IEA INTERNATIONAL ENERGY AGENCY

National Survey Report of Photovoltaic Applications in Canada for 2017

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

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PVPS

Cover Picture:

Elemental Energy's 17 MW_{DC} utility-scale photovoltaic array in Brooks, Alberta.
(Photo Credit: Kyle Bakx)

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Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its member countries.

The IEA Photovoltaic Power Systems Technology Collaboration Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The participating countries and organisations can be found on the www.iea-pvps.org website.

The overall programme is headed by an Executive Committee composed of one representative from each participating country or organization, while the management of individual tasks (research projects / activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org.

Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme (PVPS) 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 2017. Information from this document will be used as input to the annual report on trends in photovoltaic applications.

The PVPS website www.iea-pvps.org also plays an important role in disseminating information arising from the programme, including national information.

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 2017 statistics if the PV modules were installed and connected to the grid between January 1 and December 31, 2017, 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. 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 become 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 in photovoltaics vary by province. Ontario represented approximately 97% of Canada’s total cumulative installed capacity and approximately 84% of capacity growth in 2017. 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 applications of photovoltaics in Canada. Within the remainder of this sub-section, a breakdown of photovoltaics applications in Ontario will be provided.

In Ontario, 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 small-scale generation contributing to local distribution systems and communities. As shown in Figure 1, only around 1,8% (380 MW_{AC}) of Ontario's transmission connected generating capacity was composed of photovoltaics. However, on the distribution system side, photovoltaics contributed the majority of the installed capacity at 61,5% (2 029 MW_{AC}). As shown in Figure 2, growth in distributed PV systems was an important driver of expansion in 2017.

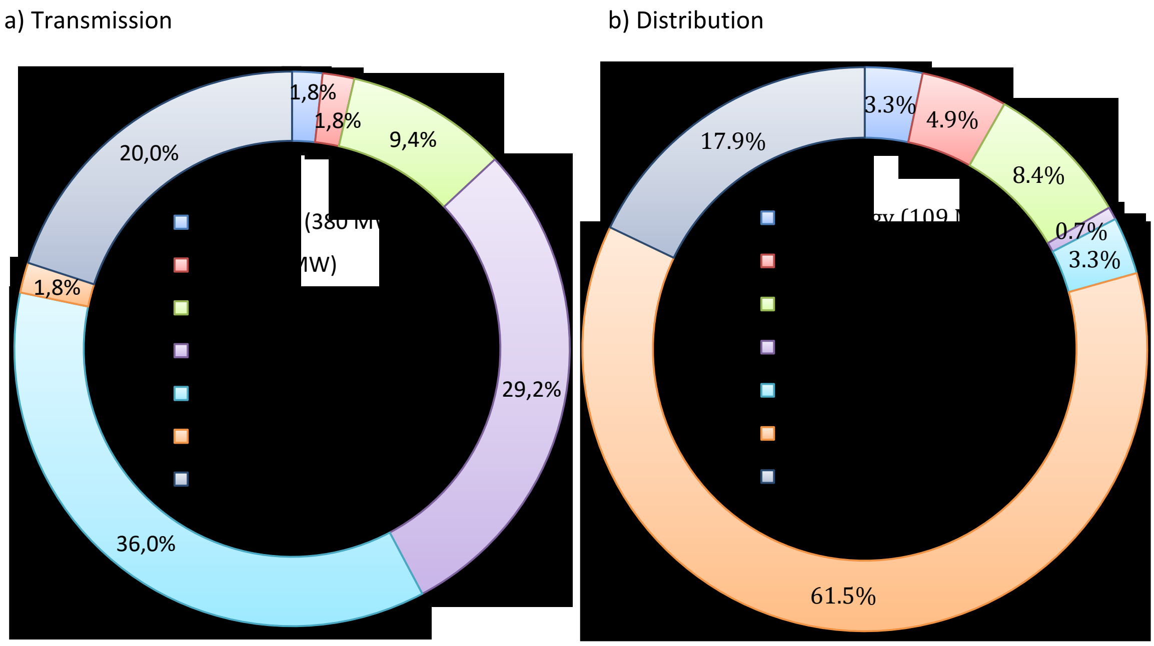

Figure 1: Commercially operational generation capacity in the province of Ontario for a) transmission-connected and b) distribution-connected systems. Numbers are given as a percentage of the total distribution and total transmission capacity. Power capacity is reported in MW_{AC}. Acronyms CHP and SC/CC refer to combined heat and power (cogeneration), and simple cycle /combined cycle, respectively.

Figure 2 summarizes Ontario's distribution and transmission-connected PV capacity over the past two years. Net metering data for Ontario are not reported.

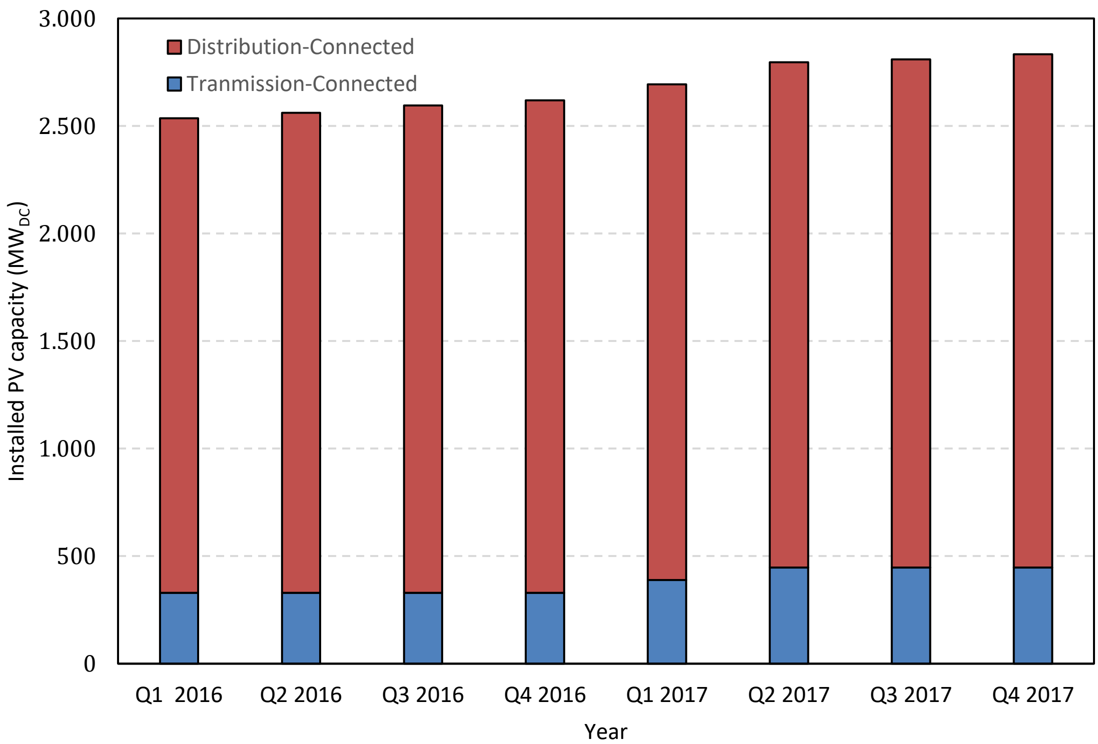

Figure 2: Distribution-connected versus transmission-connected PV systems in Ontario on a quarterly basis from 2016 and 2017. In order to convert from AC into DC, an AC to DC ratio of 85% was assumed.

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 modules 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 66% (1,079 MW_{DC}) of systems in the FIT programme are less than 500 kW. The remaining 34% (569 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 3 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.

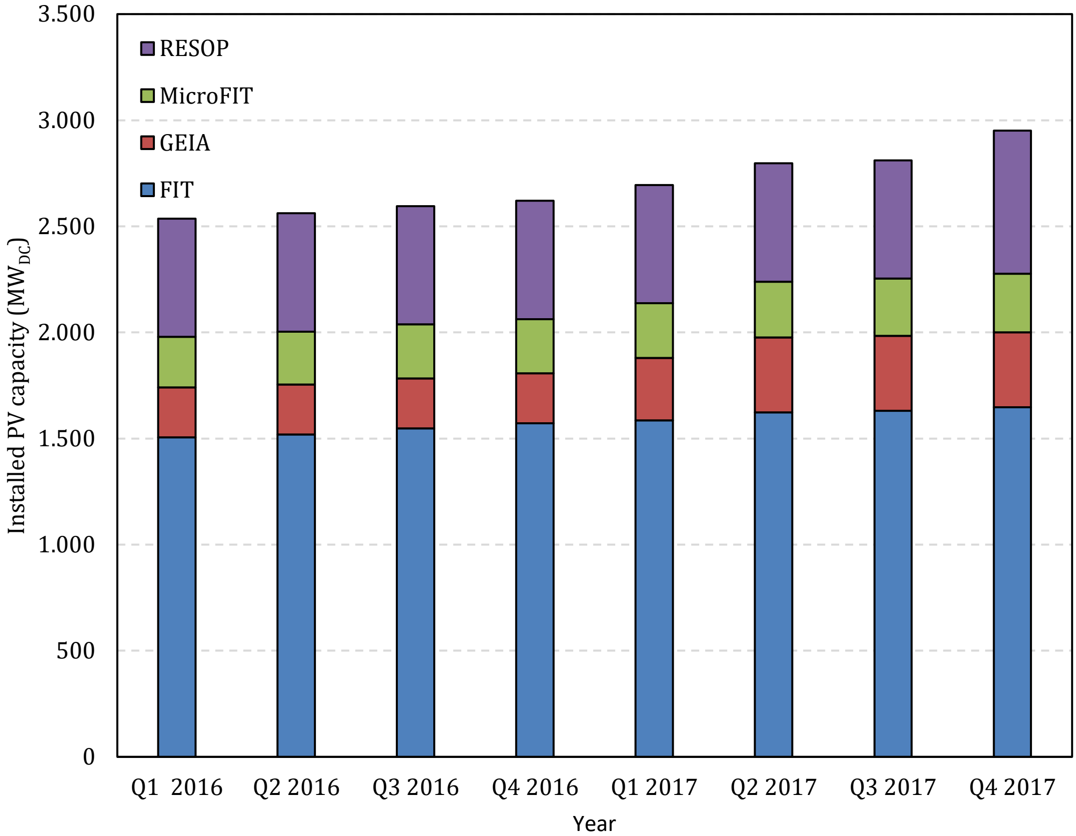

Figure 3: Ontario's cumulative installed PV capacity reported on a quarterly basis for 2016 and 2017. Seven LRP projects were initiated in March 2016, but are not yet in commercial operation. These LRP projects will become operational in 2019, and have a combined capacity of approximately 140 MW.

1.2 Total photovoltaic power installed

The national cumulative installed PV capacity at the end of 2017 was 2,91 GW_{DC}. This represents a growth of approximately 9% over the previous year. The province of Ontario had a cumulative installed photovoltaic capacity of 2,83 GW_{DC} as of December 31, 2017. In 2017, Alberta became the first province or territory outside of Ontario to install more than 5 MW_{DC} in a single year (with approximately 22 MW_{DC} of new facilities brought into service in 2017).

Table 1 shows the installed PV capacity for 2017 which was 249 MW_{DC} in total, of which 135 MW_{DC} were utility-scale transmission-connected power (assumed to be exclusively from Ontario). Cumulative data for ground mounted versus rooftop installed capacity were reported only for Ontario's FIT programme and were 510 MW_{DC} for rooftop and 1137 MW_{DC} for ground-mounted.

Table 1: PV power installed during the 2017 calendar year.

AC			MW installed in 2017	MW installed in 2017	AC or DC
Grid-connected	BAPV	Residential	114		DC
		Commercial			
		Industrial			
	BIPV (if a specific legislation exists)	Residential			
		Commercial			
		Industrial			
	Utility-scale	Ground-mounted	135		DC
		Floating			
		Agricultural			
Off-grid		Residential (SHS)			
		Other			
		Hybrid systems			
		Total	249		DC

The data collection process is described in Table 2. All provinces except for Ontario and Alberta reported PV power in DC (array nameplate power). The Ontario PV capacity data in this report were limited to systems contracted through the IESO (Independent Electricity System Operator). It does not include net metering, contracts with non-utility generators, or contracts with Ontario Power Generation or the Ontario Electricity Financial Corporation.

Table 2: Data collection process.

If data are reported in AC, please mention a conversion coefficient to estimate DC installations	In order to convert from AC into DC, an AC to DC ratio of 85% was assumed
Details of collection process performed 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 Integration of Renewable and Distributed Energy Resources.
Link to official statistics (if this exists)	See works cited
	Estimated accuracy of data: ±3%

Table 3 provides national figures on power generation and electricity demand as well as an estimate of total PV energy production. Total power generation capacity for 2017 was calculated using Statistics Canada data for 2016 for all energy sources except solar and assuming a 1,9% growth derived from the previous year [4]. Solar PV capacity data were collected by Canmet using provincial and territorial surveys and contact with utilities. Total power generation capacity from renewables for 2017 was calculated using PV data from 2017 added to 2016 data for non-PV renewables. Specifically, Statistics Canada derived growth rates from 2016 were 1,6% for hydroelectric, 7,6% for wind, and 0% for tidal which remained at around 20 MW_{AC}. Approximately 83% of Canada's increase in total power generation capacity for 2017 was from renewable sources. Total electricity demand for 2017 was estimated from 2016 data assuming an annual growth rate of 1%. Total electricity demand and total final energy demand for 2017 were calculated using 2016 data assuming a 1% annual growth based on future energy forecasts [4]. 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 [5].

Table 3: Canada's general energy and power statistics for PV, renewables, and non-renewables.

MW-GW for capacities and GWh-TWh for energy	2017	2016
Total power generation capacities (all technologies)	146,6 GW	143,7 GW [6]
Total power generation capacities (renewables including hydropower)	97,5 GW	95,1 GW [6]
Total electricity demand (consumption)	507 TWh	502 TWh [7]
Total energy demand (final consumption)	2 032 TWh	2 209 TWh [8]
New power generation capacities installed during the year (all technologies)	2,90 GW	2,27 GW [6]
New power generation capacities installed during the year (renewables including hydropower)	2,41 GW	1,83 GW [6]
Total PV electricity production in GWh-TWh	3,35 TWh	3,06 TWh
Total PV electricity production as a % of total electricity consumption	0,64%	0,59%

Table 4 summarizes Canada's transmission-connected and distribution-connected PV capacity as well as the number of centralized and distributed system contracts. Canada's centralized PV power capacity was assumed to be entirely from Ontario, and determined as the sum of all RESOP, GEIA, and large-scale FIT commercially operational systems. The only addition to the centralized PV power total, from outside of Ontario, was Alberta's 17 MW$_{DC}$ Brooks Solar array. Canada's 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 microFIT, and small-scale FIT contracts. Total 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. Figure 4 summarizes Canada's cumulative installed PV capacity by province and territory.

Table 4: Additional PV information for the 2017 calendar year.

Capacity metrics	2017 numbers
Number of PV systems in operation in your country (a split per market segment is interesting)	Centralized: 164 (All from Ontario with the exception of Alberta's Brooks Solar array) Distributed: 35 211 (29 434 from Ontario, 5 777 from rest of Canada)
Capacity of decommissioned PV systems during the year in MW	0
Total capacity connected to the low-voltage distribution grid in MW	2 466 MW_{DC} (2386 MW_{DC} from Ontario, 80 MW_{DC} from the rest of Canada)
Total capacity connected to the medium voltage distribution grid in MW	NA
Total capacity connected to the high-voltage transmission grid in MW	447 MW_{DC} (12 systems, all from Ontario)

Table 5 summarizes the centralized versus distributed PV power capacity. 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 building integrated (BIPV) or building applied (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 all of the PV capacity in the other provinces is distributed (with the exception of Alberta's Brooks solar array).

Table 5: The cumulative installed PV power in 4 sub-markets.

Year	Off-grid domestic (MW_{DC})	Off-grid non-domestic (MW_{DC})	Grid-connected distributed (MW_{DC})	Grid-connected centralized (MW_{DC})	Total (MW_{DC})
1992	0,10	0,69	0,17	0	0,96
1993	0,19	0,84	0,19	0,01	1,23
1994	0,31	0,99	0,20	0,01	1,51
1995	0,45	1,19	0,21	0,01	1,86
1996	0,61	1,70	0,24	0,01	2,56
1997	0,86	2,26	0,25	0,01	3,38
1998	1,38	2,82	0,26	0,01	4,47
1999	2,15	3,38	0,29	0,01	5,83
2000	2,54	4,30	0,30	0,01	7,15
2001	3,32	5,16	0,34	0,01	8,83
2002	3,85	5,78	0,37	0,00	10,00
2003	4,54	6,89	0,40	0,00	11,83
2004	5,29	8,08	0,47	0,04	13,88
2005	5,90	9,72	1,07	0,06	16,75
2006	6,68	12,30	1,44	0,06	20,48
2007	8,09	14,77	2,85	0,06	25,77
2008	10,60	16,88	5,17	0,06	32,72
2009	15,19	20,01	12,25	47,12	94,57
2010	22,85	37,25	27,74	193,29	281,13
2011	23,31	37,74	131,16	366,11	558,29
2012	NA	NA	218,68	547,29	765,97
2013	NA	NA	273,19	937,29	1 210,48
2014	NA	NA	540,85	1 302,23	1 843,08
2015	NA	NA	735,81	1 782,50	2 518,31
2016	NA	NA	790,11	1 871,65	2 661,76
2017	NA	NA	906,91	2 006,29	2 913,20

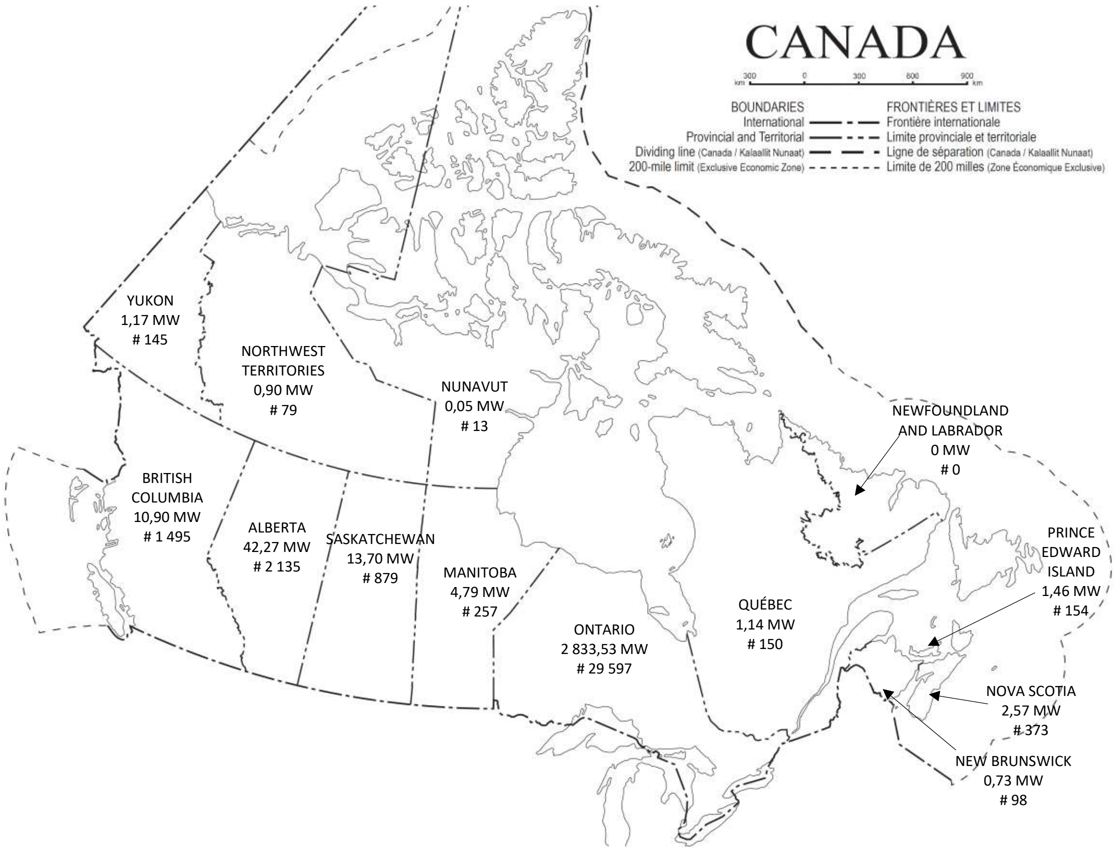

Figure 4: Map showing the Canadian provinces and territories, grid-connected PV power capacity (reported in MW_{DC}), and the number of utility interconnected PV systems as of December 31, 2017. This map is for illustrative purposes only and sizes or distance scales are approximate. Net metering estimates are not included.

1.3 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 6 provides information on these technology categories.

No official data are currently available on the number of decentralized energy storage systems in Canada although several pilot programmes and demonstration projects are operational. The Canadian government continues to expand renewable energy capacity in remote communities. For example, Colville Lake, Northwest Territories, recently installed a hybrid solar/diesel/battery generating station which allows diesel generators to be shut down for prolonged periods during the summer thus reducing fuel use and related emissions by 20 to 25% [9]. At the provincial level, Ontario announced the Green Ontario programme in 2017 which was intended to provide rebates for PV systems with energy storage capacity. However, this programme has been cancelled at the time of writing [10].

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, Quebec, 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 two years, the 2017 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 or greenhouse gas reduction. 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 [11].

Regarding electric vehicles, sales in Canada increased 68% in 2017. In particular, Ontario had a growth in electric car sales of 120%. In Quebec, during the last four months of 2017, electric vehicle sales represented approximately 2% of all passenger car purchases. Electric bus adoption in Canada is growing and various pilot projects are underway in major cities such as Montreal, Vancouver, and Toronto. According to the Canadian Urban Transit Association, there were 5 919 non-electric buses in service across the country with approximately 1 000 buses replaced each year. 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. There are, however, approximately 12 all-electric buses in operation across the country in various pilot programmes. No official, federally compiled figures on the number of hybrid and electric buses are available [12]. However, a 2010 survey estimated that around 1 250 hybrid buses were in regular service across the country [13]. 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.

Table 6: Information on key enablers.

Enabler type	Description	Annual volume (units)	Total volume (Units)	Source
Decentralized storage systems (MW)	No provincial or federal programmes	NA	NA	NA
Residential Heat Pumps	The majority of heat pumps in Canada are air-source	21 200	775 400	[14]
Electric cars	Fully-electric and plug-in hybrid	18 564	47 800	[15]
Electric buses/trucks	Hybrid buses (mostly 40 foot, diesel-electric)	NA	≈ 1 250	[13]
Other	NA	NA	NA	NA

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

As shown in Table 7, over the past decade (2007 - 2017), relative module prices have declined by approximately 82%. The minimum price shown in Table 7 is an import. All estimates are a representation of all known prices, and exclude VAT/TVA/sales tax [16].

Table 7: Typical module prices for selected years ($/$W_{DC}$). The prices reported are collected through an online survey and through manufacturer interviews which are representative of the retail module price. The prices for 2017 include the mark-up from the distributor and installer, and refer mostly to residential systems.

Year	1997	1998	1999	2000	2001	2002	2003
Standard crystalline silicon module price(s): Typical	NA	NA	11,09	10,70	9,41	7,14	6,18
Lowest prices							
Highest prices							
Year	2004	2005	2006	2007	2008	2009	2010
Standard crystalline silicon module price(s): Typical	5,53	4,31	5,36	4,47	3,91	3,31	2,27
Lowest prices							
Highest prices							
Year	2011	2012	2013	2014	2015	2016	2017
Standard crystalline silicon module price(s): Typical	1,52	1,15	0,95	0,85	0,80	0,78	0,80
Lowest prices		0,85	0,80	0,82	0,75	0,66	0,75
Highest prices						0,90	0,81

2.2 System prices

The industry reported system prices for grid-connected systems. The average installed turnkey price for grid connected applications in 2017 from projects ranging in size from 5 - 500 kW was $1,80 - 3,20/$W_{DC}$. For comparison, the price in 2016 was approximately $2,00 - 3,50/$W_{DC}$. However, prices vary regionally, and according to system size. A summary of representative system prices is provided in Table 8 and Table 9. From 2016 to 2017, the range of system prices for applications decreased up to 10%.

Table 8: Estimates of turnkey prices of typical applications ($/$W_{DC}$) **[16]**.

Category/Size	Typical applications and brief details	$/$W_{DC}$
Off-grid Up to 1 kW (SHS)		NA
Off-grid > MW scale		NA
Grid-connected rooftop up to 5-10 kW (residential BAPV)	Building applied PV system on a house	2,50 - 3,20

Category/Size	Typical applications and brief details	$/W$_{DC}$
Grid-connected rooftop from 10 to 250 kW (commercial BAPV)	Building applied PV system on a commercial rooftop	2,00 - 2,50
Grid-connected rooftop above 250kW (industrial BAPV)	Large building applied PV system on a commercial rooftop (250 – 500 kW)	1,80 - 2,00
Grid-connected ground-mounted above 10 MW	Ground-mounted utility scale PV system (1 - 10 MW)	< 1,80
Other category (hybrid diesel-PV, hybrid with battery…)		NA
Floating PV		NA
Agricultural PV		NA
Residential BIPV (tiles, or complete roof).		NA
Industrial BIPV		NA

Table 9: National trends in system prices for different applications ($/W$_{DC}$).

Category	2002	2003	2004	2005	2006	2007	2008	2009
Residential PV systems < 5-10 KW	NA	14,50	10,00	10,00	8,50	8,50	6,50	8,50
Commercial and industrial BAPV	NA	NA	12,60	10,00	12,60	10,00	NA	6,00 - 8,00
Ground-mounted > 10 MW	NA	NA	NA	NA	NA	NA	NA	NA
Category	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Residential PV systems < 5-10 KW	6,50 - 8,00	6,79	3,00 - 5,00	3,44	3,00 - 4,00	2,80 - 6,00	3,00 - 3,50	2,50 - 3,20
Commercial and industrial BAPV	6,00	5,27	4,00	3,27	2,20 - 2,90	2,20 - 2,90	2,00 - 3,00	1,80 - 2,50
Ground-mounted > 10 MW	4,00	3,50	2,80	2,88	2,00 - 2,60	2,00 - 2,60	< 2,00	< 1,80

2.3 Cost breakdown of PV installations

Table 10 and Table 11 give a break-down of estimated costs for residential and utility-scale PV systems.

2.3.1 Residential PV systems < 5 - 10 kW

Table 10: Cost breakdown for a residential PV system.

Cost category	Average ($/W$_{DC}$)	Low ($/W$_{DC}$)	High ($/W$_{DC}$)
Hardware			
Module	0,78	0,66	0,90
Inverter	0,45	0,30	0,60
Other (racking, wiring…)	0,33	0,18	0,48
Soft costs			
Installation	1,80	1,20	2,40
Customer Acquisition			
Profit			
Other (permitting, contracting, financing…)			
Subtotal hardware	1,56	1,14	1,98
Subtotal soft costs	1,80	1,20	2,40
Total installed cost	**3,36**	**2,34**	**4,38**

2.3.2 Utility-scale PV systems > 10 MW

Table 11: Cost breakdown for an utility-scale PV system.

Cost Category	Average ($/W$_{DC}$)	Low ($/W$_{DC}$)	High ($/W$_{DC}$)
Hardware			
Module	NA	NA	NA
Inverter	NA	NA	NA
Other (racking, wiring, etc.)	NA	NA	NA
Soft cost	NA	NA	NA
Installation labour			
Customer acquisition	NA	NA	NA
Profit	NA	NA	NA
Other (contracting, permitting, financing etc.)	NA	NA	NA
Subtotal hardware	NA	NA	NA
Subtotal - soft cost	NA	NA	NA
Total installed cost	NA	NA	NA

2.4 Financial parameters and specific financing programmes

With more than 97% 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 plans to invest $35 billion into infrastructure projects of which $5 billion is devoted to renewable energy initiatives such as photovoltaics [17].

Table 12: PV financing scheme.

Average rate of loans – residential installations	NA
Average rate of loans – commercial installations	NA
Average cost of capital – industrial and ground-mounted installations	NA

2.5 Specific investment programmes

The vast majority of investment programmes supporting photovoltaics in Canada have existed in Ontario and were operated by the IESO as described in Section 1. Prior to 2017, several other programmes also existed at the provincial and municipal levels that have each given rise to market activity in the 10's or 100's of kW's up to a few MW's. The most significant of these programmes has been the SaskPower Net-Metering Rebate Programme in the province of Saskatchewan.

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) [18]. Additional details are provided in Table 13.

Table 13: Specific investment programmes.

Third Party Ownership (no investment)	Several companies offer third party ownership and leasing services. The residential market in Ontario has been dominated by this approach to date.
Renting	A number of companies offered rented systems in Canada in 2017. However, it is more common that after a specified term the system becomes the property of the renter (i.e. leasing).
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.
Crowdfunding (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.
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.

2.6 Additional country information

Canada’s electricity sector is regulated provincially and is comprised primarily of a mixture of wholesale open markets and vertically integrated crown corporations. Electricity generation in Canada was estimated to be 583 TWh in 2017 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 million inhabitants at the end of 2017. Additional information is provided in Table 14.

Table 14: Country information.

Retail electricity prices for a household (power demand ≤ 40 kW)	16,66 - 17,05 c/kWh [19]
Retail electricity prices for a commercial company (power demand from 40 kW to 2500 kW)	12,07 - 16,66 c/kWh [19]
Retail electricity prices for an industrial company (power demand from 5 000 kW to 50 000 kW)	9,17 - 10,71 c/kWh [19]
Population at the end of 2017 (or latest known)	36 963 854 [7]
Country size (km^2)	9 985 000
Average PV yield (according to the current PV development in the country) in kWh/kWp	1 150
Name and market share of major electric utilities	Hydro-Québec, BC Hydro and Power, Alectra

3 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 defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

3.1 Direct support policies for PV installations

3.1.1 New, existing or phased out measures in 2017

3.1.1.1 Climate change 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 rise to below 1,5^{o}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 [9] 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 climate actions to further reduce emissions, adaptation measures to mitigate the damage of climate catastrophe, and supporting the growth of clean technologies. There is also a degree of flexibility allocated to the provinces to pursue their own emissions reductions strategies at the local level.

3.1.1.2 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. 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. As discussed in Section 1, 2017 was the last year for Ontario’s microFIT and FIT programmes. Ontario’s net-metering regulation now forms the basis for future project development.

3.1.1.3 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.

3.1.1.4 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 [20]. The Government of Alberta have 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 is expected to take place in 2018. The province's Renewable Electricity Programme (REP) is also intended to procure 5 GW of utility-scale renewable electricity [21]. 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.

3.1.1.5 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. In particular, the federal government initiative studying PV system performance, cost, and durability north of the 60^{th} parallel provides funding for the monitoring of PV arrays in remote communities. The project time-span is from April 2015 to March 2019.

3.1.1.6 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.

3.1.1.7 Support for electric vehicles (and VIPV)

The support measures for electric vehicles are mainly situated in Quebec, Ontario and British Columbia. These three provinces account for approximately 95% of all electric vehicles sold in Canada [22]. Electric vehicle support measures in these provinces are not explicitly linked to the storage opportunity they provide for photovoltaics, but are offered in the context of reducing greenhouse gas emissions from the transport sector, and improving air quality. A summary of annual electric vehicle sales based on survey data [15] is given in Figure 5.

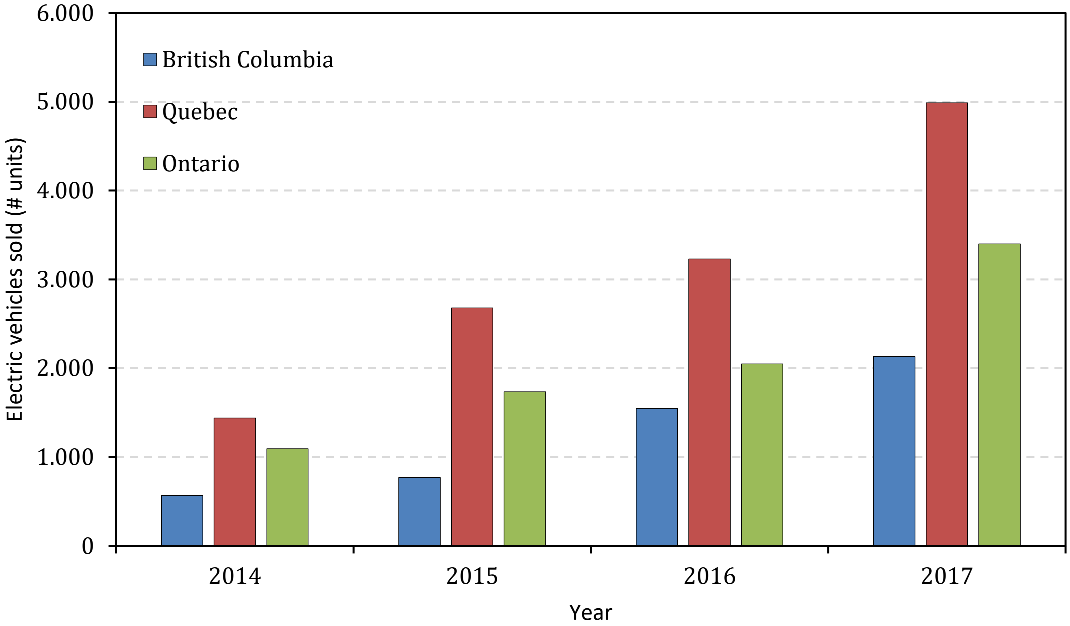

Figure 5: Annual electric vehicle sales in Canada in the three provinces with the largest sales volume.

Quebec has set a target for 100 000 electric vehicles on the road by 2020 and 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 [23].

Up until June 2018, Ontario offered an electric and hydrogen vehicle incentive programme. Following a recent election, Ontario's new government cancelled all rebates for electric and hydrogen vehicles. The effect of these cutbacks on electric vehicle adoption in Ontario may become evident in the next four years. 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 installation of home and workplace charging stations, respectively. Electric vehicle owners also gained access to high occupancy vehicle lanes along major highways even when driving alone [24].

British Columbia offers $5 000 off the purchase of a fully electric, fuel cell electric, or plug-in-hybrid vehicle through its clean energy vehicle programme. Another incentive offers a $6 000 rebate to trade in a 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 [22].

Table 15: Summary table of PV support measures.

	Residential		Commercial or industrial		Ground-mounted (including floating)	
	On-going measures	Measures that commenced during 2017	On-going measures	Measures that commenced during 2017	On-going measures	Measures that commenced during 2017
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	No					
Income tax credits	No					
Self-consumption	Many utilities offer residential lease-to-own programmes					
Net-metering						
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						
Other (specify)						

3.2 Self-consumption measures

Table 16: Summary of self-consumption measures.

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 and distribution grids	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	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

3.3 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.

3.4 Tenders, auctions and similar schemes

Ontario's IESO has used three procurement methodologies: standard offer, bilateral-negotiations, and competitive bid as described in Section 1. 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 3.1.1.4 above.

3.5 Financing and cost of support measures

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.

3.6 Indirect policy issues

In 2016, Canada’s Federal Government announced that there would be a price on carbon throughout Canada starting at a minimum of $10 per tonne in 2018, and rising by $10 per year to $50 per tonne in 2022. This measure will level the economic playing field between emitting and non-emitting resources and create new revenue streams for re-investment in technologies that displace greenhouse gas emissions, such as solar PV. In 2016, the Federal Government also launched the Pan-Canadian Framework on Clean Growth and Climate Change which presented a strategy for Canada to meet its national obligations under the Paris Agreement.

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 (Table 17). 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 17: Production information for the year for silicon feedstock, ingot, and wafer producers.

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

4.2 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 may only be counted to a country if the encapsulation takes place in that country.

Table 18 presents data from three companies in Canada producing PV modules, all of which have their facilities located in the province of Ontario and are involved in contract manufacturing of modules for other multi-national companies. Together, these 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 is summarised in Table 18.

Table 18: Production and capacity information for 2017.

Cell/Module manufacturer (or total national production)	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MW)		Maximum production capacity (MW/yr)	
		Cell	Module	Cell	Module
	Wafer-based PV manufactures				
Canadian Solar	sc-Si, mc-Si	NA	380	NA	760
Heliene	mc-Si				
Silfab	sc-Si, mc-Si				
Total			380		760
	Thin film manufacturers				
	Cells for concentrator PV				
Total			**380**		**760**

4.3 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 Solar Photovoltaics in Canada* can be found online on the CanmetENERGY website [25].
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 Schneider-Electric (Xantrex), Eaton and Sungrow Canada.

5 PV IN THE ECONOMY

5.1 Labour places

The number of labour places was calculated using the model for Jobs and Economic Development Impact (JEDI) developed by NREL [26]. 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. The amount of PV-related employment by category is given in Table 19.

Table 19: Estimated PV-related labour places in 2017.

Labour type	Number of 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	712
Distributors of PV products	4053
System and installation companies	
Electricity utility businesses and government	NA
Other	NA
Total	4870

5.2 Business value

The value of PV business in Canada as it relates to the solar PV capacity installations in 2017 is estimated in Table 20.

Table 20: Approximate value of the PV industry to the Canadian economy.

Sub-market	Capacity installed in 2017 (MW)	Price ($/W)	$ Amount in Million	Totals
Off-grid domestic	*NA*	*NA*	*NA*	*NA*
Off-grid non-domestic	*NA*	*NA*	NA	*NA*
Grid-connected distributed	131,8	2,50	329,5	329,5
Grid-connected centralized	117,64	2,00	235,3	235,3
				564,8
Export of PV products				NA
Change in stocks held				NA
Import of PV products				NA
Value of PV business				564,8

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 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.

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 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 climate policy and the rapidly declining costs in solar electricity, many utilities began to explore PV seriously in 2016 and continue to do so in 2017.

6.3 Interest from municipalities and local governments

There are over 3 500 urban and rural municipalities in Canada. All are driven to be economically and environmentally sustainable. Many municipalities continued to be leaders in solar adoption themselves while several others explored solar throughout 2017.

7 HIGHLIGHTS AND PROSPECTS

Canada's solar sector is approaching 3 GW installed capacity and has experienced a significant increase in investments since the province of Ontario's 2009 Green Energy and Economy Act. The Ontario PV market is currently experiencing a slowdown in new array installation due to the closing of the Large Renewable Procurement, Feed-In-Tariff (FIT), and microFIT programmes. While the amount of newly installed utility-scale PV capacity in Ontario may be reducing, there appears to be strong growth potential in small-scale PV systems connected to local electricity distribution systems. Photovoltaic installation among the other provinces is increasing particularly in Alberta, Saskatchewan, and British Columbia. A federal policy on photovoltaic support measures is needed and would lead to more uniform PV capacity installation across the country. Achieving Canada's commitment to greenhouse gas emissions reductions of 30% below 2005 levels by 2030 represents a significant opportunity for solar electricity to capture an increasing proportion of total electricity supply. A combination of falling costs, climate policy, and consumer demand point to PV increasing its contribution to Canada's supply. According to the National Energy Board, Canada's future renewable energy capacity is expected to grow significantly with wind capacity doubling and solar capacity more than tripling by 2040 [27].

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