations from local context, especially given the influence of topical events and culture. Our results move past theoretical and political debates to identify priority areas to target such as affordability (i.e. access) and the need to maintain subsistence lifestyles (i.e. preference and quality). In summary, food and water are generally available, but they are not always preferred, and quality can be an issue. While energy is typically good quality and available, affordability is an issue. Our approach can be used to identify different ways to explore FEW security in depth, the results of which can be used to focus efforts at improving security or to highlight ways communities in rural Alaska are doing well and could share lessons with other communities in rural areas.

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Author contributions

JIS, BJ, and HPH conceived and wrote the paper. JIS and BJ were involved in data curation and formal analysis. EW contributed to funding acquisition, editing, and writing. All authors approved the manuscript for submission.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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