Technology Collaboration Programme
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International Energy Agency
Photovoltaic Power Systems Programme

Task 1 Strategic PV Analysis and Outreach

PVPS

National Survey Report of PV Power Applications in CANADA

2022

Natural Resources Canada, CanmetENERGY in Varennes
Canadian Renewable Energy Association (CanREA)

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What is IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6 000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems." To achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Cop- per Alliance are also members.

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What is IEA PVPS Task 1?

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology cooperation. An important deliverable of Task 1 is the annual "Trends in photovoltaic applications" report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2022. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

Authors

- **Main Content:** C. Baldus-Jeursen (Natural Resources Canada), Y. Poissant (Natural Resources Canada), P. Mckay (Canadian Renewable Energy Association)
- **Data:** C. Baldus-Jeursen (Natural Resources Canada), Y. Poissant (Natural Resources Canada), P. Mckay (Canadian Renewable Energy Association), E. Knaggs (ComAp Controls)
- **Analysis:** C. Baldus-Jeursen (Natural Resources Canada), Y. Poissant (Natural Resources Canada)

COVER PICTURE

The North Klondike grid-tied PV system supplies power to the city of Whitehorse and generates approximately 1.6 GWh of electricity annually. Photo credit: Solvest Inc. (Andrew Serack Photography)

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1 INSTALLATION DATA

The PV power systems market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all their installation and control components. Other applications such as small mobile devices are not considered. In this report, PV installations are included in the 2022 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2022.

1.1 Applications for Photovoltaics

This report only examines grid-connected PV systems. The amount of off-grid capacity is difficult to track and considered negligible by comparison. However, off-grid solar PV applications (with or without battery storage), or hybrid systems including a small wind turbine or diesel generator, can be found throughout Canada. These systems are often located in remote northern communities. Installation capacity data for floating PV, agrivoltaics, building-integrated PV (BIPV), building-added PV (BAPV), and vehicle-integrated systems (VIPV) are not tracked. This report contains aggregated PV data.

The continued decline in the cost of generating solar electricity has resulted in grid-connected PV systems approaching grid parity throughout Canada, with applications varying by province. Ontario and Alberta represented approximately 63% and 31% of Canada’s total cumulative installed capacity in 2022, respectively.

1.2 Total PV Power Installed

The cumulative national installed PV capacity at the end of 2022 was 4.32 GW_{AC}. This represents a growth of approximately 12% over the previous year. The increase in installed PV capacity for 2022 was 469 MW_{AC}. Table 1 summarizes Canada's centralized and decentralized PV capacity. Centralized PV installations, by definition, have no self-consumption and only inject electricity to the grid. Distributed PV, by contrast, allows self-consumption. Centralized PV capacity was mostly located in Ontario (1811 MW_{AC}) and Alberta (1165 MW_{AC}). For Ontario, centralized capacity was determined as the sum of all Renewable Energy Standard Offer Programme (RESOP), Green Energy Investment Agreement (GEIA), and large-scale Feed-in Tariff (FIT) systems. Ontario's distributed capacity was the sum of all microFIT, small-scale FIT contracts, and net metering.

Data were collected by contacting local utilities or by accessing reports on contracted electricity supply. Respondents were requested to divide their installation data into centralized and decentralized systems using a 500 kW_p threshold. The level of detail reported by utilities to quantify PV capacity may vary by province and territory, but the uncertainty is expected to be within ±3%.

Table 1: Annual PV power installed during calendar year 2022

		Installed PV capacity in 2022 [MW]	AC or DC
	Decentralized	126	AC
	Centralized	343	AC

	Off-grid	Not tracked	AC
	Total	469	AC

The data collection process is described in Table 2. More than 95% of Canada's PV capacity data are reported by provincial utilities in AC. The Ontario PV capacity data in this report were limited to systems contracted through the Independent Electricity System Operator (IESO) and the Ontario Energy Board (OEB). Net metering data for Ontario, reported by the OEB, refers to embedded generators that do not participate in the IESO-administered market. For 2021, and all year prior, AC data were converted to DC using an AC/DC ratio of 0.85. Beginning in 2022, this conversion coefficient was changed to 0.67 to better reflect utility-scale system performance. The new conversion coefficient was retroactively applied to 2021 to allow capacity comparison between these two years. The coefficient is based on the 465 MW_{AC} / 692 MW_{DC} Travers PV array in Alberta, which is assumed to be a reasonable representation of a typical commercial array. The same coefficient is applied for both centralized and decentralized systems.

Table 2: Data collection process

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	PV capacity data in this report are in AC. To convert from AC to DC, a conversion coefficient of 0.67 was used.
Is the collection process done by an official body or a private company/Association?	Data were collected by an official body, Natural Resources Canada, through the Renewable Energy Integration program.
Link to official statistics (if this exists)	See works cited

Table 3 summarizes the centralized versus distributed PV power capacity increase between 2010 and 2022. Centralized PV systems are typically ground-mounted, provide bulk power, and exist on the supply side of electricity meters. They inject electricity and do not allow self-consumption. As mentioned previously, centralized PV systems are defined as having power capacity greater than 500 kW_p and may be connected to either the distribution grid or transmission grid. By contrast, distributed PV systems are connected to the distribution network, are on the demand side of the electricity meter, and are often embedded into a customer's premises allowing for self-consumption. Distributed systems may be located on residential or commercial buildings and can be further categorized as BIPV or BAPV depending on whether the modules replace conventional building materials.

Table 3: Cumulative installed PV power in 4 sub-markets. The AC/DC conversion coefficient of 0.85 was used from 2010 to 2020 inclusive and was changed to 0.67 for 2021 and 2022.

Year	Off-grid [MW_{AC}] (including large hybrids)	Grid-connected distributed [MW_{AC}]	Grid-connected centralized [MW_{AC}]	Total [MW_{AC}]
2010	51.09	23.58	164.30	238.96
2011	51.89	111.49	311.19	474.57
2012	-	185.88	465.20	651.07

2013	-	232.21	796.70	1 028.91
2014	-	459.72	1 106.90	1 566.62
2015	-	625.44	1 515.13	2 140.56
2016	-	673.76	1 590.90	2 264.66
2017	-	787.39	1 705.35	2 492.74
2018	-	924.50	1 706.15	2 630.65
2019	-	1 001.82	1 825.90	2 827.72
2020	-	1 114.32	1 953.56	3 067.89
2021	-	1 176.80	2 676.84	3 853.64
2022	-	1 303.15	3 019.94	4 323.09

Figure 1 shows the installed capacity by province and territory for grid-connected PV power and the number of utility-interconnected PV systems as of December 31, 2022. Data on PV energy storage sites are not tracked. Nunavut did not report its PV capacity figures in 2022. Thus, PV capacity is underestimated for this jurisdiction and the last available year of data is shown in parentheses. Table 4 provides details on the total PV capacity connected to the distribution and transmission grids. Capacity connected to the low-voltage distribution grid was the sum of all grid-connected capacity from all provinces and territories. Transmission grid-connected capacity was made up of systems publicly reported by utilities in Ontario and Alberta.

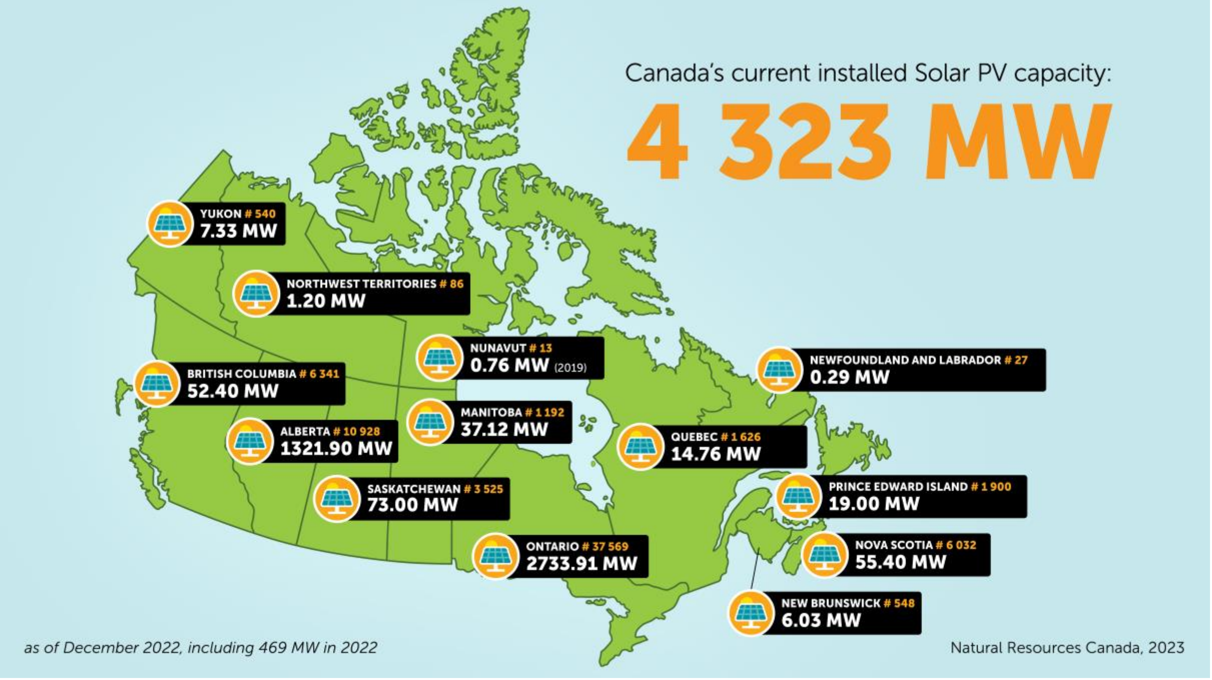

Figure 1: Map showing the PV power capacity (MW_{AC}) and number of installed systems for the provinces and territories. This map is for illustrative purposes only. Distance scale is approximate.

Table 4: Other PV market information

	2022
Number of PV systems in operation in your country	70 327
Decommissioned PV systems [MW_{AC}]	Not tracked
Repowered PV systems [MW_{AC}]	Not tracked

Table 5 provides national figures on power generation and electricity demand as well as an estimate of total PV energy production. Total energy generation capacity for 2022 was calculated using Statistics Canada's annual electricity generation estimates [1]. Total electricity demand was estimated from the Canadian Energy Regulator's report on Energy Futures and Statistics Canada's supply and demand figures for primary and secondary energy [2]. To estimate PV energy production, the total power (MW_{AC}) was multiplied by the average yearly Canadian PV potential which was assumed to be 1 150 kWh/kW_p. The average PV potential was determined using satellite-based insolation data and assuming a conservative performance ratio of 75% [3].

Table 5: PV power and the broader national energy market

	2022	2021
Total power generation capacities [TWh]	640.1	627.7
Total renewable power generation capacities (including hydropower) [TWh]	434.6	415.9
Total electricity demand [TWh]	588.9	580.3
New power generation capacity-installed [GW]	Not tracked	Not tracked
Estimated total PV electricity production (including self-consumed PV electricity) [TWh]	7.4	6.6
Total PV electricity production as a % of total electricity consumption	1.26	1.14
Average yield of PV installations (in kWh/kW_p)	1 150	1 150

1.3 Key enablers of PV development

Whether connected to PV or not, enabling technologies such as decentralized storage and electric cars, buses, and trucks can increase a grid's hosting capacity and provide storage capacity. There were 117 994 electric vehicles purchased in Canada in 2022, consisting of both battery-electric and plug-in hybrids [4]. In terms of centralized storage, although PV battery energy storage system data are not publicly available, work is underway to track these installations. Overall electrical storage capacity is around 500 MW or 4.1 GWh of which 80% is battery-based. Additional storage capacities are available as pumped hydro and compressed air. Most projects are utility-scale and behind-the-meter storage, which are connected to the transmission or distribution grid [5].

Table 6: Information on key enablers.

	Description	2022 Volume	Total Volume	Source
Decentralized storage systems [MW_{AC}]	Data are from 2021	-	507.3	Natural Resources Canada [5]
Residential heat pumps [# of units sold]	Linear growth assumption	21 200	881 400	Canada Energy Regulator [6]
Electric cars [# of units sold]	BEV + PHEV	117 994	373 701	Statistics Canada [4]
Electric buses and trucks [# of units sold]	Electric bus data are from 2021	-	3 053	Statistics Canada [4]

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Crystalline silicon module prices vary by manufacturers and module type. In terms of technology trends, the Canadian market shows a transition from monofacial to bifacial, from PERC to higher efficiency TOPCon and SHJ cell types, and from full to half-cut cell arrangements. More projects are expected to favour bifacial PV and single axis tracking systems. Table 7 shows wholesale price estimates applied to high efficiency monocrystalline modules of 290 W and above. Value-added taxes are excluded.

Table 7: Typical module prices

Year	Lowest price of a standard module crystalline silicon [$/W]	Highest price of a standard module crystalline silicon [$/W]	Typical price of a standard module crystalline silicon [$/W]
2019	0.50	0.74	0.62
2020	0.40	0.74	0.44
2021	0.41	0.78	0.46
2022	0.45	0.80	0.63

2.2 System prices

PV system prices, shown in Table 8 and Table 9, incorporate hardware costs such as mounting materials and inverters, as well installations and development. Prices do not include recurring charges after installations such as battery replacement or operation and maintenance. Additional costs incurred due to the remoteness of a site or any specialized installation requirements are not considered. Value-added taxes are excluded.

Table 8: Turnkey PV system prices of different typical PV systems

Category/Size	Typical applications and brief details	Current prices [$/W]
Off-grid 1 – 5 kW	A stand-alone PV system that generates electricity for a device or a household and is not connected to the grid.	Not tracked
Residential BAPV 5 – 10 kW	A grid-connected, roof-mounted, or distributed PV system that produces electricity for grid-connected households such as roof-mounted systems on villas and single-family homes.	2.42 – 2.82
Residential BIPV 5 – 10 kW	A grid-connected, roof-mounted, or distributed PV system that produces electricity for grid-connected households such as roof-mounted systems on villas and single-family homes.	Not tracked

Small commercial BAPV 10 – 100 kW	A grid-connected, roof-mounted, distributed PV system that produces electricity for grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores, etc.	2.07 – 2.71
Small commercial BIPV 10 – 100 kW	A grid-connected, building integrated, distributed PV system that produces electricity for grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores, etc.	Not tracked
Large commercial BAPV 100 – 250 kW	A grid-connected, roof-mounted, distributed PV system that produces electricity for grid-connected large commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores, etc.	2.22 – 2.50
Large commercial BIPV 100 – 250 kW	A grid-connected, building integrated, distributed PV system that produces electricity for grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores, etc.	Not tracked
Industrial BAPV > 250 kW	A grid-connected, roof-mounted, distributed PV system that produces electricity for grid-connected industrial buildings, warehouses, etc.	1.68 – 2.22
Small centralized PV 1 – 20 MW	A grid-connected, ground-mounted, centralized PV system that works as a central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	1.65 – 1.90
Large centralized PV > 20 MW	A grid-connected, ground-mounted, centralized PV system that works as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	< 1.31

Table 9: National trends in system prices for different applications

Year	**Residential BAPV** Grid-connected, roof-mounted, distributed PV system 5-10 kW **[$/W]**	**Small commercial BAPV** Grid-connected, roof-mounted, distributed PV systems 10-100 kW **[$/W]**	**Large commercial BAPV** Grid-connected, roof-mounted, distributed PV systems 100-250 kW **[$/W]**	**Centralized PV** Grid-connected, ground-mounted, centralized PV systems 10-50 MW **[$/W]**
2019	2.50 – 2.75	1.80 – 2.50	1.80 – 2.00	1.25
2020	2.40 – 2.70	1.80 – 2.25	1.60 – 2.00	1.25
2021	2.50 – 2.83	1.89 – 2.36	1.68 – 2.10	1.31
2022	2.42 – 2.82	2.07 – 2.71	2.22 – 2.50	1.31

2.3 Cost breakdown of PV installations

The cost breakdown of a typical 5 – 10 kW roof-mounted, grid-connect, distributed PV systems on a residential single-family house is presented in Table 10.

The cost structure presented does not rationalize for volume and is from the customer's point of view without reflecting the installer companies' overall costs and revenues. The "average" category in Table 10 represents the average cost for each cost category and is the average of the typical cost structure. The average cost is taking the whole system into account and summarizes the average end price to customers. The "low" and "high" categories are the lowest and highest cost reported in each segment. These costs are individual posts, i.e. summarizing these costs do not give an accurate system price.

Table 10: Cost breakdown for a grid-connected roof-mounted, distributed residential PV system of 5 – 10 kW

Cost category	Average [$/W]	Low [$/W]	High [$/W]
Hardware			
Module	0.625	0.45	0.8
Inverter	0.585	0.36	0.81
Mounting material	0.35	0.27	0.43
Other electronics (cables, etc.)	0.11	0.08	0.14
Subtotal Hardware	1.67	1.16	2.18
Soft costs			
Planning	-	-	-
Installation work	0.89	-	-
Shipping and travel expenses to customer	-	-	-
Permits and commissioning (i.e. cost for electricians, etc.)	0.14	-	-
Project margin	0.21	-	-
Subtotal Soft costs	**1.24**	-	-
Total (excluding VAT)	**2.91**	-	-

2.4 Financial parameters and specific financing programs

Financing from institutional lenders is available for projects, or portfolios of projects, that meet certain financial thresholds. There are fewer financing options for residential and small commercial projects, but the number of options for low-cost capital is growing.

One interesting PV financing scheme that has currently been made available in Ontario by the IESO is third-party ownership. This allows homeowners and other generators to benefit from net metering without having to cover the costs of installing or owning the PV asset.

2.5 Specific Investment Programs

As outlined in Section 3, there are a variety of investment mechanisms across the country to support PV development. Additional details are provided in Table 11.

Table 11: Summary of existing investment schemes

Investment Schemes	Additional Information
Third-party ownership (no investment)	Several companies offer third-party ownership and leasing services. This had been the dominant financing mechanism for residential solar under Ontario's FIT programs, but now the practice is less common for net metering installations in that province. Third-party ownership models for net metering are more common in Alberta and Nova Scotia.
Renting	Several companies offered rented systems in Canada in 2022. However, it is more common that after a specified term the system becomes the property of the renter (i.e. leasing).
Financing through utilities	No utilities offered PV on-bill financing in 2022.
Community investment in PV plants	Several PV energy cooperatives have been incorporated to facilitate investment in, and ownership of these systems.
International organization financing	The Green Energy Investment Agreement (GEIA), initiated in 2010, mandated investment and cooperation between the Government of Ontario, Samsung, and the Korea Electric Power Corporation.

2.6 Additional country information

Canada's electricity sector is provincially regulated and comprised primarily of vertically integrated crown corporations or investor-owned utilities with a deregulated energy-only market system in the province of Alberta and a partially deregulated market in Ontario. Electricity demand in Canada was estimated to be 589 TWh in 2022 with the largest producers of electricity being the provinces of Quebec, Ontario, British Columbia, and Alberta.

Table 12: Country information (electricity prices vary by province and territory and figures quoted in this table represent an average rate across selected cities) [7]

Retail electricity prices for a household (consumption: 1000 kWh) [¢/kWh]	8.72 (lowest) 16.26 (average) 20.94 (highest)

Retail electricity prices for a commercial company (power demand: 1 000 kW, load factor: 56%) [¢/kWh]	9.09 (lowest) 13.78 (average) 18.21 (highest)
Retail electricity prices for an industrial company (power demand: 5 000 kW, load factor: 85%) [¢/kWh]	6.13 (lowest) 10.69 (average) 14.78 (highest)

3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a direct influence on PV development by incentivizing or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

Table 13: Summary of PV support measures

Category	Residential		Commercial + Industrial		Centralized	
Measures in 2022	**On-going**	**New**	**On-going**	**New**	**On-going**	**New**
Feed-in tariffs	yes	-	yes	-	yes	-
Feed-in premium (above market price)	-	-	-	-	-	-
Capital subsidies	yes	-	yes	-	-	-
Green certificates	-	-	-	-	-	-
Renewable portfolio standards with/without PV requirements	-	-	-	-	-	-
Income tax credits	-	-	-	-	-	-
Self-consumption	yes	yes	yes	yes	-	-
Net-metering	yes	yes	yes	yes	-	-
Net-billing	yes	yes	yes	yes	-	-
Collective self-consumption and delocalized net-metering	yes	yes	-	-	-	-
Sustainable building requirements	-	-	-	-	-	-
BIPV incentives	-	-	-	-	-	-
Merchant PV facilitating measures	-	-	-	-	-	-
Other (specify)	-	-	-	-	-	-

3.1 National targets for photovoltaics

The federal government has committed to 90% of Canada's electricity coming from non-emitting sources by 2030 and a net zero electricity sector by 2035. However, there is currently no specific target for PV set by the federal, provincial, or territorial governments.

3.2 Direct support policies for PV installations

3.2.1 Federal commitments

Canada's current target for reducing greenhouse gas emissions is 40 – 45% below 2005 levels by 2030. The Government of Canada's framework for emissions reduction and renewable energy is outlined in the 2016 Pan-Canadian Framework on Clean Growth and Climate Change. This was supplemented by the 2030 Emissions Reduction Plan [8]. Canada has also joined over 120 countries in committing to be net-zero emissions by 2050 and in 2021, assented the Canadian Net-Zero Emissions Accountability Act. These documents outline a variety of approaches such as carbon pricing, emissions reductions, adaptation, and support for low carbon technologies. Country-wide carbon pricing was implemented in 2018. The price began at $20 per CO_2 equivalent tonne in 2019 and increased by $10 per year to reach $50 per tonne in 2022. The program plans a price increase of $15 per year to reach $170 per tonne in 2030. The program does not apply to provinces that implement their own carbon pricing schemes so long as they define an equivalent price. Additionally, the Smart Renewables and Electrification Pathways Program provides $1.56 billion over eight years to support renewable capacity, energy storage, and grid modernization projects [9]. In terms of targeted support for PV, the Canada Greener Homes Grant provides $1,000 per installed kilowatt for residential customers with a maximum of up to $5,000 per household and up to $40 000 in interest-free loans over a 10-year term [10]. There is also the Accelerated Capital Cost Allowance (ACCA) and the Canadian Renewable and Conservation Expense (CRCE) tax incentive [11].

3.2.2 Solar PV Support Measures by Province and Territory

Support measures can be divided into 1) solar incentives such as tax breaks and rebates, 2) utility policies such as electricity time-of-use pricing, net metering, interconnection fees, and 3) system financing options such as low-interest loans, the Property Assessed Clean Energy (PACE) programs, or on-bill financing. PACE programs allow the system cost to be repaid through property taxes. The average cost per installed watt for each jurisdiction is given in Table 14. However, these prices are merely an approximate guide and are dependent on system size, choice of installers, and additional market factors. The electricity bill rate design for each province and territory is also included since it provides a measure of the amount of money that may be saved by implementing PV. Better rate design maximizes the amount of money that can be saved for a reduction in electricity usage and helps encourage distributed energy generation. Table 14 shows the percentage amount of money saved for the example case of a 50% reduction in electricity use to 750 kWh per month in different parts of the country.

Province or territory	Solar incentives ($/W)	Electricity bill rate design (% savings)	Utility rate for PV electricity, ¢/kWh)	System cost ($/W) & financing options
Alberta	Municipal incentives	41% Flat, net billing	17	2.51 – 2.77 Partial PACE

British Columbia	Provincial tax exemption (regional)	54% Tiered, net metering	13	2.54 – 2.69 Energy loan
Manitoba	None	47% Flat, net metering	10	2.63 – 2.90 On-bill financing
New Brunswick	0.25	45% Flat, net metering	13	2.65 – 3.24 Energy loan
Newfoundland and Labrador	None	46% Flat, net metering	14	3.53 – 4.31 None
Northwest Territories	50% (only for off-grid and non-hydro)	54% Tiered, net metering	38	2.43 – 2.68 PACE pending
Nova Scotia	0.6	48% Flat, net metering	17	2.74 – 3.35 PACE
Nunavut	None	72% Tiered, net metering	38	4.00 < None
Ontario	None	43% Time-of-use or tiered	13	2.34 – 2.59 Partial PACE
Prince Edward Island	1.00	45% Tiered, net metering	17	2.73 – 3.33 Energy loans
Quebec	None	49% Tiered, net metering	7	2.56 – 2.83 None
Saskatchewan	None	45% Flat, net metering	18	2.64 – 3.22 PACE pending
Yukon	0.8 (only for off-grid)	48% Tiered	19	2.29 – 2.81 Partial PACE

Table 14: Summary of support measures by province and territory.

3.2.3 BIPV development measures

There are currently no policies to support BIPV either provincially or federally.

3.3 Self-consumption measures

Table 15: Summary of self-consumption regulations for small private PV systems in 2022

PV self-consumption	1	Right to self-consume	Throughout Canada
	2	Revenues from self-consumed PV	Applied as credits or monetarily depending on the jurisdiction
	3	Charges to finance Transmission, Distribution grids & Renewable Levies	Offset in some instances, paid in others depending on the jurisdiction
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Applied as credits or monetarily depending on the jurisdiction
	5	Maximum timeframe for compensation of fluxes	Most typically one year
	6	Geographical compensation (virtual self-consumption or metering)	Typically uniform within a jurisdiction
Other characteristics	7	Regulatory scheme duration	Various, depending on jurisdiction
	8	Third party ownership accepted	Various, depending on jurisdiction
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	Various, depending on jurisdiction
	10	Regulations on enablers of self-consumption (storage, DSM…)	Various, depending on jurisdiction
	11	PV system size limitations	Various, depending on jurisdiction
	12	Electricity system limitations	Various, depending on jurisdiction

3.4 Collective self-consumption, community solar and similar measures

Measures for collective self-consumption (e.g. PV systems for several apartments in the same building), virtual net-metering (allowing consumption and production in different places), and community solar (investment by private or public organizations) are rare. There are several examples of community-owned PV in British Columbia, whereby members invest on a per-panel basis and may receive a proportional credit on their hydro bill or be paid an annual dividend [12] [13]. In Ontario, the IESO is developing several virtual net-metering demonstration projects [14].

3.5 Tenders, Auctions & Similar Schemes

Measures vary between jurisdictions. For example, in Ontario the IESO used three renewable energy procurement methodologies: standard offer, bilateral negotiations, and competitive bid, with most PV contracts in Ontario awarded by standard offer. Solar PV contract periods are generally awarded for 20 years. The way in which incentives are paid in Canada varies from region to region. Ontario's feed-in tariff is funded by electricity consumers. Other programs are funded through revenues from carbon pricing programs or provincial and municipal taxes.

3.6 Other utility-scale measures including, floating and agricultural PV systems

There are currently no support measures for floating or agricultural photovoltaics. However, the not-for-profit Agrivoltaics Canada association [15] provides a bridge between farmers, PV installers, academia, and provincial and federal funding organizations to begin several agrivoltaic pilot projects. Agrivoltaics Canada advocates for provincial policy support and changes in land-use designations to stimulate the deployment of PV systems on farmland.

3.7 Social Policies

In terms of PV policy, support measures are largely left to the provinces and territories to define. However, as stated previously, PV is eligible for several national support programs announced by the Federal Government, including the $500 million Low Carbon Economy Challenge Fund, the $100 million Smart Grid Program, the $520 million Clean Energy for Rural and Remote Communities program, the $1.56 billion Smart Renewables and Electrification Pathways fund, and various tax incentive programs for industry [11]. As discussed in previous reports, 2017 was the last year for Ontario's microFIT and FIT programs. Ontario's net-metering regulation now forms the basis for future project development.

3.8 Indirect policy issues

3.8.1 Rural electrification measures

Canada has approximately 300 off-grid communities with a total population of around 200,000 people. There is an ongoing transition in these communities from diesel fuel to renewable energy sources supported by the $520 million Clean Energy for Rural and Remote Communities Initiative. This initiative was gifted the name Wah-ila-toos to ease access for Indigenous and remote communities. A Federal Government initiative studying PV system performance, cost, and durability north of the 60th parallel, also provides funding for the monitoring of PV arrays in remote communities.

3.8.2 Support for Electricity Storage and Demand Response Measures

Ontario's Smart Grid Fund has resulted in several PV projects with electricity storage. The Federal Government's Smart Grid program, started in 2018, supports combined solar and storage projects. Other measures were outlined in the 2020 federal policy update [16].

3.8.3 Support for encouraging social acceptance of PV systems

There are currently no programs at the national or regional level to explicitly encourage the social acceptance of PV systems.

3.9 Financing and cost of support measures

As discussed, the way in which incentives are paid in Canada varies by region. Over the past few years, governments in several countries have faced both financial and political pressures due to the high cost of feed-in-tariff programs. To control the rising costs of subsidies like FIT, there has been a shift towards "winner takes all" methods of competitive bidding and auctions. However, the competitive bidding process tends to favour large suppliers while shutting out smaller companies, community groups, and cooperatives.

Although the cost of PV systems continues to fall, a distinction must be drawn between construction costs and auction prices. Construction costs continue to decline, driven by technological improvements and economies of scale. Nevertheless, the competitive pressures of auction-based purchasing strategies may drive down auction costs faster than construction costs. This has resulted in shrinking profit margins for investors and declining investor interest, as shown in Ontario's reduced PV capacity growth after 2015.

3.10 Grid integration policies

3.10.1 Grid connection policies

Interconnection policies determine the size of PV system that can be connected to the grid and the financial compensation that such systems receive for the electricity that they produce. The grid interconnection process, array size limits, and electricity rates paid for renewable electricity vary substantially by jurisdiction. Table 14 shows a breakdown of typical prices utilities pay to PV system owners who can, depending on the rate level of support, indirectly encourage or discourage the adoption of photovoltaics. The waiting time for grid interconnection is currently not tracked in this report.

3.10.2 Grid Access Policies

Grid access costs are part of the soft costs in Table 10 and are linked to installation and commissioning expenditures. Grid access policies, procedures, and interconnection times vary by province and territory and their effects on market development are not tracked in this report.

4 INDUSTRY

4.1 Production of feedstocks, ingots and wafers (crystalline silicon industry)

Canada continues to produce feedstock for the global solar industry through 5N Plus: a producer of high-purity tellurium, cadmium, zinc and related compounds (Table 16). 5N Plus is a Canadian company with 14 manufacturing facilities located throughout Canada, US, Malaysia, England, China, Belgium, and Laos. They have 18 sales offices in Asia, Europe, North and South America. First Solar is their primary customer and is the largest thin film PV producer worldwide. There are currently no producers of polysilicon, silicon ingots, or silicon wafers in Canada. However, pilot production of polysilicon by Ubiquity Solar may be a contributor in the coming years.

Table 16: Silicon feedstock, ingot and wafer producer's production information for 2022

Manufacturers	Process & technology	Total Production	Product destination	Price
5N Plus	CdTe & CIGS high purity compounds	350 tonnes (2010 est.)	First Solar and other thin film PV manufacturers	

4.2 Production of PV cells and modules (including thin film and CPV)

Module manufacturing is defined as the industry performing the encapsulation process. A company may also be involved in the production of ingots, wafers or the processing of cells, in addition to fabricating the modules with frames, junction boxes, and more. The manufacturing of modules may only be counted to a country if the encapsulation takes place in that country. Table 17 present data from four Canadian companies producing PV modules, all of which have their facilities located in Ontario or Quebec and are involved in contract manufacturing for other multinational companies. Together, these four companies produce an estimated 475 MW/year of crystalline silicon modules.

Table 17: PV cell and module production and production capacity information for 2022

Cell/Module manufacturer	Technology	Total Production [MW]		Maximum production capacity [MW/yr]	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Canadian Solar	c-Si, mc-Si	-	475	-	1 050
Heliene	mc-Si	-		-	
Silfab	c-Si, mc-Si	-		-	
Stace	c-Si, mc-Si, CPV	-		-	
Totals		-	**475**	-	**1 050**

4.3 Manufacturers and suppliers of other components

The balance of the system technology market in Canada is mainly served by foreign companies with operations in Canada or production through contract manufacturing. However, domestic solar racking manufacturers including FastRack, Polar, Terragen and hb Solar dominate the Canadian market. Other companies that have Canadian development and manufacturing facilities include Eaton, Hammond Power Solutions, and Nexans. Typical balance of system components manufactured or supplied in Canada include inverters (central/string, microinverter, power optimizer), racking and mounting (rooftop, ground-mount, dual/single axis trackers), and wiring (cabling and combiner box). Among these components, the manufacturing of central inverters has experienced the largest growth and is primarily used for commercial rooftops and utility-scale systems.

5 PV IN THE ECONOMY

5.1 Labour places

The effect of PV in the economy was determined to use the installed PV capacity in each province and territory. These data were input into a newly developed tool called the Economic Impacts of Electrification Initiatives (EI^2) model. This model was developed by the Trottier Energy Institute and Ecole Polytechnique through the NRCan-supported energy modelling initiative [17]. The estimate of the total number of jobs is an aggregate of two types: permanent operation and maintenance of installed capacity in previous years and temporary construction due to new installations in 2022. This partial estimate is highly conservative since it does not include solar PV system design and engineering, sales and marketing, project development and management, or legal/financial services and administration which collectively constitute a significant share of jobs.

Table 18: Estimated PV-related full-time labour places in 2022

Market category	Number of full-time labour places
Research and development (not including companies)	105
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	12 519
Distributors of PV products and installations	345
Other	
Total	**12 969**

5.2 Business value

The value of PV business in Canada as it relates to the solar PV capacity installations for 2022 is estimated to be approximately $1.81 billion. Calculations were performed at the provincial and territorial level using installed PV capacity estimates as input to the EI^2 model. The EI^2 model incorporates financial multipliers specific to each region. Economic impacts were the sum of operation and maintenance associated with previously installed capacity added to the construction impacts due to new PV capacity in 2022. Operation and maintenance encompassed onsite labour, local revenue, and supply chain effects. The construction phase related to modules and supply chain, project development, and onsite labour output.

6 INTEREST FROM ELECTRICITY STAKEHOLDERS

6.1 Structure of the electricity system

Each Canadian province and territory has jurisdiction over its electricity sector. As a result, the market structure and regulations in each jurisdiction are unique (although several inter-ties do exist). For example, Quebec, British Columbia, Manitoba, and Newfoundland and Labrador are hydropower-dominated provinces characterized by low production costs, a dynamic export orientation, and public ownership. Ontario, Alberta and New Brunswick moved away from the centrally managed model through the creation of independent system operators and wholesale markets. Saskatchewan, Nova Scotia, and Prince Edward Island are structured along vertically integrated utilities.

6.2 Interest from Electricity Utility Businesses

Given the diversity in market structures across Canada, the interest from electricity utility businesses is variable. In Ontario, several utilities have established unregulated subsidiaries to act as generators and participate in Ontario's Feed-In Tariff program while others simply interconnect projects and handle the settlement of payments. In other jurisdictions, utilities offer rebates, manage net-metering, and are considering solar financing products such as lease-to-own.

6.3 Interest from municipalities and local governments

There are over 3500 urban and rural municipalities in Canada interested in environmental sustainability and continued exploration PV opportunities throughout 2022.

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

Canada's PV sector has reached 4.32 GW_{AC} of commercially operational capacity, a growth of approximately 12% over the previous year. Canada has joined over 120 countries in committing to net-zero emissions by 2050 and has strengthened its commitment to move towards a net-zero electricity system by 2035. Achieving Canada's greenhouse gas emissions reduction targets requires significant decarbonisation and distributed electrification and represents an important development opportunity for the Canadian PV industry.

7.2 Prospects

According to multiple net zero scenarios from different studies including the latest Canada Energy Regulator's Energy Future report, solar and wind will comprise most of the added electricity generation. The falling capital and operating costs, climate change mitigation policies, and increasing consumer demand make PV one of the most attractive options for utilities and power producers. However, PV installations remain variable across the provinces and territories based on their current energy mix and climate change mitigation plan.

8 REFERENCES

[1] Government of Canada, "Electric power generation, monthly generation by type of electricity, Table: 25-10-0015-01 (formerly CANSIM 127-0002)," Statistics Canada, [Online]. Available: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510001501. [Accessed 23 August 2022].

[2] Government of Canada, "Supply and demand of primary and secondary energy in terajoules, annual (Table: 25-10-0029-01, formerly CANSIM 128-0016)," Statistics Canada, [Online]. Available: https://www.statcan.gc.ca/eng/start. [Accessed 3 April 2019].

[3] S. Pelland , D. McKenney, Y. Poissant, R. Morris , K. Lawrence, K. Campbell and P. Papadopol, "The development of photovoltaic resource maps for Canada," in *31st Annual Conference of the Solar Energy Society of Canada (SESCI)*, Montréal, 2006.

[4] Statistics Canada, “New zero-emission vehicle registrations, quarterly,” Government of Canada, 24 July 2023. [Online]. Available: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2010002501. [Accessed 22 June 2023].

[5] S.-R. McLean, A. Wadhera, S. Wong and M. Roy, “Smart Grid in Canada,” Natural Resources Canada, Varennes, 2020-2021.

[6] C. E. Regulator, “Market Snapshot: Steady growth for heat pump technology,” Government of Canada, 9 June 2023. [Online]. Available: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2018/market-snapshot-steady-growth-heat-pump-technology.html. [Accessed 7 August 2023].

[7] Hydro-Quebec, "Comparison of Electricity Prices in Major North American Cities 2022," Montreal, 2022.

[8] Environment and Climate Change Canada, “2030 Emissions Reduction Plan,” Government of Canada, Ottawa, 2022.

[9] Natural Resources Canada, "Smart Renewables and Electrification Pathways Program," Government of Canada, [Online]. Available: https://www.nrcan.gc.ca/climate-change/green-infrastructure-programs/smart-renewables-and-electrification-pathways-program/23566. [Accessed 20 September 2021].

[10] Natural Resources Canada, "Canada Greener Homes Grant," Government of Canada, 13 August 2021. [Online]. Available: https://www.nrcan.gc.ca/energy-efficiency/homes/canada-greener-homes-grant/23441.

[11] Natural Resources Canada, "Tax Savings for Industry: Class 43.1 and Class 43.2 and Canadian Renewable and Conservation Expenses," Government of Canada, [Online]. Available: https://www.nrcan.gc.ca/science-data/funding-partnerships/funding-opportunities/funding-grants-incentives/tax-savings-industry/5147. [Accessed 2 August 2021].

[12] Nelson Hydro Administration, "Solar Generation," [Online]. Available: https://www.nelson.ca/223/Solar-Generation. [Accessed 23 September 2021].

[13] “Invest in BC solar - BC's first community-owned solar investment program,” SolShare Energy, [Online]. Available: https://www.solshare.ca/. [Accessed 22 September 2022].

[14] Ontario Solar Installers, "What is virtual net-metering?," [Online]. Available: https://ontario-solar-installers.ca/solar-panel-installers/what-is-virtual-net-metering/. [Accessed 19 October 2021].

[15] M. Carter and P. Gossage, “Agrivoltaics Meaningfully Combining Solar and Agriculture,” Agrivoltaics Canada, 20 December 2022. [Online]. Available: https://agrivoltaicscanada.ca/. [Accessed 31 July 2023].

[16] Environment and Climate Change Canada, "A healthy environment and a healthy economy," Government of Canada, Ottawa, 2020.

[17] E. Edom, "Energy Modelling Initiative: EI2," Trottier Energy Institute, April 2021. [Online]. Available: https://emi-ime.ca/ei2/.