IEA INTERNATIONAL ENERGY AGENCY

Task 1 Strategic PV Analysis and Outreach

PVPS

National Survey Report of PV Power Applications in Canada 2018

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PHOTOVOLTAIC POWER SYSTEMS
TECHNOLOGY COLLABORATION PROGRAMME

Cover picture:

Fenlands Banff Recreation Centre 280 kW photovoltaic array in Banff, Alberta.
Photo credit: SkyFire Energy solar power systems

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 IEA carries out a comprehensive programme of energy cooperation among its 30 member countries and with the participation of the European Commission. The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the collaborative research and development agreements (technology collaboration programmes) 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*."

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. This report has been prepared under Task 1, which deals with market and industry analysis, strategic research and facilitates the exchange and dissemination of information arising from the overall IEA PVPS Programme.

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 Canadian National Survey Report for the year 2018. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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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 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 2018 statistics if the PV modules were installed and connected to the grid between January 1 and December 31, 2018, although commissioning may have taken place at a later date. All financial figures are reported in Canadian currency ($ CAD).

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 compared to grid-connected capacity. However, many provinces and territories have off-grid applications which may consist of a PV array or a hybrid system that includes, for example, a small wind turbine or diesel generator. These systems are usually sited remotely with or without battery storage, but are increasingly installed in less remote areas as costs come down and system installers and the public becomes more aware of opportunities. The residential off-grid market consists primarily of remote homes and cottages, and communications (radios). The off-grid non-residential market consists of water pumping, road signals, navigational buoys, telecommunication repeaters, and industrial monitoring and controlling.

The continued decline in the cost of generating solar electricity has resulted in grid-connected PV systems approaching grid parity throughout Canada. Applications of PV vary by province. Ontario represented approximately 96% of Canada’s total cumulative installed capacity and approximately 84% of capacity growth in 2018. Thus, at least until the other provinces begin to increase their PV capacity significantly in the coming years, a closer look at Ontario's electricity infrastructure provides a useful overview for the current PV applications in Canada. Within the remainder of this sub-section, a breakdown in Ontario will be provided.

Ontario’s grid-connected solar generating facilities are linked either to the transmission or distribution systems. Transmission connected photovoltaic generation refers to large capacity projects connected to the high-voltage grid (lines greater than 50 kV). Distribution connected generation, also called embedded generation, is a small-scale generation contributing to local distribution systems and communities. Approximately 1,8% (380 MW_{AC}) of Ontario's transmission connected generating capacity was composed of PV. However, on the distribution side (not including net metering), PV contributed the majority of the installed capacity at 62,4% (2 116 MW_{AC}). Growth in distributed PV systems was an important driver of expansion in 2017. Figure 1 summarizes Ontario's distribution and transmission-connected PV capacity over the past two years. Net metering PV capacity, not included in Figure 1, amounts to approximately 23 MW_{AC}.

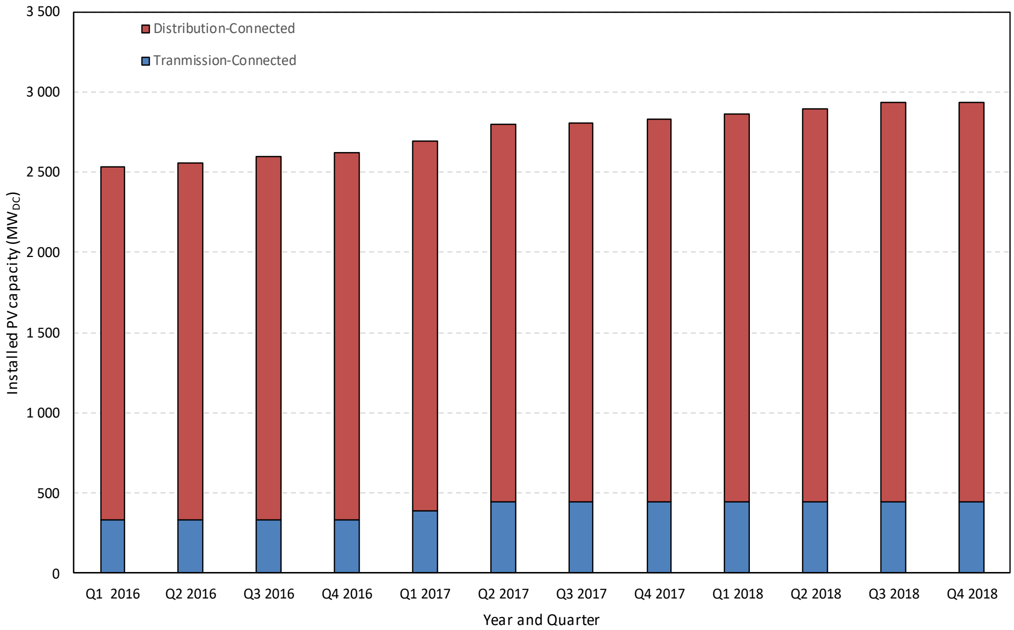

Figure 1: Distribution-connected versus transmission-connected PV systems in Ontario on a quarterly basis from 2016 and 2018.

The renewable energy procurement strategy in Ontario has involved five different contract programmes which (with the exception of the Green Energy Investment Agreement) cover wind, solar, bioenergy, and hydroelectricity projects. Most projects are run through the Independent Electricity System Operator (IESO).

1. The Feed-in Tariff (FIT) programme, launched in 2009 with the Ontario government's Green Energy and Green Economy Act, was a method of procuring solar, wind, hydro, and biomass generating capacity in order to replace the province's coal-fired power plants. It applied only to projects of installed capacity greater than 10 kW. The FIT and microFIT programmes provided, under a collection of different project size tiers, a guaranteed price for a fixed contract term for renewable electricity sold to the province. Contract periods range from 20 years for solar PV up to 40 years for hydroelectricity projects. After a directive from the Ministry of Energy, the final application period for FIT projects occurred in 2016 after which point no further contracts would be awarded. The price offered for PV electricity for FIT projects reduced as module prices on the market dropped. For example, in 2009 a 500 kW capacity PV project would receive a rate of 65,3 ¢/kWh. By 2017, this rate had dropped by 67% to 20,7 ¢/kWh [1]. Approximately 37% (640 MW$_{DC}$) of systems in the FIT programme are less than or equal to 500 kW. The remaining 63% (1 079 MW$_{DC}$) are larger than 500 kW and consist mostly of facilities greater than 10 MW.

2. The microFIT programme was launched in 2009 and applied only to smaller projects of installed capacity less than 10 kW. This support programme was mainly of interest to homeowners. Nearly all microFIT contracts and installed capacity is photovoltaic. MicroFIT concluded at the end of 2017.

3. The Green Energy Investment Agreement (GEIA) was initiated in 2010 between the Ontario government and Samsung and the Korea Electric Power Corporation. Although the agreement has undergone several alterations since then, the goal was to develop 2,5 GW of wind and solar generating capacity in the province and create clean energy manufacturing jobs. So far, four manufacturing plants have opened and the agreement is expected to continue contributing to the renewable energy sector over the next 20 years [2].

4. The Renewable Energy Standard Offer Programme (RESOP) was launched in 2006 by the Ontario Power Authority in order to provide a stable pricing regime over a twenty-year period for electricity from renewable energy projects. RESOP was later succeeded by the FIT, microFIT and LRP programmes [3].

5. The Large Renewable Procurement (LRP) programme was launched in 2014 to replace the FIT programme for projects with generating capacity exceeding 500 kW. The first phase of LRP operated from 2014 to 2016. The second phase of the LRP was suspended in 2016 and the programme has since been cancelled. The LRP programme was designed to ensure a better price for large-scale systems and to control the number of installation projects.

Figure 2 shows the installed PV capacity in Ontario divided by programme type (excluding net metering). The majority of the installed PV capacity and capacity growth in Ontario has been achieved through the FIT and RESOP programmes. Seven LRP projects were initiated in March 2016 and will be operational in 2019 with a combined capacity of 140 MW.

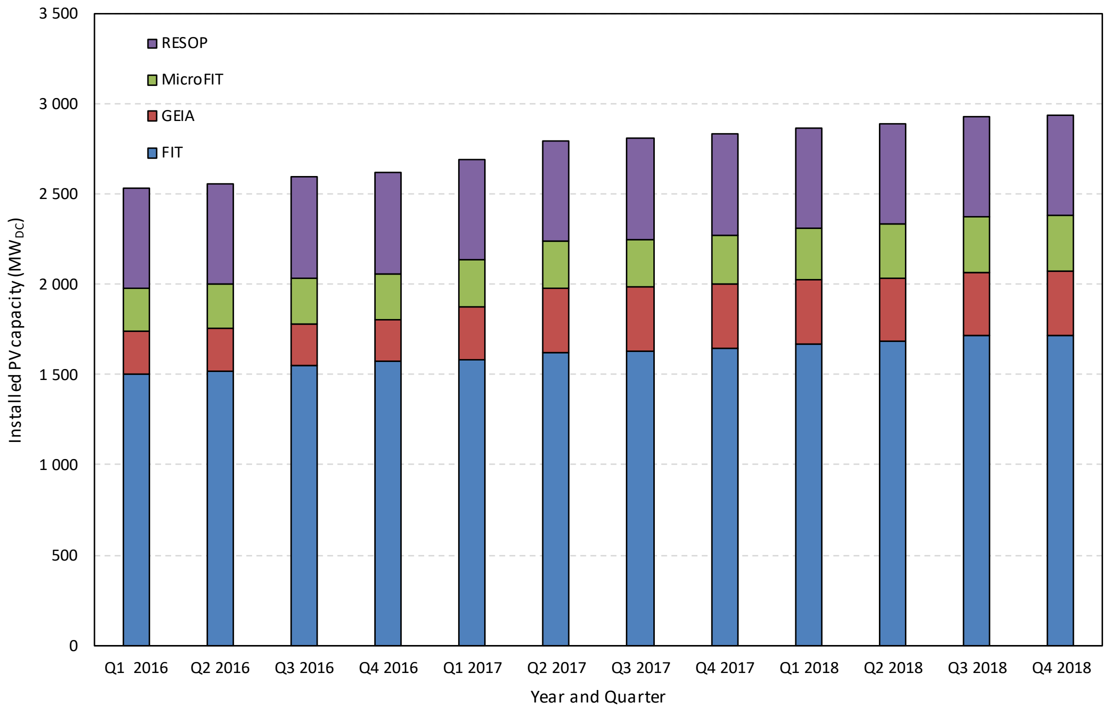

Figure 2: Ontario's cumulative installed PV capacity reported on a quarterly basis from 2016 and 2018.

Ontario's annual PV capacity additions peaked in 2015 at 671 MW_{DC} and declined to 111 MW_{DC} for 2018. Photovoltaic output is high during summer periods of peak demand. Thus, PV provides an important relief to the electricity grid. As the amount of grid-connected PV capacity in Ontario increases, summer peaks are reduced and shifted later into the day [4]. Peak demand in Ontario is also greatly affected by time-of-use rates and the Industrial Conservation Initiative (a demand response program for industrial customers implemented in 2010). The ability for embedded photovoltaic generation to offset electricity demand during peak periods in Ontario is estimated by monthly Solar Capacity Contribution values (Table 1). Comparing the average daily energy demand in Ontario between 2002 and 2016, there was a decrease in evening and nighttime hourly demand of approximately 1 500 MW. However, during peak load periods around midday, grid-connected PV caused a demand decrease by as much as 2 700 MW [5].

Table 1: Solar Capacity Contribution values for transmission-connected PV (380 MW). Distribution-connected PV was not included in the calculation.

Month	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
SCC	0,0%	0,0%	0,0%	1,3%	2,9%	10,1%	10,1%	10,1%	8,6%	0,0%	0,0%	0,0%

It is expected that future increases in installed capacity in Ontario will largely be distribution-connected rather than transmission-connected.

1.2 Total photovoltaic power installed

The cumulative national installed PV capacity at the end of 2018 was 3,10 GW_{DC}. This represents a growth of approximately 5.5% over the previous year. Off-grid PV is not tracked and is assumed to be negligible compared to the grid-connected total.

Table 2 summarizes Canada's centralized and decentralized PV capacity. Centralized PV installations are assumed to only inject electricity and there is no self-consumption by the consumer. Distributed PV, by contrast, allows self-consumption. Centralized PV capacity was assumed to be mainly from Ontario, and was determined as the sum of all RESOP, GEIA, and large-scale FIT ($>$ 0,5 MW_{AC}) systems. The only addition to the centralized PV power total, from outside of Ontario, was Alberta's 17 MW_{DC} Brooks Solar array and British Columbia's 1.05 MW_{DC} Kimberley system. Canada's decentralized (or distributed) capacity was the sum of all other provinces and territories added to the Ontario distributed total. Ontario's distributed capacity was the sum of all microFIT, and small-scale FIT contracts.

Table 2: Cumulative PV power installed up to December 31, 2018

		Total PV capacity	AC or DC
PV capacity	Off-grid	Data not tracked	Not Applicable
	Distributed	1,09	GW_{DC}
	Centralized	2,01	GW_{DC}
	Total	3,10	GW_{DC}

However, among the Canadian provinces and territories, there is no standardized collection of PV capacity figures that distinguishes between ground mounted and rooftops, commercial versus residential, or building-integrated BIPV and building-added BAPV. The closest estimates for ground-mounted and rooftop PV is from Ontario's quarterly reports. Nevertheless, these reports may be somewhat indicative of the country as a whole since Ontario represents 96% of the installed country-wide capacity. The IESO reporting on contracted electricity supply provides a breakdown for ground-mounted and rooftop systems that are part of the FIT category only. Thus, the cumulative capacity for rooftop and ground mounted systems in Ontario as of December 31, 2018, was approximately 566 MW_{DC} and 721 MW_{DC}, respectively.

Table 3 provides details on the total capacity connected to the distribution and transmission grids. Capacity connected to the low-voltage distribution grid was the sum of Ontario's distribution grid-connected capacity plus the capacity of all other provinces and territories. Total capacity connected to the high-voltage transmission grid was composed only of Ontario's transmission-connected systems.

Table 3: Other PV market information.

	2018 Cumulative Capacity
Number of PV systems in operation in Canada	43 836 (during 2018, there were 8 461 new systems)
Total capacity connected to the low voltage distribution grid [MW]	2 648 MW_{DC}
Total capacity connected to the high-voltage transmission grid [MW]	447 MW_{DC}

The data collection process is described in Table 4. All provinces except for Ontario, Alberta, and Newfoundland and Labrador reported PV power in DC (array nameplate power). Capacities reported in AC were converted to DC using an AC/DC conversion coefficient of 0.85. The Ontario PV capacity data in this report were limited to systems contracted through the IESO (Independent Electricity System Operator), and the Ontario Energy Board (OEB). These data do not include contracts with non-utility generators, or contracts with Ontario Power Generation or the Ontario Electricity Financial Corporation. Net metering data for Ontario, reported by the OEB, refers to embedded generators that do not participate in the IESO-administered market. Net metering data are not collected for the other provinces or territories in this report.

Table 4: Outline of the data collection process.

Data reporting	Although data are collected in either AC or DC depending on the province, data are reported in DC. In order to convert from AC into DC (for Ontario, Alberta, and Newfoundland and Labrador), an AC to DC ratio of 85% was assumed.
Collection by an official body or a private company/Association?	Data were collected by Natural Resources Canada (NRCan) through the CanmetENERGY branch under the programme for Renewable Energy Integration. Where table fields were left blank, data were either not available or were insufficient to make an estimate.
Link to official statistics	See works cited
Accuracy	Estimated accuracy of data: ±3%

Table 5 summarizes the centralized versus distributed PV power capacity increase between 1992 and 2018. Centralized PV systems are typically ground mounted, are on the supply side of electricity meters, provide bulk power, 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 or not the modules replace conventional building materials. Since a breakdown of PV power capacity for each project is available only for Ontario, it is assumed that most of the PV capacity in the other provinces is distributed (with the exception of Alberta's Brooks solar array, and British Columbia's Kimberley Sun-Mine project).

Table 5: Cumulative installed PV power in 3 sub-markets.

Year	Off-grid [MW_{DC}]	Grid-connected distributed [MW_{DC}]	Grid-connected centralized [MW_{DC}]	Total [MW_{DC}]
1994	1,3	0,20	0,01	1,51
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	2 932,63
2018	NA	1088,01	2007,34	3 095,35

Figure 3 shows the installed capacity by province and territory for grid-connected PV power (reported in MW_{DC}), and the number of utility interconnected PV systems as of December 31, 2018.

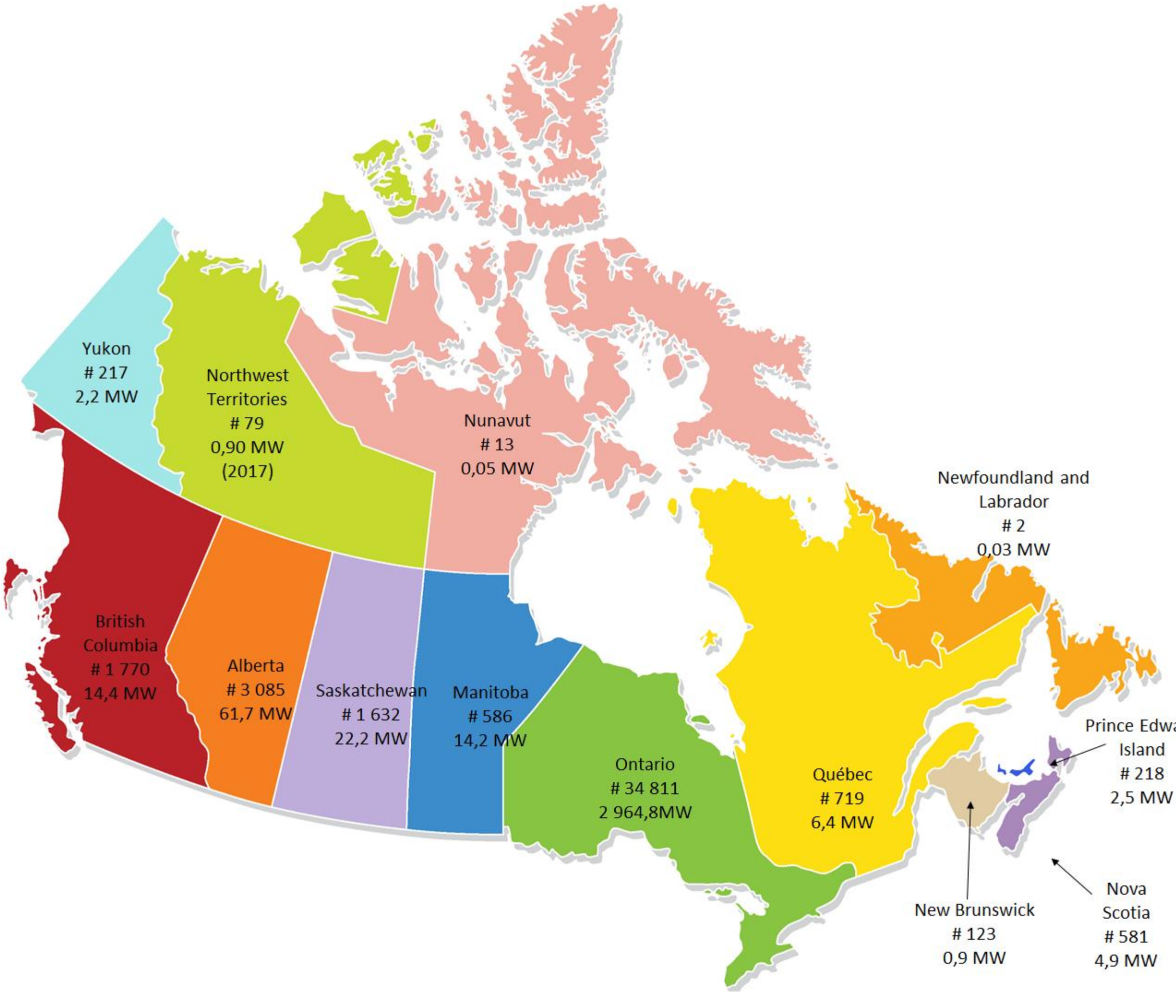

Figure 3: Map showing the Canadian provinces' and territories' PV power capacity (MW_{DC}). Note: PV data for Northwest Territories were not made available for 2018, and so 2017 values are reported.

Figure 4 gives an overview of Ontario's net metering, which is under the jurisdiction of the OEB. The programme has two principal requirements: power generated must be from renewable sources (wind, water, solar, or biomass), and the energy generated must be for the customer's own use or be paired with a storage facility. Alterations to Ontario's net metering programme came into force on July 1, 2017, which expanded net metering equipment to systems larger than 500 kW. The PV capacity data collected by the IESO and the OEB were added together to obtain the total capacity for the province. The OEB also collects data on energy storage facilities linked to PV arrays. As of December 31, 2018, the total capacity of installed storage facilities (distributed among four solar projects) was 509 kW_{AC} [6]. Data on PV electrical storage sites in other provinces and territories are not currently collected for this report.

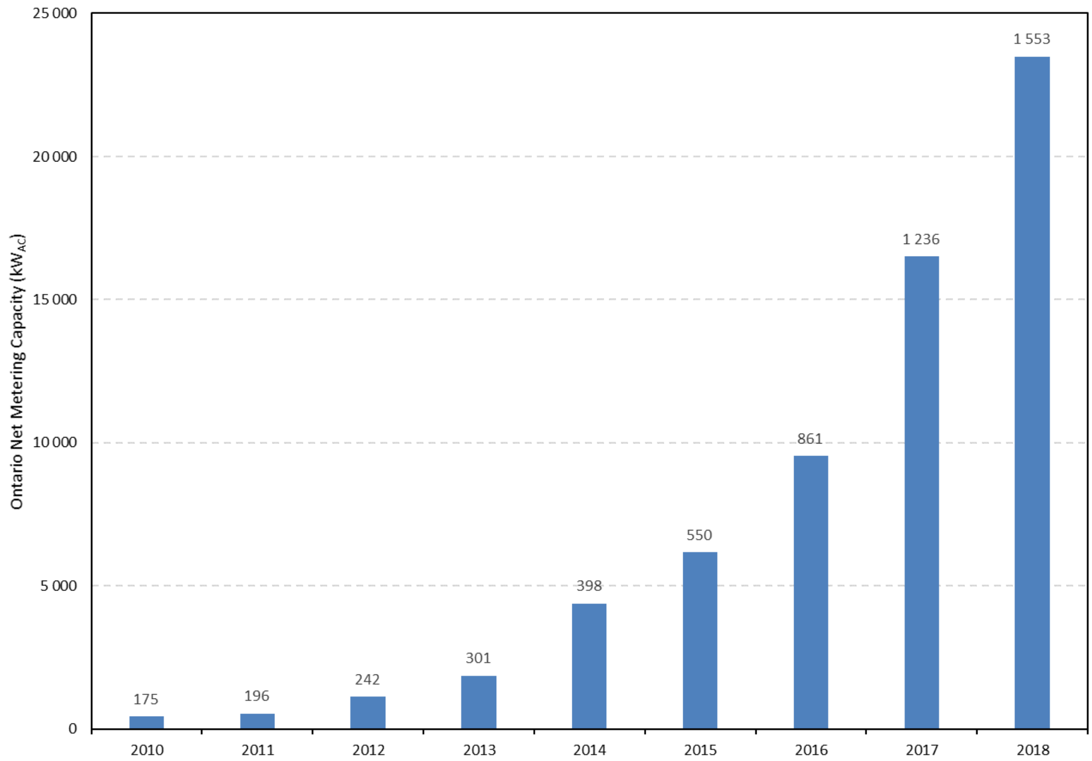

Figure 4: Ontario cumulative net metering capacity timeline. The corresponding number of system installations are shown above each year.

Table 6 provides national figures on power generation and electricity demand as well as an estimate of total PV energy production. Total power generation capacity for 2018 was calculated using Statistics Canada data for 2017 [7] for all energy sources and National Survey Report (NSR) PV capacity data. In order to derive the 2018 total power generation capacity, a 0,8% per year growth rate was assumed [8]. Total renewable power generation capacities were calculated in a similar manner except using technology specific growth rates derived from the previous year (0,4% growth for hydro, and 3.6% growth for wind) [7]. Total electricity demand was estimated from Statistics Canada's supply and demand for primary and secondary energy [9]. New power generation and renewable power generation capacities installed in 2017 and 2018 were estimated using Statistics Canada data for wind, tidal and hydro [7], with NSR data used for PV capacity. In order 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/kW$_p$. The average PV potential was determined using satellite-based insolation data and assuming a typical performance ratio of 0,75 [10]. Photovoltaic electricity production was calculated as a percentage of total capacity using Statistics Canada annual generation estimates (including energy imports and excluding energy exports) [11].

Table 6: PV power and the broader national energy market.

	2017	2018
Total electrical power generation capacities (all technologies) [GW] [7] [8]	145,4	146,6
Total renewable power generation capacities (including hydropower) [GW] [7]	95,7	96,6
Total electricity demand [TWh] [8]	527,6	531,8
Total energy demand [TWh] [9]	2 286	2 309
New power generation capacities installed during the year [GW] [7]	1,865	1,317
New renewable power generation capacities installed during the year (including hydropower) [GW] [7]	0,576	0,897
Estimated total PV electricity production (including self-consumed PV electricity) [TWh] [10]	3,37	3,56
PV electricity production as a % of total electricity generation capacity	0,57	0,60

2 KEY ENABLERS OF PV DEVELOPMENT

Enabling technologies such as decentralized storage, and electric cars, buses and trucks, whether connected to PV or not, can increase the grid's hosting capacity and/or directly provide storage capacity. Indirect technology, such as heat pumps, provide a capacity for heating and cooling which may require electricity produced by a PV array. Table 7 provides information on these technology categories.

No official data at a federal level are currently available on the number of decentralized energy storage systems in Canada. A view of Ontario is, however, available through the Ontario Energy Board which recorded a cumulative total of four PV electrical storage facilities with combined capacity of 509 kW_{AC} [12].

Regarding heat pump capacity, the residential heating and cooling market provides opportunity for energy savings and greenhouse gas reduction. The Canadian residential building sector accounts for approximately 15% of the country's secondary energy end use of which around 81% was due to space heating and water heating. This corresponds to approximately 16% of Canada's total greenhouse gas emissions. In a study comparing air-source and ground-source heat pumps in five Canadian provinces (Nova Scotia, Québec, Ontario, Alberta, and British Columbia) it was shown that heat pumps could provide up to 66% secondary energy savings and up to 84% greenhouse gas reduction. Cold climate air-source heat pumps were most cost-competitive in the eastern provinces while the adoption of ground-source heat pumps depended on a variety of factors such as borehole cost. Regarding installed heat pump capacity, there has been linear growth between 2000 and 2015. While heat pump installation data are not available for the past three years, the 2018 installed capacity was estimated by extrapolation of the linear trend. Heat pump installation has increased steadily in Canada but the installed capacity is still too small to have an effect on secondary energy use. One of the main challenges to making heat pump technology widely available is competition with the low cost of natural gas and electrical baseboard heating prices. Natural Resources Canada research into heat pump technology focuses on the use of ejectors with air-source heat pumps, and the use of CO_2 refrigerant to reduce borehole size in ground-source heat pumps [13]. The two provinces with the largest number of residential heat pumps are Québec and Ontario which, in 2015, accounted for approximately three quarters of the Canadian total.

As of September 2018, the combined sales of both plug-in hybrid (PHEV) and battery electric vehicles (BEV) in Canada reached 34 357. This represented an increase of 166% over the third quarter of 2017. If the current rate continues, there will be more electric vehicles purchased in 2018 than the previous three years combined. Provincial incentives in Ontario for EVs were discontinued in June 2018, and while sales of EVs predictably peaked at that time to take advantage of programme benefits, EV sales showed robust recovery and monthly growth in the aftermath of programme cancellation. Provincially, the largest adopters of EV technology remain Québec, Ontario, and British Columbia [14].

Electric bus adoption in Canada is growing and pilot projects are underway in Montreal, Vancouver, and Toronto. Domestic electric bus production is centred in Quebec (Nova Bus) and Manitoba (New Flyer Industries). Electric bus operation in Canada is almost entirely hybrid buses consisting of a mix of parallel hybrid systems and series hybrid systems. The parallel hybrid system has a relatively small battery and electric motor where the battery is recharged only while the vehicle is in motion. Series hybrid systems are plug-in hybrids and thus interact with the electricity grid. No official, federally compiled figures on the number of hybrid and electric buses are available, however it is estimated that at least 1 250 hybrid electric buses are in service across the country. For example, approximately 33% of Toronto's 1 700 bus fleet is hybrid and growth in hybrid bus numbers is expected in most cities. Montreal will also be adding 300 hybrid buses to its fleet by 2020. By comparison, electric bus purchases are fewer but expected to grow as battery costs reduce. Electric bus operation is concentrated in Montreal (36), Toronto (10), Vancouver (4), and Victoria (2). Many municipalities are targeting substantial increases in fleet electrification. For example, all new fleet additions in Montreal are either hybrid or fully electric, with a goal of 100% electric by 2040 [15].

Table 7: Information on key enablers. For Electric cars, the number of units sold during the year is reported to the end of September, 2018.

	Description	2018	Cumulative volume	Source
Decentralized storage systems	No provincial or federal programmes	NA	NA	NA
Residential Heat Pumps [# of units]	The majority of heat pumps in Canada are air-source	21 200	796 600	[16]
Electric cars [# of units]	Combined sales of PHEV and BEV	34 357	80 298	[14]
Electric buses and trucks [# of units]	Hybrid buses (mostly 40 foot, diesel-electric)	NA	≈ 1 250	[17]

3 COMPETITIVENESS OF PV ELECTRICITY

3.1 Module prices

Crystalline silicon module prices vary by manufacturer and module type (monocrystalline and multicrystalline). As of August, 2018, modules from China are on average 7.3 cents cheaper than Europe and the rest of Asia. However, the trend for decrease in module spot prices remains similar in all markets. The general trend in module price decline is 10 to 20 % year-on-year. However, for most bids, the country of origin may play little role in the pricing. Monocrystalline spot market and wholesale prices may vary from as low as 0.41 $/W up to approximately 1 $/W depending on manufacturers.

For 2018, in Table 8, wholesale price estimates applied to high efficiency monocrystalline modules for modules of 290 W and above (such as PERC, HIT, n-type, or back-contact cell types). To obtain the 2018 lowest and highest wholesale price estimates, survey data from twelve module manufacturers were used [18].

Table 8: Typical module prices for selected years ($/W$_{DC}$).

Year	Lowest price of a standard module crystalline silicon	Highest price of a standard module crystalline silicon	Typical price of a standard module crystalline silicon
2005	----	----	4,31
2006	----	----	5,36
2007	----	----	4,47
2008	----	----	3,91
2009	----	----	3,31
2010	----	----	2,27
2011	----	----	1,52
2012	0,85	----	1,15
2013	0,80	----	0,95
2014	0,82	----	0,85
2015	0,75	----	0,80
2016	0,66	0,9	0,78
2017	0,75	0,81	0,8
2018	0,61	0,65	0,63

Photovoltaic system prices, shown in Table 9, take into account hardware costs such as mounting materials and inverters, as well as installations and development. The lifespan of arrays was assumed to be 25 years with new inverters purchased after 12,5 years. A decommissioning cost was applied and a residual equipment value of 15% was assumed. Land costs were based on Statistics Canada estimates in each province depending on the type of use. Land costs were assumed to be negligible for commercial, community, and residential applications since modules would be installed on rooftop property that had already been purchased [19].

Table 9: Turnkey PV system prices of different typical PV systems.

Category/Size	Typical applications and details	Current prices [$/W$_{DC}$]
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.	NA
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.	2,93
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.	NA
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.	2,21
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, agricultural facilities, grocery stores, etc.	NA
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, agricultural facilities, grocery stores, etc.	2,21
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, agricultural facilities, grocery stores, etc.	NA
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity for grid-connected industrial buildings, warehouses, etc.	1,46
Small centralized PV 1-20 MW	Grid-connected, ground-mounted, centralized PV systems that operate as centralized 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.	1,46
Large centralized PV >20 MW	Grid-connected, ground-mounted, centralized PV systems that operate as centralized 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.	1,46 (1,56[1])

[1] This figure refers to the estimated cost for a monocrystalline PV system with single-axis tracking

Table 10: National trends in system prices for different applications

Year	Residential BAPV Grid-connected, roof-mounted, distributed PV systems 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 [$/W]	Small centralized PV Grid-connected, ground-mounted, centralized PV systems 10-20 MW [$/W]
2005	10,00	10,00	10,00	NA
2006	8,50	12,60	12,60	NA
2007	8,50	10,00	10,00	NA
2008	6,50	NA	NA	NA
2009	8,50	6,00 - 8,00	6,00 - 8,00	NA
2010	6,50 - 8,00	6,00	6,00	4,00
2011	6,79	5,27	5,27	3,50
2012	3,00 - 5,00	4,00	4,00	2,80
2013	3,44	3,27	3,27	2,88
2014	3,00 - 4,00	2,20 - 2,90	2,20 - 2,90	2,00 - 2,60
2015	2,80 - 6,00	2,20 - 2,90	2,20 - 2,90	2,00 - 2,60
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	2,21	1,46	1,46

3.2 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 at the end of 2018 is presented in Table 11.

The cost structure presented is from the customer's point of view and does not reflect the installer companies' overall costs and revenues. The “average” category in Table 11 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 the customer. The “low” and “high” categories are the lowest and highest costs that have been reported within each segment. These costs are individual posts, i.e. summarizing these costs do not give an accurate system price.

Table 11: Cost breakdown for a grid-connected roof-mounted, distributed residential PV system of 5-10 kW.

Cost category	Average [$/$W_{DC}$]	Low [$/$W_{DC}$]	High [$/$W_{DC}$]
Hardware			
Module	0,63	0,61	0,65
Inverter	0,45	0,30	0,60
Other electronics (mounting, cables, etc.)	0,33	0,18	0,48
Subtotal Hardware			
Soft costs			
Planning			
Installation work	1,52	1,20	2,40
Shipping and travel expenses to customer			
Permits and commissioning (i.e. cost for electricians, etc.)			
Project margin			
Subtotal Soft costs	1,52		
Total (excluding VAT)	2,93		
Average VAT			
Total (including VAT)			

3.3 Financial parameters and specific financing programmes

With more than 96% of Canada's total cumulative installed capacity contracted with long-term power purchase agreements with the IESO in the province of Ontario, financing from institutional lenders has been available for projects, or portfolios of projects, that meet certain financial thresholds. Residential and small commercial projects have been less well served but the number of new options for low-cost capital is growing.

The Canadian Infrastructure Bank, a federal government crown corporation, was established in June 2017. The Bank uses federal financing to attract private and institutional partners and is investing $35 billion into infrastructure projects of which $5 billion is devoted to renewable energy initiatives such as PV [20].

3.4 Specific investment programmes

The vast majority of investment programmes supporting Canadian PV were in Ontario and operated by the IESO as described in Section 1. Prior to 2017, several other programmes also existed in other provinces resulting in the installation of 10's or 100's of kW's up to a few MW's. The most significant of these programmes was the SaskPower Net-Metering Rebate Programme in the province of Saskatchewan which was shut down for review in 2019.

In 2017, several new adoption programmes in the province of Alberta were implemented including the "Residential & Commercial Solar Programme," the "Municipal Solar Programme" and the "Indigenous Solar Programme." It is these programmes that caused Alberta to become the first province outside Ontario to exceed the installation of 5 MW in a single year.

In 2017, the Government of Canada also continued to offer tax incentives for commercial solar PV systems including accelerated depreciation as Class 43.2 Accelerated Capital Cost Allowance (ACCA) and the Canadian Renewable and Conservation Expense (CRCE) [21]. Additional details are provided in Table 12.

Table 12: Summary of existing investment schemes.

Investment schemes	Current status
Third-party ownership (no investment)	Third-party ownership is not permitted under current Ontario net metering regulations.
Renting	Not permitted under current regulations.
Leasing	A number of companies offered leased systems in Canada in 2017.
Financing through utilities	No utilities are yet to offer on-bill financing specifically for solar PV as of the end of 2017.
Investment in PV plants against free electricity	A number of “Solar Gardens” are under development or in operation in Canada including in the City of Nelson, British Columbia.
Crowd funding (investment in PV plants)	Several solar energy co-operatives have been incorporated to facilitate investment in, and ownership of, solar PV systems.
Community solar	There are several approaches to "Community Solar" being trialled and tested throughout Canada.
International organization financing	The Green Energy Investment Agreement (GEIA), initiated in 2010, mandated investment and cooperation between the Government of Ontario and Samsung and the Korea Electric Power Corporation.
Other (please specify)	Under Ontario’s FIT programme, many companies install and own systems on residential and commercial/industrial rooftops that are leased by a third party whereby the building owner receives monthly payments for the space on the roof with little or no initial investment.

3.5 Additional country information

Canada’s electricity sector is regulated region-by-region according to each province and territory and is comprised primarily of a mixture of wholesale open markets and vertically integrated crown corporations. Electricity generation in Canada was estimated to be 653.3 TWh in 2018 with the largest producers of electricity being the provinces of Quebec, Ontario, British Columbia, and Alberta. The population of Canada was estimated to be approximately 37,2 million inhabitants at the end of 2018. Additional information is provided in Table 13.

Table 13: Country information

Retail electricity prices for a household (power demand ≤ 40 kW)	8,20 - 19,35 c/kWh [22]
Retail electricity prices for a commercial company (power demand from a) 40 kW to b) 2500 kW)	a) 10,44 - 17,76 c/kWh [22] b) 7,79 - 16,58 c/kWh

Retail electricity prices for an industrial company (power demand from a) 5 000 kW to b) 50 000 kW)	a) 5,8 - 12,2 c/kWh [22] b) 4,99 -12,03 c/kWh [22]
Population at the end of 2018	37 242 571 [23]
Country size [km^2]	9 985 000 [23]
Average PV yield in [kWh/kW]	1 150 kWh / kW_p
Name and market share of major electric utilities	A partial list: Hydro-Québec, BC Hydro and Power, Hydro One

4 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have an influence on PV development by incentivizing or simplifying the process. Indirect support policies change the regulatory environment in a way that can push PV development. Table 14 provides a summary of key measures.

Table 14: Summary of PV support measures

	On-going measures in 2018 – Residential	**Measures introduced in 2018 – Residential**	**On-going measures in 2018 – Commercial + Industrial**	**Measures introduced in 2018 or on-going – Commercial + Industrial or centralized**
Feed-in tariffs	(Province of Ontario) 50 MW microFIT (≤ 10 kW)		(Province of Ontario) 123,5 MW and 100 MW of FIT 3 and FIT 3 extension (> 10 ≤ 500 kW)	
Feed-in premium (above market price)				
Capital subsidies	Saskatchewan and other provinces and municipalities such as Medicine Hat, Alberta, Northwest Territories			
Green certificates	Yes (voluntary)			
Renewable portfolio standards (RPS) with/without PV requirements				
Income tax credits				
Self-consumption	Many utilities offer residential lease-to-own programmes			

Net-metering	Ontario and British Columbia have net-metering programmes. Net-metering in Saskatchewan is under review for an indeterminate period. Although Saskatchewan's rebate has been extended to 2021, it has been capped at 16 MW which leaves only an additional 2 MW for expansion.			
Net-billing				
Collective self-consumption and virtual net-metering	Several provinces and regulators explored a variety of approaches to "Community Solar" in 2017			
Commercial bank activities e.g. green mortgages promoting PV				
Activities of electricity utility businesses				
Sustainable building requirements			Yes (voluntary)	
BIPV incentives				

4.1 National targets for PV

There is no specific national target for PV set by the federal government or among the provinces and territories. Nevertheless, several provinces have set targets for increased percentages of renewables, and several cities (for example Edmonton, Victoria, Guelph, and Nelson) have committed to 100% renewable energy in the coming years [24].

4.1.1 New, existing or phased out measures in 2018

4.1.1.1 Global warming commitments

Canada's current greenhouse gas emissions reductions target is a lowering of 30% below 2005 levels by 2030. Through Canada's commitment to the Paris Agreement (the 21st yearly Conference of the Parties, COP 21) in December 2015, a transition towards a low carbon economy is underway in order to limit global average temperature rises to below 1,5°C. A first step towards Canada's commitment to meet these goals was made by enacting the Pan-Canadian Framework on Clean Growth and Climate Change [25] to address Canada's international obligations under the United Nations Framework Convention on Climate Change. The Pan-Canadian Framework has four parts: pricing carbon, complementary actions to further reduce emissions, adaptation measures to mitigate the damage of global warming, and supporting the growth of clean technologies. There is also a degree of flexibility allocated to the provinces to pursue their own emissions reduction strategies at the local level.

The Federal Government implemented country-wide carbon pricing in fall 2018. The price began at $20 per CO_2 equivalent tonne in 2019 and increases by $10 each year to reach $50 per tonne in 2022. The programme does not apply to those provinces, such as British Columbia, which already has carbon pricing mechanisms in place.

4.1.1.2 Description of support measures (excluding BIPV, VIPV and rural electrification)

In terms of PV policy, support measures are largely left to the provinces and territories to define. However, solar PV will be eligible for several national support programmes announced by the Federal Government in 2017 including the $500 million Low Carbon

Economy Challenge Fund, the $220 million Clean Energy for Rural and Remote Communities and the $100 million Smart Grid Programme. Ontario's net-metering regulation now forms the basis for future project development.

Québec: the primary support measure for PV was the RenoVert programme which provided residents with a tax credit worth 20% of systems cost with a maximum credit of $10 000. This programme operated during 2018, but expired on March 31, 2019. It has not been renewed for the next fiscal year.

4.1.1.3 BIPV development measures

There are currently no policies to support BIPV either provincially or federally. However, several voluntary green building programmes have resulted in demonstration projects.

4.1.1.4 Utility-scale measures including floating and agricultural PV

Policies to support utility-scale PV, in the context of this report, focus on Ontario, Alberta and Saskatchewan, which together account for approximately 99% of Canada's commercially operational PV capacity.

Ontario: The main support mechanism for utility-scale PV was the FIT programme which provided a category for system sizes larger than 500 kW. Ontario's Large Renewable Procurement (LRP) programme also contributed to large-scale PV projects contracting 140 MW in the first round in 2016, but the second phase of LRP intended for 2017 was cancelled prior to commencement.

Alberta: Emissions Reductions Alberta provided support to Alberta's first utility scale PV project, the 15 MW_{AC} distribution-connected Brooks Solar 1 facility. At this stage, the remainder of Alberta's installed PV capacity is either grid-connected microgeneration or off-grid rural [26]. The Government of Alberta has also committed to procuring 135 000 MWh of utility-scale solar electricity per year to power more than half of their own operations. This procurement took place in 2018. The province's Renewable Electricity Programme (REP) also intends to procure 5 GW of utility-scale renewable electricity [27]. In 2017, the first round was completed resulting in 600 MW of wind power with contract pricing in the range of $30-43/MWh. The second and third rounds were also announced to procure 300 MW and 400 MW respectively (the former requiring equity participation from indigenous communities). However, due to the procurement structure, it is not expected that utility-scale solar PV will participate in the REP until the fourth and subsequent rounds.

Saskatchewan: The province of Saskatchewan held a competitive procurement for the region's first 10 MW solar facility in 2017. A second 10 MW facility is expected to be procured in 2019.

4.1.1.5 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 cleaner sources of energy including solar. The programme for Clean Energy for Rural and Remote Communities (CERRC) aims to reduce dependence on diesel fuel for electricity and heating needs. In terms of PV, CERRC provides $60 million for demonstration projects and $90 million for deployment of commercial-scale renewable energy for the purposes of displacing diesel fuel [28]. Commercial-scale projects must be of at least 250 kW capacity. This program spans six years beginning in 2018.

4.1.1.6 Support for electricity storage and demand response measures

Several innovation funds have given rise to solar projects with electricity storage including the province of Ontario's Smart Grid Fund. The Federal Government's Smart Grid programme, announced in 2017, is also expected to result in support for combined solar and storage projects across Canada.

4.2 Self-consumption measures

Table 15: Summary of self-consumption regulations for small private PV systems in 2018.

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
	13	Additional features	None

4.3 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 several private or public persons) have begun in several Canadian jurisdictions with the potential for implementation in 2018.

4.4 Tenders, auctions & similar schemes

Ontario's IESO has used three procurement methodologies: standard offer, bilateral negotiations, and competitive bid as described in Section 1. Bilateral-negotiation and competitive bid processes are rare. The vast majority of contracts in Ontario for PV have been awarded by standard offer. In 2017, contracts for commercial-scale solar PV projects in the fifth and final round of the FIT programme were awarded by tender. Utility-scale competitive procurements in Alberta and Saskatchewan are described in section 4.2.1.4 above. Solar PV contract periods are generally awarded for a period of 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. Means by which other programmes are funded include revenues of carbon pricing programmes and provincial and municipal taxes.

5 INTEREST FROM ELECTRICITY STAKEHOLDERS

5.1 Structure of the electricity system

Each Canadian province and territory has jurisdiction over its electricity sector. As a result, the market structure and regulations of each is unique (although several inter-ties do join the systems). 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 an independent system operator and wholesale markets. Saskatchewan, Nova Scotia, and Prince Edward Island are structured along vertically integrated utilities and highly dependent on fossil fuels, leading to high prices as in restructured provinces.

5.2 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 programme while others simply interconnect projects and handle the settlement of payments. In other jurisdictions, utilities offer rebates, manage net-metering, and are considering offering solar financing products such as lease-to-own. Given the renewed focus on global warming policy and the rapidly declining costs in solar electricity, many utilities began to explore PV and continue to do so in 2018.

5.3 Interest from municipalities and local governments

There are over 3 500 urban and rural municipalities in Canada. Many municipalities continued to explore PV applications throughout 2018.

5.4 Social Policies

In terms of PV policy, support measures are largely left to the provinces and territories to define. However, solar PV will be eligible for several national support programmes announced by the Federal Government in 2017 including the $500 million Low Carbon Economy Challenge Fund, the $220 million Clean Energy for Rural and Remote Communities and the $100 million Smart Grid Programme. Ontario's net-metering regulation now forms the basis for future project development. There is also the Federal tax provision for clean energy equipment. Clean energy equipment, such as PV, qualifies for an accelerated Capital Cost Allowance rate (a deductible portion of the capital cost of a depreciable property). This rate is between 30 % and 50 % for equipment purchased after 1994 and 2005 respectively [29].

Other sub-national measures of importance launched in 2017 include the province of Alberta's $36 million Residential and Commercial Solar Programme implemented by Energy Efficiency Alberta. This consists of a subsidy providing a $ 0.9 per watt incentive to residential systems. The maximum allowable grant is the lesser of 10% of the system cost or $ 10 000. In addition to homeowners and small businesses, all publicly funded institutions and non-profit organizations are eligible. Commercial and non-profit groups receive incentives of $ 0,75 and $ 1,00 per watt respectively. The programme is fully subscribed and no longer accepting new applications [30].

The Government of Québec offers the Rénoclimat and Novoclimat programme providing incentives for home energy efficiency upgrades. Rebates can range from $ 2 000 to $ 4 000. For PV, as outlined previously, the Réno Vert programme was the primary incentive mechanism for distributed installations in 2018, providing a tax credit of 20% of system cost worth a maximum of $10 000. This programme, although not renewed for the 2019 fiscal year, may be reactivated at a later date [31].

Announced in December 2017, the Ontario GreenOn solar rebates program (which used proceeds generated by the cancelled Cap and Trade programme) stimulated growth in rooftop PV in Ontario in 2018. However, with the cancellation of GreenOn in 2019, there is a paucity of direct PV support mechanisms in upcoming years [31].

British Columbia has one solar energy incentive, a provincial sales tax exemption. The exemption applies to photovoltaic modules and all balance of system components [31].

5.5 Retrospective measures applied to PV

On July 5, 2018, 758 solar PV and wind energy projects were cancelled in Ontario. The solar projects cancelled were in the FIT5 (small community project) and LRP1 (competitive bid market price) contracts. The cancellations negatively affected local ownership among small communities and First Nations, as well as impacting local distributors and installers.

5.6 Indirect policy issues

5.6.1 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 cleaner sources of energy including solar. The programme for Clean Energy for Rural and Remote Communities (CERRC) aims to reduce dependence on diesel fuel for electricity and heating needs. In terms of PV, CERRC provides $60 million for demonstration projects and, for commercial-scale projects greater than 250 kW capacity, $90 million is available in project financing to displace diesel fuel.

5.6.2 Support for electricity storage and demand response measures

Several innovation funds have given rise to solar projects with electricity storage including the province of Ontario's Smart Grid Fund. The Federal Government's Smart Grid programme, announced in 2017, is also expected to result in support for combined solar and storage projects across Canada.

5.6.3 Support for electric vehicles (and vehicle integrated PV)

The support measures for electric vehicles (EVs) are mainly situated in Quebec, Ontario, and British Columbia. However, support policies for EVs in Ontario were discontinued in June 2018 by a new provincial government which withdrew from the cap and trade programme that funded these incentives. Together, Québec, British Columbia, and Ontario account for approximately 95% of all electric vehicles sold in Canada [32]. Electric vehicle support measures in these provinces are not explicitly linked to the storage opportunity they provide for renewable energy, but are offered in the context of reducing greenhouse gas emissions from the transport sector, and improved air quality. A summary of monthly electric vehicle sales up to and including the third quarter of 2018 is given Figure 5 [14].

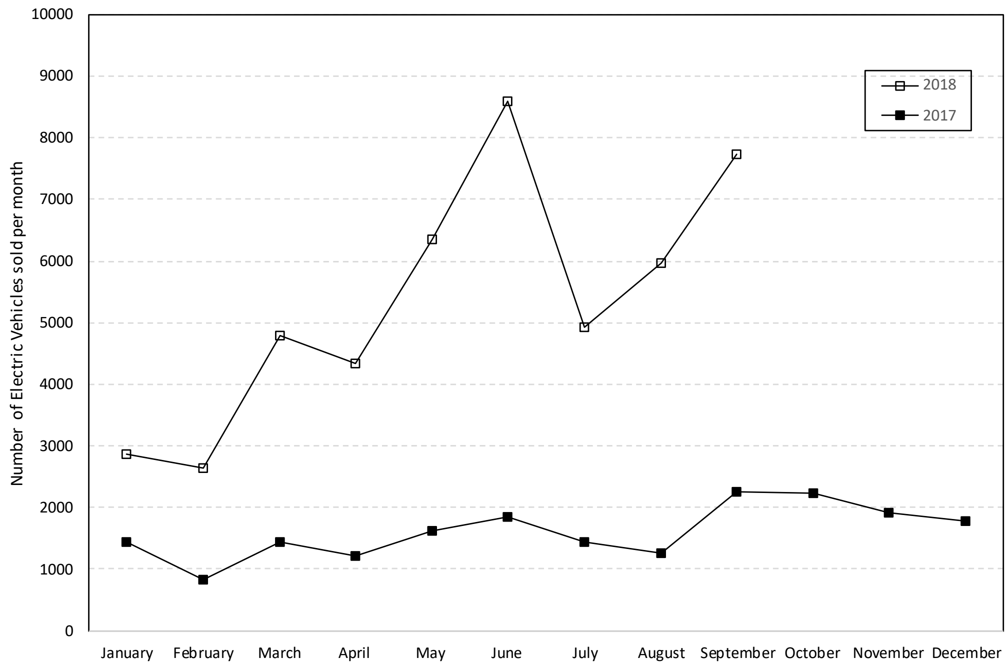

Figure 5: Monthly electric vehicle sales in Canada by number of units. Plug-in EV sales are composed of battery electric vehicles and plug-in hybrid electric vehicles excluding non-plug-in hybrid vehicles.

Quebec has set a target for 100 000 electric vehicles on the road by 2020, one million by 2030, and provides rebates of up to $8 000 for electric vehicles including fully electric, plug-in hybrid, hydrogen fuel cell cars, and electric motorcycles. A $4 000 discount is available on used electric vehicles. Quebec also has Canada's largest network of public charging stations [33].

Up until June 2018, Ontario offered an electric and hydrogen vehicle incentive programme. Rebates for fully electric or plug-in-hybrid vehicles were scaled by battery size and electric range. Rebates ranged from $5 000 up to $14 000. Ontario offered 50% and 80% price reduction for the installation of home and workplace charging stations, respectively [34]. Following a recent provincial election, Ontario's new government cancelled all rebates for electric and hydrogen vehicles. The effect of these cutbacks on electric vehicle adoption in Ontario will be a point of study in the coming years. It is the cancellation of this programme that explains the spike in EV purchasing in June 2018, shown in Figure 5, as people sought to benefit from incentives while they were still available.

British Columbia offers $5 000 off the purchase of a fully electric, fuel cell electric, or plug-in-hybrid vehicles through its clean EV programme. Another incentive offers a $6 000 rebate to trade in gasoline-driven car for a fully electric vehicle. The charging incentive provides a 75% reduction on the purchase and installation of a home charging station, and a 50% reduction for workplace charging infrastructure [32].

5.6.4 Curtailment policies

Project economics can be affected by curtailment. Although curtailment of PV power due to excess generation during low load periods, transmission congestion, or interconnection issues may occur, no data are collected on these features for this report.

5.6.5 Other support measures

Canada’s Federal Government has implemented a price on carbon starting at $20 per tonne in 2019, and rising by $10 per year to $50 per tonne in 2022. This measure puts a price on pollution and attempts to create new revenue streams for re-investment in technologies that displace greenhouse gas emissions.

5.7 Financing and cost of support measures

The way in which incentives are paid in Canada varies from region to region. Ontario's feed-in tariff is funded by electricity consumers. Means by which other programmes are funded include revenues of carbon pricing programmes and provincial and municipal taxes. Although PV installation has grown at impressive rates in Ontario, this has been predominantly under the feed-in-tariff based methodology. Over the past few years, governments in several countries have faced both financial and political pressures under feed-in-tariff programmes. Partly in an effort to control the rising costs of subsidies, there has in Ontario 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 photovoltaic 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 drive down auction costs faster than construction costs. This has resulted in shrinking profit margins for investors which, combined with the cancellation of government subsidised FIT/microFIT and LRP programme, has led to declining investor interest. This may explain Ontario's 80% reduction in PV capacity growth in 2018 as compared to its peak in 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. Such practices were, for example, recently reported by the International Renewable Energy Agency (IRENA) [35], for PV projects in India and Brazil. Declining investment must also be considered in the context of interest rates, which determine the cost of capital used to finance solar projects, and which constitute a significant portion of total project costs. A rise in interest rates would reduce investment levels.

6 INDUSTRY

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

Canada continues to produce feedstock for the global solar industry through 5N Plus (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 America and South America. First Solar (US) is their primary customer and is the largest thin film PV module 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 16: Feedstock, ingot and wafer producer's production information for 2018.

Manufacturers (or total national production)	Process & technology	Total production	Product destination	Price
5N Plus	CdTe & CIGS high purity compounds[2]	350 tonnes (2010 est.)		

[2] CdTe refers to cadmium telluride. CIGS refers to the chalcopyrite crystal structure consisting of copper indium gallium (di)selenide.

6.2 Production of photovoltaic cells and modules (including TF and CPV)

Module manufacturing is defined as the industry where the process of the production of PV modules (the encapsulation) is done. 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, etc. The manufacturing of modules is only counted if the encapsulation takes place in Canada.

Table 17 presents data from four companies in Canada producing PV modules, three of which have their facilities located in Ontario, and the fourth in Québec. All are involved in contract manufacturing of modules for other multi-national companies. Together, these four companies produced an estimated 380 MW/year, largely for the domestic market in Canada. Total PV cell and module manufacturing together with production capacity information are summarised in Table 17.

Table 17: PV cell and module production capacity information for 2018

Cell/Module manufacturer (or total national production)	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS)	Total Production [MW]		Maximum production capacity [MW/yr]	
		Cell	Module	Cell	Module
Wafer-based PV manufacturers					
Canadian Solar	sc-Si, mc-Si		390		880
Heliene	mc-Si				
Silfab	sc-Si, mc-Si				
Stace	sc-Si, mc-Si				
Thin film manufacturers					
Cells for concentration					
Totals			**390**		**880**

6.3 Manufacturers and suppliers of other components

A comprehensive sector profile report was published in March 2012 which explores the whole PV supply chain in Canada, including balance of system technologies. The Sector Profile for PV in Canada can be found on the CanmetENERGY website [36]. The balance of system technology market in Canada is mainly served by foreign companies with operations in Canada, or production through contract manufacturing. The companies that have development and manufacturing facilities in Canada include, Eaton and Sungrow Canada.

7 PV IN THE ECONOMY

7.1 Job creation

The amount of employment created by PV was calculated using the model for Jobs and Economic Development Impact (JEDI) developed by NREL [37]. The JEDI model was customized for Canada using Canadian national multipliers, local costs, and local content percentages. These data were provided by Natural Resources Canada and Compass Renewable Energy Consulting Inc. [38]. The amount of PV-related employment by category is given in Table 18.

Table 18: Estimated PV-related labour places in 2018.

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	4 301
Distributors of PV products	
System and installation companies	
Electricity utility businesses and government	
Other (operation and maintenance of previously constructed, legacy, systems)	1 103
Total	**5 509**

7.2 Business value

The value of PV business in Canada as it relates to the solar PV capacity installations in 2018 is estimated in Table 19.

Table 19: Estimation of the value of the PV business in 2018 (VAT is excluded). The vast majority of growth in PV capacity in 2018 occurred in distributed generation.

Sub-market	Capacity installed in 2018 [MW]	Average price [$/W]	$ Amount in million	Sub-market
Off-grid				
Grid-connected distributed	161,6	2,50	404	
Grid-connected centralized	1,05	2,00	2,1	
Total value of PV business in 2018 ($ amount in million)			406,1	

8 HIGHLIGHTS AND PROSPECTS

8.1 Highlights

Canada's PV sector has reached 3,10 GW_{DC} installed capacity of which approximately 96% is located in Ontario. The PV market in Ontario is experiencing a slowdown due to the closing of the Large Renewable Procurement, Feed-In-Tariff (FIT), and microFIT programmes. Across the country, there is continued growth in small-scale PV systems connected to local electricity distribution systems particularly in Ontario, Québec, Alberta, Saskatchewan, and British Columbia.

8.2 Prospects

A federal policy on photovoltaic support measures is needed to increase PV capacity and provide a homogeneous uptake of PV across the country. Achieving Canada's commitment to greenhouse gas emissions reductions of 30% below 2005 levels by 2030 represents a significant opportunity for Canadian photovoltaic industry development. A combination of falling costs, global warming mitigation policies, and consumer demand point to an increasing amount of PV generation. According to the National Energy Board, Canada's future renewable energy capacity is expected to grow with wind capacity doubling and solar capacity more than tripling by 2040 [39]. However, in order to meet emissions reduction targets, a large and rapid increase in investment in PV (and other renewable technologies) in Canada is required. As outlined in section 5.7, depending solely on profit-driven private sector investments in the absence of feed-in-tariff programmes has led to a slowdown in new PV capacity building at precisely a time when an increase is needed to fight global warming. As a result, outside-of-market mechanisms may be required to push renewable technology deployment levels to reach their full potential.

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