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 2021

Natural Resources Canada, CanmetENERGY in Varennes

Canadian Renewable Energy Association (CanREA)

Natural Resources Canada / Ressources naturelles Canada

Canadian Renewable Energy Association / Association canadienne de l'énergie renouvelable
WIND. SOLAR. STORAGE. / ÉOLIEN. SOLAIRE. STOCKAGE.

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 (PV) solar energy as a cornerstone in the transition to sustainable energy systems." In order 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 Copper 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 co-operation. 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 2021. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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COVER PICTURE

Vulcan County, Alberta, 465 MW_{DC} Travers PV array consisting of bifacial modules with single-axis tracking. Photo credit: (Greengate)

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ACKNOWLEDGEMENTS

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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 installation and control components for modules, inverters and batteries. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, PV installations are included in the 2021 statistics, if, the PV modules were installed and connected to the grid between 1 January and 31 December 2021, although commissioning may have taken place at a later date.

1.1 Applications for photovoltaics

This report considers only 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. However, a distinction between rooftop and ground-mounted PV is possible for Ontario, which reports additional information on contracted generation facilities besides nameplate capacity [1].

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 71% and 24% of Canada's total cumulative installed capacity in 2021, respectively. Growth was evident during 2021 in Alberta with the completion of Canada's largest PV array to date: a 465 MW facility located in Vulcan County. Other provinces and territories, such as Quebec, British Columbia, Saskatchewan and Prince Edward Island continue to show robust PV capacity growth as well.

Grid-connected PV generating facilities are linked either to the transmission or distribution systems. Transmission-connected PV generation refers to large capacity projects connected to the high-voltage grid (lines with voltages greater than 50 kV). Distribution-connected generation, also called embedded generation, is small-scale generation contributing to local distribution systems and communities. As shown in Figure 1, most of the installed capacity growth over the past several years has been distribution rather than transmission-connected. However in 2021, with the addition of new transmission-connected capacity from Alberta and the commissioning of the Travers PV array, most of Canada's PV capacity growth was on the transmission-connected side.

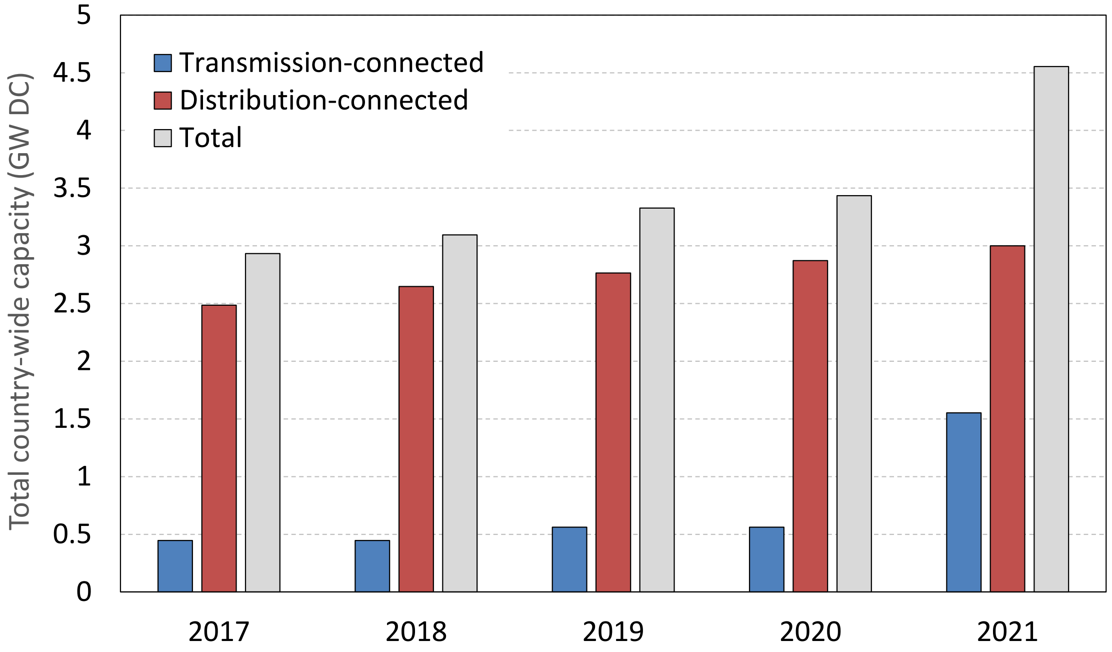

Figure 1: Cumulative distribution versus transmission-connected PV capacity

1.2 Total photovoltaic power installed

The national cumulative installed PV capacity at the end of 2021 was 4.55 GW_{DC}. This represents a growth of approximately 26% over the previous year. Table 1 shows the increase in installed PV capacity for 2021 which was 944 MW_{DC}.

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 assumed to be almost entirely located in Ontario (2130 MW_{DC}) and Alberta (991 MW_{DC}). 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) (>0.5 MW_{AC}) systems. Ontario's distributed capacity was the sum of all microFIT, small-scale FIT contracts, and net metering.

Table 1: Annual PV power installed in 2021

		Installed PV capacity in 2021 [MW]	AC or DC
	Decentralized	95.6	DC
	Centralized	848.4	DC
	Off-grid	Not tracked	DC
	Total	944.0	DC

The data collection process is described in Table 2. Ontario, Alberta, Nova Scotia, and Newfoundland and Labrador report their PV capacities in AC, while the rest report in DC. 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.

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 DC. To convert from AC to DC, a conversion coefficient of 0.85 was assumed.
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
Estimated accuracy of data:	±3%

Table 3 summarizes the centralized versus distributed PV power capacity increase between 1995 and 2021. Centralized PV systems are typically ground-mounted, provide bulk power, exist on the supply side of electricity meters, and perform the function of a centralized power station. For the purposes of this report, centralized PV systems are defined as having power capacity greater than 0.5 MW_{AC} and may be connected to either the distribution grid or transmission grid. By contrast, distributed PV systems have a power capacity equal to or less than 0.5 MW_{AC}, are connected to the distribution network, and are on the demand side of the electricity meter. Distributed systems are often 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

Year	Off-grid [MW] (including large hybrids)	Grid-connected distributed [MW] (BAPV, BIPV)	Grid-connected centralized [MW] (Ground, floating, agricultural…)	Total [MW]
1995	1.64	0.21	0.01	1.86
1996	2.31	0.24	0.01	2.56
1997	3.12	0.25	0.01	3.38
1998	4.2	0.26	0.01	4.47
1999	5.53	0.29	0.01	5.83
2000	6.84	0.30	0.01	7.15
2001	8.48	0.34	0.01	8.83
2002	9.63	0.37	0.00	10.00

2003	11.43	0.40	0.00	11.83
2004	13.37	0.47	0.04	13.88
2005	15.62	1.07	0.06	16.75
2006	18.98	1.44	0.06	20.48
2007	22.86	2.85	0.06	25.77
2008	27.48	5.17	0.06	32.72
2009	35.2	12.25	47.12	94.57
2010	60.1	27.74	193.29	281.13
2011	61.05	131.16	366.11	558.29
2012	NA	218.68	547.29	765.97
2013	NA	273.19	937.29	1 210.48
2014	NA	540.85	1 302.23	1 843.08
2015	NA	735.81	1 782.50	2 518.31
2016	NA	792.66	1 871.65	2 664.31
2017	NA	926.34	2 006.29	2 932.64
2018	NA	1 087.65	2 007.23	3 094.88
2019	NA	1 178.61	2 148.12	3 326.73
2020	NA	1 310.97	2 298.31	3 609.28
2021	NA	1 406.93	3 146.71	4 553.64

Figure 2 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, 2021. Data on PV energy storage sites are not tracked. Nunavut did not report its PV capacity figures in 2021. Thus, PV capacity is underestimated for this jurisdiction and the last available year of data is shown in parentheses.

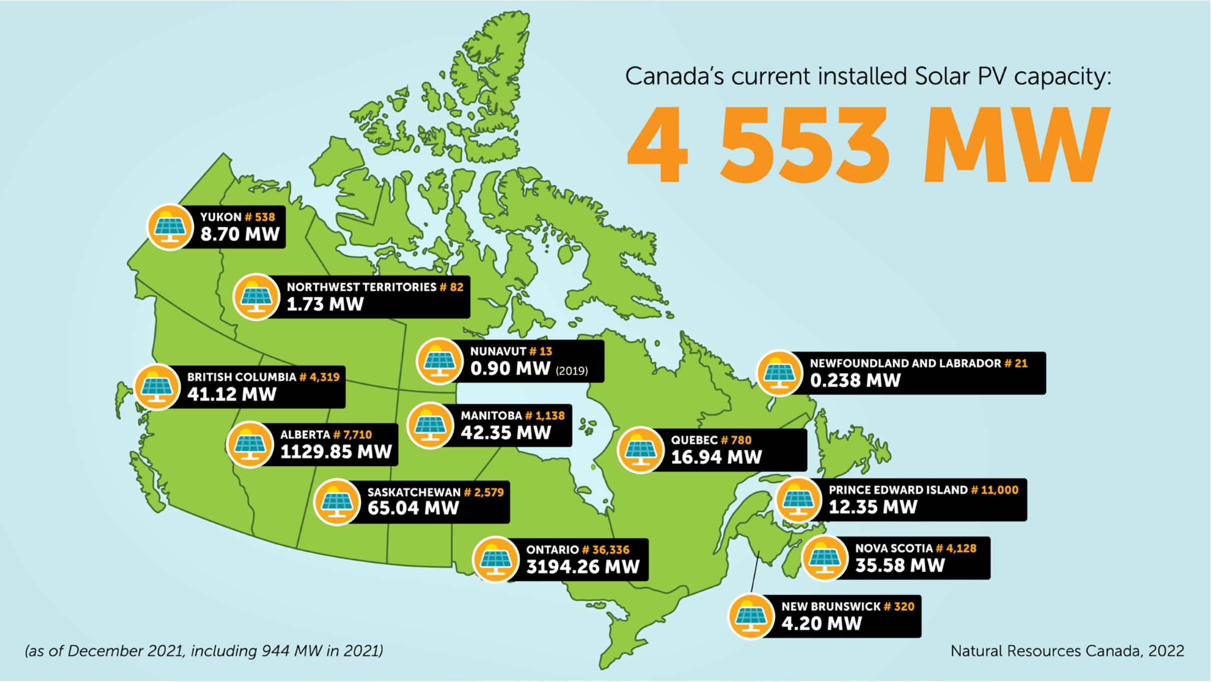

Figure 2: Map showing the PV power capacity (MW_{DC}) and number of installed systems for the provinces and territories. This map is for illustrative purposes only. Distance scale is approximate.

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 Ontario and Alberta utilities.

Table 4: Other PV market information

	2021
Total capacity connected to the high-voltage transmission grid [MW]	1552
Number of PV systems in operation in your country	68 964
Decommissioned PV systems during the year [MW]	Not tracked
Repowered PV systems during the year [MW]	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 2021 was calculated using Statistics Canada's annual electricity generation estimates [2]. 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 [3]. To estimate PV energy production, the total nameplate power was multiplied by the average yearly

Canadian PV potential which was assumed to be 1 150 kWh/kWp. The average PV potential was determined using satellite-based insolation data and assuming a conservative performance ratio of 0.75 [4].

Table 5: PV power and the broader national energy market

	2021	2020
Total electrical energy generation [TWh]	627.65	635.57
Total renewable energy generation (including hydropower) [TWh]	415.91	421.45
Total electricity demand [TWh]	554.50	545.73
New power generation capacities installed [GW]	Not tracked	Not tracked
New renewable power generation capacities (including hydropower) [GW]	Not tracked	Not tracked
Estimated total PV electricity production (including self-consumed PV electricity) in TWh	5.24	4.15
Total PV electricity production as a % of total electricity consumption	0.83	0.65
Average yield of PV installations (in kWh/kWp)	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 66,800 electric vehicles purchased in Canada in 2021, consisting of both battery-electric and plug-in hybrids [5]. This represented a growth of 42.5% over the previous year. In terms of centralized storage, although PV battery energy storage system (BESS) data are not publicly available, work is underway to track these installations under the research directives of the Canada Smart Grid Action Network (CSGAN). Overall electrical storage capacity is around 500 MW/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 [6]. In addition to battery systems, hydrogen production is also being explored. For example, a deal was recently signed with Germany-based Thyssenkrupp to build an 88 MW green hydrogen facility in Varennes. Once completed in 2023, it will produce 11,000 metric tonnes per year [7].

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Crystalline silicon module prices vary by manufacturer and module type (monocrystalline and multicrystalline). Among large Chinese PV manufacturers, module spot prices rose slightly in 2021 due to supply chain disruptions. These price increases were also reflected in the European and Canadian markets. In terms of technology trends, the Canadian market shows a transition from 60-cell to 72-cell modules in residential installation, from traditional mono to mono PERC, and from full-cell to half-cell layout. Additional projects using bifacial PV, perhaps in conjunction with single-axis tracking systems, are also expected. Table 6 shows whole-sale price estimates applied to high efficiency monocrystalline modules of 290 W and above (such as PERC, HIT, n-type, or back-contact cell types). Value-added taxes are excluded.

Table 6: 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]
2016	0,66	0,90	0,78
2017	0,75	0,81	0,80
2018	0,61	0,65	0,63
2019	0,50	0,74	0,62
2020	0,40	0,74	0,44
2021	0.41	0.78	0.46

2.2 System prices

PV system prices, shown in Table 7 and Table 8 take into account hardware costs such as mounting materials and inverters, as well installation and development. Prices do not include recurring charges after installation such as battery replacement or operation and maintenance.

Table 7: 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 is a system that is installed to generate electricity for a device or a household that is not connected to the public grid.	Not tracked
Residential BAPV 5-10 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity for grid-connected households (typically roof-mounted systems on villas and single-family homes).	2.50 – 2.83

Residential BIPV 5-10 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity for grid-connected households (typically, on villas and single-family homes).	Not tracked
Small commercial BAPV 10-100 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity for grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	1.89 – 2.36
Small commercial BIPV 10-100 kW	Grid-connected, building integrated, distributed PV systems installed to produce 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	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity for grid-connected large commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	1.68 – 2.10
Large commercial BIPV 100-250 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity for grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	Not tracked
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity for grid-connected industrial buildings, warehouses, etc.	1.68 – 2.10
Small centralized PV 1-20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power stations. 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	Grid-connected, ground-mounted, centralized PV systems that work as central power stations. 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 8: 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]**
2016	3.00 – 3.50	2.00 – 3.00	2.00 – 3.00	2.00
2017	2.50 – 3.20	1.80 – 2.50	1.80 – 2.50	1.80
2018	2.93	1.80 – 2.50	1.80 – 2.50	1.46
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

2.3 Cost breakdown of PV installations

The cost breakdown of a typical 5-10 kW roof-mounted, grid-connected, distributed PV system on a residential single-family house is presented in Table 9. The cost structure is from the customer's point of view and does not reflect the installer companies' overall costs and revenues. The "average" category in Table 9 represents the average cost for each category. It takes the whole system into account and summarizes the average end price to the customer. The "low" and "high" categories are the lowest and highest cost that has been reported within each segment. These costs are individual posts, i.e. summarizing these costs may not give an accurate system price.

Table 9: 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	0.46	0.41	0.78
Inverter	0.45	0.31	0.61
Mounting material	0.22	0.18	0.47

Other electronics (cables, etc.)	0.17	----	----
Subtotal Hardware	**1.30**		
Soft costs			
Planning	----	----	----
Installation work	0.89	----	----
Shipping and travel expenses to customer	----	----	----
Permits and commissioning (i.e. cost for electrician, etc.)	0.14	----	----
Project margin	0.21	----	----
Subtotal Soft costs	**1.24**		
Average VAT			
Total (including VAT)	**2.54**		

2.4 Financial parameters and specific financing programs

In Canada, 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.

2.5 Specific investment programs

As outlined in Section 3.2, there are a variety of investment mechanisms across the country. Additional details are provided in Table 10.

Table 10: 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	A number of companies offered rented systems in Canada in 2021. 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 on-bill financing specifically for PV as of the end of 2021.
Community investment in PV plants	Several solar energy co-operatives have been incorporated to facilitate investment in, and ownership of, PV 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 554 TWh in 2021 with the largest producers of electricity being the provinces of Quebec, Ontario, British Columbia, and Alberta.

Table 11: Country information (electricity prices vary by province and territory and figures quoted in this table represent an average rate across selected cities) [8]

Retail electricity prices for a household [¢/kWh]	13.93 (average) 7.39 (lowest) 17.26 (highest)
Retail electricity prices for a commercial company [¢/kWh]	15.32 (average) 10.72 (lowest) 21.14 (highest)
Retail electricity prices for an industrial company [¢/kWh]	10.76(average) 5.24 (lowest) 12.35 (highest)

3 POLICY FRAMEWORK

This chapter describes the support policies for PV. Direct support policies may be aimed at incentivizing or simplifying existing programs. Indirect support policies change the regulatory environment in a way that can push PV development.

Table 12: Summary of PV support measures

Category	Residential		Commercial + Industrial		Centralized	
Measures in 2021	**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	-	-	-	-	-	-

3.1 National targets for PV

The federal government has committed to 90% of Canada’s electricity coming from non-emitting sources by 2030. 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 to 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 [9]. 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 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 $964 million over four years to support renewable capacity, energy storage, and grid modernization projects [10]. In terms of targeted support for PV, the Canada Greener Homes Grant provides $1000 per installed kilowatt for residential customers with a maximum of up to $5000 per household and up to $40000 in interest-free loans [11]. There is also the Accelerated Capital Cost Allowance (ACCA) and the Canadian Renewable and Conservation Expense (CRCE) tax incentive [12].

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 and interconnection fees, and, 3) system financing option—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 13. However, these prices are merely an approximate guide and are dependent on system size, choice of installer, and other market factors.

Table 13: Summary of support measures by province and territory

Province or territory	Solar incentives ($/W)	Utility policies ($/kWh)	System cost ($/W) & financing options
Alberta	Municipal incentives	0.17 Flat, net billing	2.51 - 2.77 Partial PACE
British Columbia	Provincial tax exemption (regional)	0.13 Tiered, net metering	2.54 - 2.69 Energy loan
Manitoba	None	0.10 Flat, net metering	2.63 - 2.90 On-bill financing
New Brunswick	0.25	0.13 Flat, net metering	2.65 - 3.24 Energy loan
Newfoundland and Labrador	None	0.14 Flat, net metering	3.53 - 4.31 None
Northwest Territories	50% (only for off-grid and non-hydro)	0.38 Tiered, net metering	2.43 - 2.68 PACE pending

Nova Scotia	0.6	0.17 Flat, net metering	2.74 - 3.35 PACE
Nunavut	None	0.38 Tiered, net metering	4.00+ None
Ontario	None	0.13 Time-of-use or tiered	2.34 - 2.59 Partial PACE
Prince Edward Island	1.00	0.17 Tiered, net metering	2.73 - 3.33 Energy loan
Quebec	None	0.10 Tiered, net metering	2.56 - 2.83 None
Saskatchewan	None	0.18 Flat, net metering	2.64 - 3.22 PACE pending
Yukon	0.8 (only for off-grid)	0.19 Tiered	2.29 - 2.81 Partial PACE

3.2.3 BIPV development measures

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

3.3 Self-consumption measures

Table 14: Summary of self-consumption regulations for small private PV systems in 2021

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 [13] [14]. In Ontario, the IESO is developing several virtual net-metering demonstration projects [15].

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 the vast majority of PV contracts in Ontario awarded by standard offer. Solar PV contract periods are generally awarded over 20 years. The ways 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 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, and the $100 million Smart Grid Program, and various tax incentive programs for industry [12].

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. Other sub-national measures of importance included Alberta's $36 million Residential and Commercial Solar Program (2017 to 2019).

3.7 Indirect policy issues

3.7.1 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 $220 million Clean Energy for Rural and Remote Communities program. 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.

3.7.2 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, announced in 2017, is also expected to support combined solar and storage projects. Other measures were outlined in the 2020 federal policy update [16].

3.8 Financing and cost of support measures

As discussed, the ways 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 take 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. Auction-based competition has, in some countries, resulted in the emergence of dive bidding and what has been termed the "winner's curse" whereby a successful bidder underbids in order to win the contract and then cannot deliver power at the agreed-upon price.

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 15). 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 in Sarnia by Ubiquity Solar may be a contributor in the coming years.

Table 15: Silicon feedstock, ingot and wafer producer's production information for 2021

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 photovoltaic cells and modules (including TF 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 16 presents data from four companies in Canada producing PV modules all of which have their facilities located in Ontario or Quebec, and are involved in contract manufacturing for other multi-national companies. Together, these companies produced an estimated 475 MW/year of crystalline silicon modules. Notably, Stace also manufactures CPV modules.

Table 16: PV cell and module production and production capacity information for 2021

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

4.3 Manufacturers and suppliers of other components

The balance of 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 rooftop and utility-scale systems.

5 PV IN THE ECONOMY

5.1 Labour places

The effect of PV in the economy was determined using 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 from installed capacity in previous years and temporary construction due to new installation in 2021. 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 17: Estimated PV-related full-time labour places in 2021

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	14 812
Distributors of PV products and installations	
Other	-
Total	**14 917**

5.2 Business value

The value of PV business in Canada as it relates to the solar PV capacity installations for 2021 is estimated in Table 18. Similar to Table 17, 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 and construction impacts due to new PV capacity in 2021. Operation and maintenance encompassed onsite labour, local revenue and supply chain effects. The construction phase quantified module and supply chain, project development and onsite labour output.

Table 18: Estimation of the value of the PV business in 2021 (VAT is excluded)

Sub-market	Capacity installed [MW]	Average price [$/W]	Value	Sub-market
Off-grid	-	-	-	-
Grid-connected distributed	1406.55	-	-	-

Grid-connected centralized	3146.71	-	-	-
Value of PV business in 2021 ($ amount in billion)				2.18

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 is 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. 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 and highly dependent on fossil fuels leading to higher prices.

6.2 Interest from electricity utility businesses

Given the diversity in market structures across Canada, the interest from electricity utility businesses is equally 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 to offer solar financing products such as lease-to-own. Given the rapidly declining costs in solar electricity, some utilities such as Hydro Quebec sought to expand their PV capacity in 2021.

6.3 Interest from municipalities and local governments

There are over 3500 urban and rural municipalities in Canada, many of which are interested in environmental sustainability, and continued exploring PV opportunities throughout 2021.

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

Canada's PV sector has reached 4.55 GW_{DC} installed capacity, a growth of approximately 26% over the previous year. However, without a comprehensive pan-Canadian policy framework with annual capacity targets, PV installation in the coming years will likely continue to be highly variable across the provinces and territories. Further policy mechanisms are needed to allow PV to reach its full potential.

7.2 Prospects

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 reductions targets requires deep decarbonisation and electrification, and represents a significant opportunity for Canadian PV industry development. According to the Canada Energy Regulator, Canada's future wind and PV capacity are expected to grow by 200% and 600% respectively, by 2050. A combination of falling costs, climate change mitigation policies, and consumer demand, point to increasing PV generation.

8 REFERENCES

[1] IESO, "Active Generation Contract List," Government of Ontario, Toronto, 2021.

[2] 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].

[3] 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].

[4] 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.

[7] K. Immoor, "First green hydrogen project becomes reality: thyssenkrupp to install 88 megawatt water electrolysis plant for Hydro-Québec in Canada," Thyssenkrupp, 18 January 2021. [Online]. Available: https://www.thyssenkrupp.com/en/newsroom/press-releases.

[8] Hydro-Quebec, "Comparison of Electricity Prices in Major North American Cities 2021," Montreal, 2021.

[10] 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].

[11] 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.

[12] 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].

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

[15] 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].

[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/.

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