ARCTIC
Vol. 76, NO. 2 (JUNE 2023) P. 225–233
https://doi.org/10.14430/arctic77896

What Gets Measured Gets Done: Challenges in Monitoring Water, Energy, and Food Security in Northern Canada

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(*Received 1 February 2023; accepted in revised form 10 May 2023*)

ABSTRACT. This paper describes the challenges that were encountered during the collection of Sustainable Development Goal (SDG) indicators for water (SDG 6), energy (SDG 7), and food (SDG 2) security in northern Canada. Our findings indicate only 49% of indicator data were publicly available, while 21% had to be calculated using alternative sources or methods, 18% had to be replaced with proxy indicators for which data were available, and 12% of indicators were deemed unavailable entirely. The most common types of data challenges were associated with completeness, timeliness, and granularity. Given the current challenges faced by residents of northern Canada, with their livelihoods closely intertwined with the accessibility and availability of water, energy and food (WEF) resources, a comprehensive plan for data collection, storage, and management of WEF-related SDGs is required to advance WEF security from an aspirational to a transformative policy agenda.

Keywords: Canada; sustainable development goals; water-energy-food nexus; security; data management; indicators

RÉSUMÉ. Dans cet article, nous décrivons les défis auxquels nous nous sommes heurtés dans le cadre de la collecte d'indicateurs relatifs aux objectifs de développement durable (ODD) de l'eau (ODD 6), de l'énergie (ODD 7) et de la sécurité alimentaire (ODD 2) dans le Nord canadien. Selon nos constatations, seulement 49 % des indicateurs de données étaient accessibles au public, tandis que 21 % des indicateurs ont dû être calculés à partir d'autres sources ou méthodes, 18 % ont dû être remplacés par des indicateurs indirects pour lesquels des données existaient et 12 % des indicateurs ont été jugés entièrement indisponibles. Les défis les plus courants concernant les types de données avaient trait à leur intégralité, à leur actualité et à leur granularité. Compte tenu des défis auxquels font face les résidents du Nord canadien actuellement, leurs moyens d'existence étant étroitement liés à l'accessibilité et à la disponibilité des ressources en eau, en énergie et en nourriture (EEF), il y a lieu de préparer un plan exhaustif pour la collecte, le stockage et la gestion des données en matière d'ODD se rapportant aux ressources en EEF afin de faire progresser la sécurité sur le plan des EEF et de délaisser les politiques axées sur l'aspiration pour passer à des politiques visant la transformation.

Mots-clés : Canada; objectifs de développement durable; liens entre l'eau, l'énergie et la nourriture; sécurité; gestion des données; indicateurs

Traduit pour la revue Arctic par Nicole Giguère.

INTRODUCTION

If one agrees that water, energy, and food (WEF) are the pillars on which global security, prosperity, and equity stand (Hague, 2010), then as a society we may be at a critical juncture. As reported by the United Nation's Statistical Division (UNSD, 2021), progress towards achieving the sustainable development goals (SDGs) related to water (SDG 6), energy (SDG 7), and food (SDG 2) security by 2030 remains in considerable doubt (Lyytimäki, 2019). Since the turn of the century, global water use has continued to rise at more than twice the rate of global population growth (Koncagul et al., 2020), with existing water reserves increasingly degraded by contamination (Ritchie and Roser, 2021), losses of wetland ecosystems (Hu et al., 2017), and transboundary water conflicts (Amini et al., 2021). Progress to provide affordable, reliable, sustainable, and modern energy for all (SDG 7) is also far from being achieved. As of 2019, one third of the global population lacked access to clean cooking fuels and technologies (IEA, 2022), while

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advances in renewable energies have been made largely in developed nations only (IEA, 2021), thereby leaving the world's most vulnerable populations even further behind. Perhaps most discouraging is the fact that since the launch of the United Nations' 2030 Agenda (UN, 2015), those experiencing hunger has increased to an estimated 811 million people, or nearly 1 in 10 of the world's population (FAO, IFAD, UNICEF, WFP, and WHO, 2021). Together, these conditions are expected to be compounded by the anticipated impacts of climate change (Rasul and Molden, 2019) and the societal inequities that have become even more apparent during the Covid-19 pandemic (Swinnen and McDermott, 2020).

As troubling as these statistics are, they are likely underestimated. In many parts of the world, there is a lack of adequate data to accurately assess national trends (UNSD, 2021). The UN's Statistical Division acknowledges that efforts to monitor SDG indicators has been hampered by the availability and accessibility of accurate, appropriate, and readily available data. The Voluntary National Reviews (VNRs) show that between 2017 and 2019 more than half of the UN member states have encountered significant data gaps that limited their ability to monitor and report progress in SDG attainment (UN, 2021). This failure has been attributed in part to the lack of human, technical, and financial capacity within National Statistical Offices (NSO), which has resulted in as few as 40%–50% of SDG indicators being tracked and reported on (MacFeely, 2019). Specific to WEF-SDGs are the added challenges posed by the complexity of WEF systems. As noted by McCarl et al. (2017), identifying and measuring progress in WEF-SDGs has been hindered by disparate and sometimes conflicting data, regional and temporal variabilities, unforeseen climate shocks, and accounting for multi-dimensional phenomena (e.g., incorporating the timing and location of return flows in calculations of water usage). Further, the aggregation of national WEF data frequently does not manifest consistently or predictably at regional scales. For example, Ingram et al. (2021) have drawn attention to the obfuscation of data for remote and sparsely populated regions when aggregated nationally (see also Abulibdeh and Zaidan, 2020). While researchers have emphasized the importance of collecting and monitoring WEF-SDG data at local (Huntington et al., 2021) and regional (Natcher and Ingram, 2021) scales, the availability and accuracy of those data are frequently inadequate. However, Rayasam et al. (2020) have noted that even when localized data are available, regional administrators can sometimes be pressured to report positive, yet inaccurate outcomes out of fear of professional and political reprisals, thereby misrepresenting local realities. Given the ineffectiveness of current monitoring frameworks, measuring the current status of WEF-SDGs remains problematic.

These challenges served as motivation for the Arctic Council's Sustainable Development Working Group (SDWG) to endorse research that would improve the collection, storage, and management of WEF-SDG data. An initial stage of this study, which is reported here, was to: (1) classify and discuss the major challenges associated with collecting WEF-SDG data; (2) advance a framework for assessing and recording quantitative and qualitative WEF-SDG indicators; and (3) offer direction for monitoring WEF-SDGs that can be used to inform public policy and safeguard the current and future welfare of northern residents. The focus of this paper is northern Canada—a region that includes Yukon, Northwest Territories, Nunavut, Nunavik, and Labrador—which experiences high rates of WEF insecurity, but because of the relatively small population (less than 1% of Canada's total population), is often obscured in the aggregation of Canada's national data. Most fundamentally, this project was inspired by the adage "what gets measured gets done" (Nhamo et al., 2018:60), and a commitment to advance WEF security in the Arctic from an aspirational to a transformative policy agenda.

BACKGROUND

The UN SDGs were introduced in 2015 with the release of Transforming our World: The 2030 Agenda for Sustainable Development (UN, 2015). Accompanying the 17 SDGs are 231 indicators that are used to monitor progress towards SDG attainment and ensure accountability among member states. These indicators represent the Global Indicator Framework (GIF), which was developed by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs, 2023). The IAEG-SDGs includes nominated experts from the member states and observers from regional and international agencies. The IAEG-SDGs has classified SDG indicators into two tiers based on the availability of global data and whether consistent methodologies exist for data collection. These tiers include:

> Tier 1: Indicator is conceptually clear, has an internationally established methodology and standards are available, and data are regularly produced by countries for at least 50% of countries and of the population in every region where the indicator is relevant.
> Tier 2: Indicator is conceptually clear, has an internationally established methodology and standards are available, but data are not regularly produced by countries.
>
> (IAEG-SDGs, 2023:1)

The IAEG-SDGs performs annual assessments and comprehensive bi-decadal reviews of the GIF. For example, in 2020 the IAEG-SDGs proposed 36 major changes to the GIF in the form of replacements, revisions, additions, and deletions (UN, 2020). As of February 2022, there were 136 Tier 1 indicators, 91 Tier 2 indicators, and 4 indicators that have components that are classified into different tiers (IAEG-SDGs, 2023). The revised set of indicators are now used to monitor progress towards the attainment of the

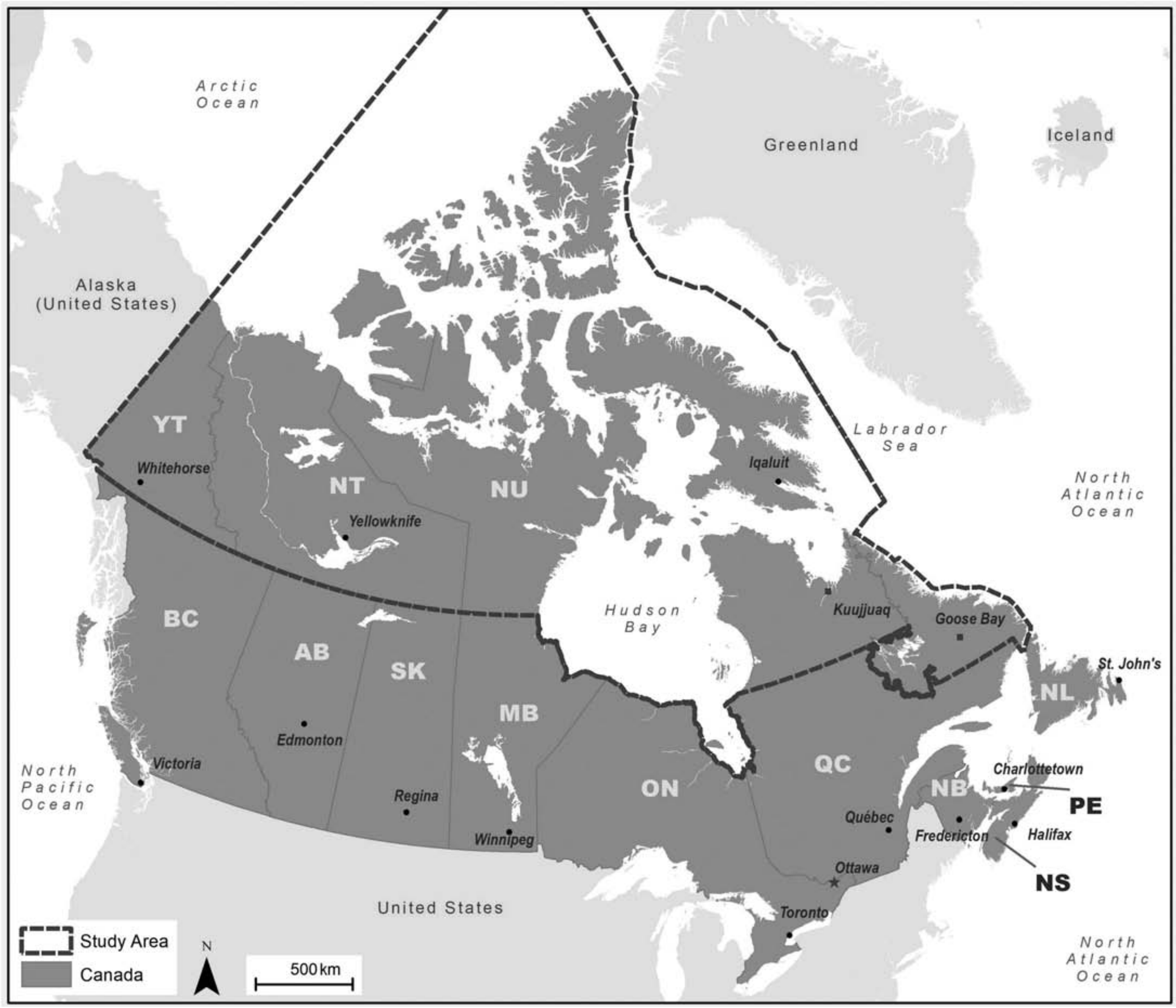

FIG. 1. Northern Canada study area.

SDGs and inform national strategies for enhancing social, environmental, and economic welfare (e.g., Government of Canada, 2021).

In Canada, Statistics Canada is the primary government organization responsible for the collection, collation, analysis, presentation, and dissemination of SDG data. In 2018, Statistics Canada introduced an online data hub for disseminating Canada's SDG data. The hub is used to track Canada's progress in achieving the SDGs and serves as an open access data repository. Statistics Canada also provides regular updates to ensure relevance and to meet national and international reporting obligations. Whereas the GIF is used to guide the monitoring activities of Canada and the other members states, countries are free to introduce other goals, targets, and indicators that reflect the conditions of their respective states. In Canada, 31 ambitions and 76 corresponding indicators have been introduced through the Canadian Indicator Framework (CIF), which is now used alongside the GIF to chart Canada's progress in achieving the SDGs (Government of Canada, 2019). Nine of the CIF indicators measure WEF related SDGs (Appendix A).

While the CIF is unique to the Canadian context, there is overlap with the GIF. For example, GIF 7.2.1 and CIF 7.3.1 are both designed to measure the share of renewable energy use and non-greenhouse gas emitting energy sources. Similarities are also found between GIF 2.1.2 and CIF 2.2.1 that measure the prevalence of moderate or severe food insecurity. Although derived through different means, the GIF and CIF both employ a common indicator to measure food security. According to Statistics Canada, the benefit of the CIF is that data can be disaggregated by subpopulations or categories, which aids in identifying vulnerable populations and regional disparities (Government of Canada, 2019).

METHODS

Description of Study Area

Our study area of northern Canada includes Yukon, Northwest Territories, Nunavut, Nunavik, and Labrador (Fig. 1). In the case of Nunavik and Labrador, these two regions represent the northern extensions of the provinces of Quebec and Newfoundland and Labrador. Geographically, northern Canada encompasses over four million km^2, or roughly 40% of Canada's total land area. Although Canada's northern region is vast, less than 1% of Canada's total population lives there (estimated 200,418 out of roughly 38 million) (Statistics Canada, 2023). Northern Canada's population is dispersed across 111 communities, the largest being Yukon's capital city of Whitehorse (population 28,085). Among the estimated 200,418 people who live in northern Canada, roughly 50% (100,650) self-identify as Indigenous (Statistics Canada, 2018). However, in Nunavut and Nunavik, Inuit represent as much as 90% of the population.

Data Collection

A systematic approach was used to identify the availability of data for each WEF-SDG indicator. The first stage of our review involved a targeted search of the Canadian SDG hub. This search provided data on each indicator, including status, reference period, and data source. Following this review, other government data repositories were reviewed, for instance, aggregators of data housed in the Federated Research Data Repository. University librarians with specialized knowledge relating to data repositories and government data sets were instrumental in ensuring all potential data sources were identified, although the authors assume full responsibility for data errors or omissions. In cases where indicator data were not found in public repositories, the research team turned to peer-reviewed publications to explore the availability of alternative data sources. This involved a scoping review of publications focusing on WEF systems and associated indicators in northern Canada. Finally, the team examined research reports and grey literature published by research organizations for any outstanding indicator data.

If no identified sources provided the necessary data, the research team explored alternative calculation methods. These methods involved manipulating existing data to calculate the value of interest. These methods involved mathematical calculations using raw data points and were conducted using GIS software and Python programming. For example, to calculate the degree of integrated water resources management (IWRM) planning (Indicator 6.5.1), the research team completed an IWRM implementation survey for each of the five regions in northern Canada. This involved gathering supplementary data, including a determination of whether water management plans had been developed and implemented in each region, and if so, what each of these plans entailed. To calculate average annual precipitation in each of the five study regions, a custom Python tool was coded to process and derive values from a gridded 50 km x 50 km dataset published through the Climate Atlas of Canada (2021). Alternative methods were also required to calculate two of the energy indicators for Nunavik and Labrador. These calculations were completed by collecting data on energy use and production in communities within Nunavik and Labrador. These datasets were then linked with the spatial locations of the communities in GIS, and those communities that fell within our study regions were then identified, selected, and exported to create a dataset that aligned with our study regions. Individual community values were then added together and divided by the total population of the northern communities, where appropriate, to calculate per capita values. The same strategy was used to calculate CO_2 emissions for these areas, beginning with a dataset containing the emissions of large mines and other industrial complexes, as community-level emissions data were unavailable. In the cases that the data points could not be calculated using available data, the research team explored alternative indicators for which data were available that could serve as proxies for the original indicators. If no appropriate proxies could be identified, the indicator was deemed unavailable.

Data Quality Assessment

Once the dataset was compiled, a data quality assessment for each indicator was conducted. This assessment used five data quality measures: completeness, timeliness, accuracy, granularity, and credibility (Table 1). Completeness refers to whether the data are representative of an entire area or indicator of interest. Completeness can be measured in terms of population (whether all peoples of interest are represented within the dataset) or in geographic terms (complete spatial coverage) (Statistics Canada, 2017). Timeliness considers whether the data are representative of the time frame of interest (Vancauwenbergh, 2019). Typically, older data are considered less relevant than more recent data. Accuracy refers to whether the data correctly measure the respective indicator (Statistics Canada, 2017). Granularity refers to the geographic scale(s) at which data are made available, while credibility describes the level of reliability of the data source (i.e., peer reviewed) (Statistics Canada, 2017). Members of the research team rated each data point using the guiding questions and answer choices. A composite index of data quality was calculated, using the linear summation of the scores, after the scores were normalized.

RESULTS

Data Availability

The results of our review found data for approximately 49% of the WEF indicators (Table 2). The most readily

TABLE 1. Guiding questions for assessing data quality by data source.

ID	Dimensions	Attributes		Measurement scale
1	Completeness	Q1.	Are the data representative of the region or territory (complete coverage for the region/territory; sample size; sampling technique)?	2 = Full coverage 1 = Partial coverage 0 = No coverage
2	Timeliness	Q2.	How recent were the data collected?	3 = Recent (1 to 5 years) 2 = Dated (5 to 10 years) 1 = Old (10 years+)
3	Accuracy/Reliability	Q3.	To what extent does the indicator used capture the concept you are measuring? Definition vs calculation	2 = Accurate 1 = Partially accurate 0 = Inaccurate
4	Uniqueness/Redundancy	Q4.	Does the indicator capture a unique dimension of the SDG? Is there overlap in measurement?	0 = Large overlap with most other indicators 1 = Some overlap with other indicators 2 = No overlap
5	Granularity	Q5a.	Were data available at the appropriate scale?	2 = Yes 0 = No
		Q5b.	If answer is "no" to question 5a, was the method of disaggregation to the right scale appropriate?	2 = Yes 1 = To some extent 0 = No
6	Credibility/Trust	Q6	Are data originating from a credible/trusted source?	1 = Yes 0 = No

TABLE 2. Data availability of WEF indicators.

WEF-SDG	Available data	Alternative method of calculation	Alternative indicator	Excluded
SDG 2 (Food)	30%	13%	35%	23%
SDG 6 (Energy)	67%	33%	0%	0%
SDG 7 (Water)	56%	29%	14%	0%
Total Count	49%	24%	18%	9%

available indicator data were found for SDG 7: energy (67%), followed by SDG 6: water (56%), and SDG 2: food (30%). Indicator data for SDG 2 were found to be most underrepresented, with no data available for the prevalence of undernourishment (2.1.1), prevalence of stunting (2.2.1), prevalence of malnutrition (2.2.2), and the proportion of agricultural area under productive and sustainable agriculture (2.4.1). In addition, no regionally comprehensive data were available for the prevalence of food insecurity (moderate or severe) (CIF 2.1.1), which did not include Indigenous Peoples living on reserves or other Indigenous settlements. Although this population represents less than 5% of the total Canadian population, this demographic does represent a large proportion (50%) of northern residents who suffer disproportionately from food insecurity (CCA, 2014). Other data omissions were found for Indicator 6.1.1, which measures the number of long-term public drinking water advisories. These advisories are used to warn people not to drink water that may be unsafe. These data, however, only apply to publicly funded drinking water systems and do not include private systems, such as residential wells or water that is transported privately from springs, streams, and other water bodies, which is a common practice in many Indigenous communities. Furthermore, the data used to inform CIF 6.1.1 are derived from communities south of the 60th parallel, thereby excluding Canada's northern territories. This is problematic given the frequency of which water advisories are being issued annually in northern communities (Ritchot, 2021), yet are not accounted for in Canada's SDG reporting. Similarly, the quality of Canadian river water (Indicator 6.4.1), which is based on a number of chemical and physical parameters, reflects conditions in southern Canada, and under-represent the water quality conditions of northern rivers. For these reasons, the available data do not readily capture the realities of Indigenous peoples nor the conditions in the north.

In these cases, alternative or proxy indicators were used for 18% of indicators. Proxies were not required for energy-related indicators but rather were used in the case of one water-related indicator and three food-related indicators. For example, percentage of children under five years of age affected by wasting (GIF 2.2.2) was replaced with prevalence of severe food insecurity for children aged 0–18 years. The remaining 9% of indicators were excluded from the study entirely. These indicators included data values for cereal yield; percentage of children under five years of age who are stunted; and missing data on the percentage of severe food insecurity for children aged 0–18 years in Nunavik. After removing these data points from the evaluation, the quality of the remaining data were then evaluated with a data quality assessment.

TABLE 3. Results of data quality assessment by count and percentage.

Dimensions	Attribute	%
Completeness	Coverage	
	Data are completely representative of the region or territory	66%
	Data are partially representative of the region or territory	34%
	Data are not representative of the region or territory	0%
Timeliness	Currency	
	Data are recent (within the last 5 years)	61%
	Data are dated (between 5 and 10 years)	19%
	Data are over 10 years	20%
Accuracy	Reliability	
	Indicator accurately captures the goal	74%
	Indicator partially captures the goal	26%
	Indicator inaccurately captures the goal	0%
Granularity	Scale	
	Data are available at the appropriate scale	52%
	Method of (dis)aggregation to the right scale is appropriate	11%
	Method of (dis)aggregation to the right scale is appropriate to some extent	26%
	Method of (dis)aggregation to the right scale is inappropriate or unavailable	10%
Credibility	Source	
	Data comes from a credible/trusted source	100%
	Data does not come from a credible/trusted source	0%

Data Quality

Issues with data completeness, timeliness, and granularity were most prominent throughout this assessment. While 66% of the data were fully representative of the five regions of northern Canada, 34% were only partially representative (Table 3). Issues with data coverage were typically encountered alongside granularity issues. While 52% of the data were available at the appropriate scale, 48% were not and required additional processing. In most cases, the disaggregation method was deemed to be only somewhat appropriate. These included indicators that were calculated using two or more different data sources, one or more of which was available at the correct scale or could be aggregated appropriately and one or more of which were only available for a region larger than the study region and could not be disaggregated. For the remainder of the processed data, the disaggregation method was inappropriate or unavailable. This included those indicators for which data were only available at scales that did not align with the study regions. For example, data on annual freshwater withdrawals (Indicator 6.4.2) were only available within watershed boundaries, which do not align with territorial or regional boundaries. In this case, the research team was able to approximate the area of interest by including those watersheds which aligned most closely with the boundaries of the study regions.

Another problematic dimension of data quality relates to the timeliness of available data. Only 61% were comprised of data that were within the past five years. Of the remaining data, 19% were 5–10 years old and 20% were published more than 10 years ago. While the research team did not assess consistency of data availability over time, gaps and inconsistencies were identified in most cases. Last, 74% of the data were considered reliable in that they accurately captured the indicator being measured, while 26% partially captured the concept. Last, we determined that all sources of data were credible, either from peer review or recognized authority of the source's organization.

DISCUSSION

Our research results demonstrate that significant data challenges exist for collecting data on WEF-SDG indicators for northern Canada. When considered in combination, these challenges have the potential to inform incomplete and inaccurate understandings of the specific situations and needs of those who reside in these regions. This risk is exacerbated by the fact that Arctic nations typically report high rates of WEF security (Simpson et al., 2020), although it has been demonstrated that national-level reporting has the potential to obscure important inter-regional differences with respect to WEF security (Ingram et al., 2021).

As evidenced by the fact that only half of the data points were able to be collected directly from existing sources, a large portion of the challenges encountered throughout the research process were directly tied to issues of data availability at regional levels. The research team replaced indicators with proxy variables, and in some cases removed indicators or data points entirely as a result of these availability challenges. In cases where the required data were available but had to be processed to represent the region of interest accurately, data challenges associated with granularity, completeness, and data timeliness emerged most prominently.

Data challenges associated with granularity and completeness most commonly affected data values within

Nunavik and Labrador, the two regions within our study area that did not coincide with provincial or territorial boundaries. This challenge arose because, for many indicators, data were unavailable at units of analysis smaller than the provincial or territorial level. In cases where data were available at smaller units of analysis, these units did not necessarily provide complete coverage of the region of interest. For example, data on CO_2 emissions were available for individual industrial complexes and mines across North America, but only those facilities which emitted above a certain threshold of CO_2 in kilotonnes were included in the dataset. The fact that emissions data were not disaggregated to the community level posed significant challenges to obtaining an accurate understanding of differences in per capita CO_2 emissions among those who reside in Quebec's urban metropolises and the remote northern communities of Nunavik, for example.

Timeliness of data also presented significant challenges to this research. Timeliness issues were particularly prevalent for data in SDG 2: food, while timeliness did not pose any issues for data points within SDG 6: energy. Notably, what constitutes current data can change significantly depending on the nature of the phenomenon being measured. The authors' decision to classify data published within the last five years as recent was informed by the data needs for this project. However, there remained some notable differences among the indicators included in this study in terms of their need for recent data. For example, 10-year-old data on renewable internal freshwater resources might pose less of an issue to overall data quality than 10-year-old data on renewable energy consumption, as the latter indicator is liable to change more dramatically in a 10-year time frame than the former. However, in a rapidly changing climate, the need for timely data (as well as conceptions of what constitutes timely data) are expected to continue to evolve.

CONCLUSION

The results of this research show that there are significant challenges associated with accessing high-quality WEF-related data at sub-national and sub-regional levels in Canada. These data challenges are concerning in light of often overlooked differences in WEF security levels between remote northern regions and other more southerly regions of Canada. Given the current challenges faced by people living in northern Canada, with their livelihoods being closely intertwined with accessible and available WEF resources, a comprehensive plan for data collection, storage, and monitoring WEF-related SDGs is required. Among the requirements is the need for data to be available at multiple scales, consistently measured over time, and complete coverage for various regions of interest. Our suggestions, informed by the challenges we encountered, focus on completeness, granularity, timeliness, and reliability. When collecting data, consideration should be given to the administrative or geographic level at which the data are collected. Preferably, data should be collected and reported on at the smallest unit of analysis possible. Increasing granularity would satisfy a broad array of data needs and end users by allowing for aggregation to various scales of interest, as disaggregating data collected at larger units of analysis to accurately represent smaller units of analysis is often impossible. Published data should be made publicly accessible, and metadata should be easily accessible and directly linked to all published WEF-related data. Of equal importance are considerations around confidentiality and the need to ensure that data are made available in an ethical manner. The authors recognize that publishing finely granulated data can often undermine efforts to protect confidentiality, especially in remote regions with small and highly dispersed populations. This approach could be informed by the CARE (collective benefit, authority to control, responsibility, and ethics) Principles for Indigenous Data Governance (Carroll et al., 2020), including: 1) the rights of Indigenous Peoples to collectively benefit from the collection, analysis, and use of research data; 2) the authority of Indigenous governments to control access to data in accordance with Indigenous rights and collective interests; 3) the responsibility of state institutions to disclose how the data will be used to advance reconciliation with Indigenous Peoples; and 4) an ethical commitment to minimize harm and maximize benefits for Indigenous Peoples in the use, integration, and translation of data. To this end, we stress the need to ensure that the indicators used to measure WEF insecurity in northern and Indigenous contexts can accurately and appropriately capture local realities. These indicators should be relevant and appropriate at local levels, while retaining comparability to other scales and geographic regions wherever possible. Future research should therefore explore the possibility of identifying additional or alternative WEF indicators that reflect the distinct social, cultural, and economic realities of northern and Indigenous peoples in Canada and other Arctic regions.

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