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# Canadian Renewable Energy and Battery Energy Storage Map: Methods and Source Material

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Resource Economics and Environmental Sociology

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# Overview

As renewable energy development steadily grows in Canada, a comprehensive map of renewable energy projects captures a snapshot of Canada's changing energy landscape while offering insight into what the future holds for renewable energy. Our map project is based on a previous database and interactive map published by Patel & Dowdell (2019) from the University of Alberta. We updated this database by verifying and updating project characteristics (e.g., status, project name, owner, ownership structure, capacity), expanding the number of variables, including new projects currently in operation or in development, and creating new map layers. New map layers include a battery energy storage system layer, an Indigenous renewable energy layer, and a solar energy potential layer. We describe these layers in further detail in the sections below.

Following Hoicka et al. (2021), we expand the original dataset to include the variable "Share of Indigenous Ownership." The variable takes on four values: No Indigenous Ownership (0% ownership), Minority Indigenous Owned (1-49% ownership), Partial to Majority Indigenous Owned (50-99% ownership), Wholly Indigenous Owned (100% ownership), and Unknown for projects with an unknown degree of ownership. We included Indigenous renewable energy projects in the renewable energy layer.

Royal Roads University and the University of Guelph, our research collaborators, are currently working on creating two additional databases: a Canadian community energy layer and a renewable energy co-operative layer. These databases are in development, so our current map does not include these layers. However, future work may involve merging these data layers on the map. Adding a wind energy potential layer is also a possibility.

To create their map, Patel & Dowdell (2019) used the data visualization software Tableau. However, because of its interactive and collaborative capacities, we selected ArcGIS Online to create and present our map. The renewable energy, battery energy storage, and Indigenous renewable energy databases can be downloaded directly from the Future Energy System's website.

## Finding projects

In the renewable energy layer, we identify and classify projects based on type of energy generation (hydroelectric, wind, solar, biomass, geothermal) and capacity (in MW). Each point represents a project; the size of the point varies according to capacity. Each color represents a different type of energy generation. Clicking on a project will reveal more information about the project: owner, ownership, project name, province, status, type, year, share of Indigenous ownership, latitude, longitude, and capacity. Different types of ownership structures include community - First Nations, joint, municipal, private, and provincial. Our database includes projects equal to or greater than 1 MW. All four databases include a column containing links to project websites (where they were available), as well as a column with links or descriptions about data sources. These columns are excluded as variables on the map; however, they can still be accessed by downloading the individual databases.

Updating the existing database involved changing project names, capacity, owners, and operational status. In addition, we added newly proposed and completed projects to the database. To update projects and find new projects, we relied on existing databases related to renewable energy projects (province and country-based), utility company websites, environmental assessment registries, government websites, and datasets, as well as internet searching with Google or Microsoft Co-Pilot.

Collecting data was a dynamic process. For instance, for projects we could not locate in various datasets, we used news articles to confirm changes in ownership, project name, or operational status. We also used Bing AI and Perplexity AI to scan the internet for company websites, newspaper articles, or government postings related to specific projects. We asked questions like “Is the wind project XYZ in Alberta complete?” or “What company owns project X?”.

We determined the exact coordinates for new and proposed projects using environmental assessment applications and project websites. However, coordinates were not included for every project. In these cases, we used the coordinates of the municipality in which the project exists or estimated the coordinates manually on Google Earth based on whatever geographical descriptors were available on news articles or project websites. Where a proponent would group several projects from different municipalities under one project name, we used the location of the central municipality.

Databases used to verify projects from the original dataset and identify new projects for multiple provinces and territories include the Simon Fraser University's Canadian Energy & Emissions Data Centre (CEEDC) database of renewable energy projects, projects accepted under the federal government's Smart Renewables and Electrification Pathways Program, and the Major Projects Inventory published by Natural Resources Canada (Government of Canada, 2023, 2024b; Simon Fraser University, 2024). To find Indigenous renewable energy projects, in addition to the aforementioned sources, we used the Indigenous renewable energy dataset developed by Hoicka et al. (2021) and the Indigenous-Led Clean Energy Project Map produced by Indigenous Clean Energy (Indigenous Clean Energy. n.d.). However, the Indigenous-Led Clean Energy Project Map is no longer publicly accessible at the time of writing this report. Province-specific databases and websites used to update and find new and proposed projects are described below.

## Province-specific databases

### Alberta

Alberta's deregulated energy generation market supports the participation of numerous companies and projects. To verify existing projects and add additional projects, we used company energy project portfolios and two large government-created databases (AESO, 2024a). Developed by the government of Alberta, the first database is an inventory of both private and public sector projects valued equal to or greater than $5 million (Government of Alberta, 2024). The second database is the connection project list created by the Alberta Electricity System Operator (AESO) (AESO, 2024b). This list primarily displays projects that are in development and have applied, through the AESO, to connect to Alberta's electricity grid.

**Saskatchewan**

Electricity generation is regulated in Saskatchewan. The main electricity provider is SaskPower, a crown corporation (EnergyRates.ca, 2024c). We mainly relied on the company's renewable energy project portfolio to find renewable energy projects.

**Manitoba**

Manitoba Hydro is the primary supplier of electricity in the province, owning a large portion of hydroelectric power plants in the province (EnergyRates.ca, 2024a). With hydroelectric power as the primary renewable energy source within the province, we used Manitoba Hydro's project portfolio to update the status of projects.

**Northwest Territories**

In the Northwest Territories, Northwest Territories Power Corporation (NTPC) is the main electricity supplier (Canada Energy Regulator, 2021). NTPC generates and distributes electricity to the majority of residents in the province (Northwest Territories Power Corporation, 2024a). The status of the territory's renewable energy projects was updated based on information found on the NTPC website (Northwest Territories Power Corporation, 2024b).

**Prince Edward Island**

PEI Energy Corporation is a crown corporation that owns a large portion of the wind generation capacity in the province (Government of Prince Edward Island, 2022). We used project information found on their website to update and find additional projects (Government of Prince Edward Island, 2023).

**Ontario**

Ontario's partly regulated and deregulated energy generation sector supports many renewable energy projects, allowing citizens to purchase electricity from the provincially-owned crown corporation Ontario Power Generation (OPG) or private enterprises (EnergyRates.ca, 2024b). OPG owns the majority of the province's hydroelectric generating stations (Ontario

Power Generation, 2024). We regularly referenced OPGs website to update the status of hydroelectric projects in the province.

Private companies like Capstone Infrastructure and Axium Infrastructure own numerous wind and solar projects in Ontario (Axium Infrastructure, 2024; Capstone Infrastructure, 2024). Accordingly, we used the project portfolios on the company websites for data verification and collection. Additionally, the Independent Electricity System Operator (IESO) in Ontario provides a publicly available database of electricity generation projects connected to the electricity grid or will be connected upon completion (IESO, 2024).

### Nova Scotia

To update project status and identify newly proposed projects in Nova Scotia, we used the dataset at GNSF Data detailing wind energy projects in the province and Nova Scotia's environmental assessment registry (GNSF Data, 2024; Government of Nova Scotia, 2024a). We also obtain projects directly from Nova Scotia Power, a utility company that accounts for 95% of electricity provision in the province (Nova Scotia Power, 2024). Between 2011 and 2016, Nova Scotia implemented a Community Feed-in Tariff (COMFIT) Program to promote locally distributed renewable energy projects. We use the COMFIT dataset provided by the Government of Canada to confirm projects and verify their status (Government of Nova Scotia, 2024b).

### New Brunswick

For projects in New Brunswick, we predominantly relied on energy projects mapped and listed on New Brunswick Power's website (NB Power, 2024a, 2024b). Additionally, we used Atlantica Centre for Energy's interactive map of the province's energy resources (Atlantica Centre for Energy, 2024).

### Newfoundland and Labrador

To update projects and find new and proposed projects in Newfoundland and Labrador, we first turned to Newfoundland Power, the primary electricity distributor in the province. Their website provided a map of hydroelectric stations (Newfoundland Power, 2024). Newfoundland and Labrador Hydro, the primary generator of electricity for the province, also details hydroelectric and wind projects in the province on its website (Newfoundland & Labrador Hydro, 2024). Through the Department of Industry, Energy, and Technology, the government of Newfoundland and Labrador also provides a list of renewable energy projects across the province (Government of Newfoundland and Labrador [GovNL], 2024a, 2024b.). Additionally, we used the province's environmental assessment registry for data collection (GovNL, 2024c).

**Yukon**

Yukon's renewable energy projects were identified using the Yukon government's interactive renewable energy map and its Yukon Energy Corporation (YEC) Power generating stations map (Government of Yukon, 2021a, 2021b). YEC, a publicly owned electric utility company, also provides a map of current and planned projects on its website (Yukon Energy, 2024). In addition, we used the Yukon Environmental and Socio-economic Assessment Board project registry to identify projects undergoing environmental assessments and projects in the pre-submission phase (Yukon Environmental and Socio-economic Assessment Board, 2024). We also used the list of renewable energy projects funded under the federal government's Clean Energy for Rural and Remote Communities program (Government of Canada, 2024a).

**British Columbia**

For British Columbia's renewable energy datasets, we used the provincial government's Major Project Inventory (MPI) dataset published by the provincial government, the non-profit EnergyBCs' map of BC's electricity generating stations, and Clean Energy BC's map of current renewable projects in the province (Clean Energy BC, 2024; EnergyBC, 2017; Government of British Columbia, 2024). We also updated existing projects and located new and planned projects using BC Hydro's list of independent power producers (IPPs) with electricity purchase agreements as of April 1, 2024 (BC Hydro, 2024a). The major generator and distributor of electricity in the province, BC Hydro, also includes a list of hydroelectric projects in operation on its website (BC Hydro, 2024b).

In April 2024, BC Hydro issued a competitive Open Call for Power. In an effort to increase the share of renewable energy electricity generation in the province, the utility company is requesting proposals for renewable energy projects to acquire roughly an additional 3,000

GWH per year (BC Hydro, 2024c). The deadline for proposal submissions is September 16, 2024. Because submissions are ongoing and submitted proposals are not publicly accessible or approved by BC Hydro, our renewable energy map layer will not include these proposed projects.

### Quebec

Hydro-Québec, provincially owned, is the main electricity distributor and generator in Québec. On its website is a list of hydroelectric projects, as well as wind and hydroelectric electricity supply contracts currently in effect (Hydro Québec, 2023, 2024, 2024a). These electricity supply contracts emerged from Hydro-Québec calls for tender or purchasing programs for renewable energy projects. Hydro-Québec's most recent call for tenders, launched in 2023, is for 1,500 MW of electricity produced by wind power. In 2021, the utility company also called for the acquisition of 480 MW of renewable energy, of which Hydro-Québec provided a publicly available list of successful bids (Hydro Québec, 2024b). Additionally, from the government of Québec, we used the environmental assessment registry, the dam directory, and its list of wind energy projects (Government of Québec, 2023, 2024a, 2024b). We translated websites originally in French into English using the Google Translate Chrome extension.

## Additional map layers

### Battery energy storage

Battery energy storage systems (BESS) are an emerging technology expected to play a critical role in advancing renewable energy generation, minimizing energy and power losses, and improving grid stability (Khasanov et al., 2024; Plumer & Popovich, 2024). Batteries work by storing energy when production exceeds demand and supplying energy during peak demand periods while reducing economic costs. Importantly, these technologies enhance the reliability of weather-dependent renewable energy sources, like solar and wind. For example, batteries can absorb excess solar energy during the day, releasing it during nighttime. Moreover, as the consequences of climate change become increasingly visible, batteries can reduce pressure on the grid during heat waves and wildfires, as was the case in California in 2023 (Plumer & Popovich, 2024).

Battery energy storage is expected to increase worldwide. In 2022, global investment in battery energy storage exceeded US$20 billion; the global BESS market is projected to reach between US$120 billion and US$150 billion by 2030 (Jarbratt et al., 2023; Reclaim Finance, 2023). Currently, the United States, China, and Europe are leading deployment of BESS (Ross, 2023), while Canada has catching up to do. As these new technologies transform the global energy landscape in the next decades, we capture a snapshot of their novelty and emergence in Canada.

To identify variables in our battery energy layer, we observed different battery energy storage maps and databases: the Consortium for Battery Innovation, which displays global lead-acid battery projects; the large-scale battery storage systems database by Forschungszentrum Jülich; the European Commission Directorate-General for Energy's map of energy storage facilities in Europe 2020; and the DOE Global Energy Storage Database, which includes projects greater than 1,600 kW (Consortium for Battery Innovation, 2024; Google Maps. 2020; Nguyen, T.,& Tamrakar, 2023; Stenzel et al., 2020). Adapted from these databases and maps, we selected the following variables: owner, ownership, project name, province, location/municipality, battery type, service/use case, status, year, share of Indigenous ownership, latitude, longitude, MWh, MW, generation and storage, integrated generation and storage capacity.

In addition to the aforementioned databases, to find existing and proposed battery energy storage projects we used utility company websites, environmental registries, government websites, and news articles. Some data sources did not have information for all our variables (e.g., battery type, MWh). Battery projects with "generation and storage" involve an additional renewable energy generation component, such as solar or wind. However, not all data sources distinguish between the generation capacity and the storage capacity. These projects are captured by our "integrated generation and storage capacity" variable.

In the map, the gray-scale triangles represent battery energy storage projects. The projects are classified by service/use case, of which there are four categories: grid-scale, microgrid, behind-the-meter, and off-grid.

**Indigenous renewable energy**

Several scholars emphasize that reconciliation and climate mitigation are concurrent goals (Hoicka et al., 2021; Mcgregor, 2019). Moreover, advancing the transition to renewable energy within a reconciliation framework may support Indigenous self-determination, economic well-being, and energy autonomy and resilience (Rezaei & Dowlatabadi, 2016; Stefanelli et al., 2019). However, renewable energy is not tantamount to equitable energy. Within Indigenous territories, some renewable projects have disrupted Indigenous communities' collective institutions, access to land and cultural resources, and local autonomy (see Finley-Brook & Thomas, 2011). Moreover, Indigenous peoples are often excluded from resource and energy planning (Stefanelli et al., 2019) Thus, meaningful Indigenous participation and stewardship in Canada's renewable energy transition is critical to creating a sustainable and equitable energy future for all.

In light of this background, the Indigenous renewable energy database and map allows users to observe (not only Canada's ongoing transition to renewable energy but also) Canada's progress on reconciliation within the clean energy sector. The Indigenous renewable energy map layer displays all renewable energy projects within Canada that are equal to or greater than 1 MW. Based on Hoicka et al. (2021), we classified projects based on degree of Indigenous ownership (No Indigenous Ownership, Minority Indigenous Owned, Partial to Majority Indigenous Owned, Wholly Indigenous Owned, Unknown) to observe the extent to which Indigenous peoples are participating in and leading renewable energy projects. However, it is important to remember that the idea of Indigenous participation within this sector is a settler idea; colonial structures of exploitation still exist (Stefanelli et al., 2019). Thus, it is critical to avoid generalizations when observing Indigenous engagement in Canada's clean energy sector using this map. In other words, just because a renewable energy project involves Indigenous peoples does not necessarily indicate that reconciliation is happening.

To find additional Indigenous projects and confirm the degree of Indigenous ownership, we used an Indigenous renewable energy dataset prepared by Hoicka et al. (2021), news articles, project websites, and Indigenous-owned company websites. All sources and databases used for creating the Indigenous renewable energy database were publicly available at the time of data collection.

### Solar energy potential

For the solar energy potential layer, we downloaded data available on the government of Canada's open data portal. The data is a geodatabase file showing the mean annual photovoltaic potential at south-facing, latitude tilt orientation across Canada (Government of Canada, 2020). To reduce the data points and make the map compatible with our interactive app on ArcGIS Online, we filtered unnecessary data on ArcGIS Pro. Because photovoltaic potential (in kWh/kWp) was measured in ranges in the original dataset, we calculated the midpoint values to classify the color ramp based on photovoltaic potential. After cleaning the data on ArcGIS Pro, we uploaded the map to ArcGIS Online. The annual photovoltaic potential ranges from 750 to 1,350 kWh/kWp.

Overlaying the solar energy potential layer with solar energy projects allows researchers, renewable energy developers, and the public to observe how developers are utilizing energy potential across the country. It also allows users to locate areas with opportunities for solar energy development.

## Summary of key findings

In Canada, there are 1502 renewable energy projects in operation or development. Of these projects, 1149 are in operation, 351 in development, and the status of 2 projects are unknown. Hydroelectric projects dominate the renewable energy landscape (608), followed by wind (418), solar (340), biomass (129), geothermal (5), and tidal (2).

There are 141 battery energy storage projects. Expectedly, the majority of these are in development (114), reflecting the newness of the technology. Most of these projects fall within southern Alberta. To our knowledge, only 27 projects are in operation across the country.

We identify 149 Indigenous-owned projects that are minority Indigenous-owned, partial to majority Indigenous-owned, wholly Indigenous-owned, and Indigenous projects with an unknown share of Indigenous involvement. Among these projects, 103 are in operation and 46 are in development; 46 are wholly Indigenous-owned, 37 are partial to majority Indigenous-owned, 32 have minority Indigenous ownership, and 38 have an unknown share of Indigenous ownership.

With respect to solar energy potential, southern Alberta - an area with some of the highest solar energy potential in the country - has the greatest number of operational and planned solar energy projects relative to other provinces. Similarly, we find many solar projects in southern Ontario where there is considerable solar potential. While southern Manitoba and southern Saskatchewan have high solar energy potential, few projects are operational or planned. We could not locate any operational or in-development solar projects in Manitoba.

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