PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
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GENERAL FRAMEWORK

Canada's Department of Natural Resources (NRCan) supports priorities to promote the sustainable and economic development of the country's natural resources, while improving the quality of life of Canadians. CanmetENERGY [1], reporting to the Innovation and Energy Technology Sector of NRCan, is the largest federal energy science and technology organization working on clean energy research, development, demonstration and deployment. Its goal is to ensure that Canada is at the leading edge of clean energy technologies to reduce air and greenhouse gas emissions and improve the health of Canadians. The federal photovoltaic activities is led by the CanmetENERGY research centre located in Varennes, Quebec and funded through federal RD&D programs that include the Program of Energy Research and Development [2], the ecoENERGY Technology Initiative [3], and the Clean Energy Fund [4].

The Province of Ontario, Canada's second largest province, leads the country in photovoltaic (PV) investment. In 2010, the Ontario Ministry of Energy reaffirmed, in its Long Term Energy Plan [5], its commitment to "maintaining a clean, modern and reliable electricity system." Renewable energy sources, such as solar and wind, are slated to play a prominent role in new generation, assisted through continuation of the successful Feed-in Tariff (FIT and micro-FIT) programs [6] administered by the Ontario Power Authority (OPA) [7]. In 2010, the OPA had 3352 MW of in-service generation capacity from renewable energy, including 186 MW PV systems. Another 1243 MW of PV capacity is under development [8]. In 2010, the world's largest solar-PV facility was built by the Enbridge and First Solar 80 megawatt Sarnia Solar Project in Ontario (Fig. 1) [9].

Figure 1 : Enbridge and First Solar 80 MW Sarnia Solar Project, the largest operating photovoltaic facility in the world in 2010 (Photo courtesy of Enbridge Inc.)

NATIONAL PROGRAMME

Research and Demonstration

CanmetENERGY is responsible for conducting R&D activities in Canada that facilitate the deployment of PV energy technologies throughout the country. The PV program coordinates national research projects, contributes to international committees on the establishment of PV standards, produces information that will support domestic c apacity-building and organizes technical meetings and workshops to provide stakeholders with the necessary information to make informed decisions. Most research projects are carried out, on a cost-sharing basis, with industry, universities, research groups, quasi-public agencies, and other departments and governments. CanmetENERGY also leverages its expertise by participating in international committees on photovoltaic, participating in joint projects with industry, developing software to assist in feasibility studies, as well as developing information and training tools.

The grid integration of decentralized energy resources and renewable energy into the main electrical grid is introducing a new paradigm of electric power generation and transmission: whereas in the past electrical power was generated in large power plants, sent to the consumption areas through transmission lines, and delivered to consumers through a passive distribution infrastructure, the electrical grid is now moving to a distributed and dynamic power generation and Smart Grid infrastructure. This has significant implications for PV development and investment, as it lends itself to integration across the electricity distribution systems. CanmetENERGY is responsible for delivering on the R&D mandate of the Grid Integration of Renewable and Distributed Energy Resources (DER) – a program that supports national science and technology efforts that will contribute to the modernization of the electricity grid network, enhance the benefits of renewable and clean distributed energy resources, increase the diversity and reliability of supply, and facilitate recovery after disruptions. While numerous benefits are associated with this change, such a transition also represents many challenges for all stakeholders (utilities, independent power producers, governments, regulators, manufacturers, housing industry). Through the Energy Science and Technology funding support, NRCan addresses the technical, institutional and regulatory barriers, to promote the grid integration of clean power including photovoltaics.

The new PV Innovation Research Network [10], funded by the Natural Sciences and Engineering Research Council (NSERC), brings together a core group of 25 academic researchers in Canada, as well as CanmetENERGY, the National Research Council, the Ontario Center of Excellence and 15 industrial partners. The network will focus its efforts on organic, nanostructure and other innovative PV device approaches that have the potential to leapfrog existing and established technologies. In addition, there is a new cross-agency collaboration with the Business Development Bank of Canada to support research partnerships with industry in the field of nanomaterials that includes 2.9 million CAD.

In 2010, the Canadian Solar Buildings Research Network (SBRN) completed its five-year work program [11]. The network pooled the R&D resources of eleven universities and federal departments to develop the future generation of experts knowledgeable in solar buildings research. The goal of the research network was the development of solar-optimized buildings with integrated advanced technological systems that approached net-zero annual total energy consumption. CanmetENERGY also contributed to this research effort and is leveraging its activities through its leadership of a large international collaboration for the IEA-SHC/ECBS Task 40/Annex 52, entitled "Towards Net Zero Energy Solar Buildings". Its objective is to study current net-zero, near net-zero and very low energy buildings and to develop a common understanding of a harmonized international definitions framework, tools, innovative solutions and industry guidelines. To achieve this objective, Task/Annex experts from 18 countries, including Canada, will document research results and promote practical demonstration projects that can be replicated worldwide.

Finally, Sustainable Development Technology Canada (SDTC) [12], an arms-length foundation that operates as a not-for-profit corporation that was established by the Government of Canada in 2001, provides support for the development and demonstration of innovative technological solutions in clean energy technology solutions. SDTC works closely with an ever-growing network of stakeholders and partners to build the capacity of Canadian entrepreneurs, helping them to form strategic relationships, formalize their business plans, and build a critical mass of sustainable development capability in Canada. SDTC is the principle federally-funded body that leverages private sector resources to demonstrate market-ready technologies, including solar photovoltaic product development.

Standards and Codes

The Standards Council of Canada, an agency of the Federal department Industry Canada, is responsible for the National Standards System. It is responsible for standards accreditation of organizations and test laboratories. Standards Council of Canada is Canada's representative at the International Electrotechnical Commission (IEC), a global organization that works towards the harmonization of standards in a broad range of electrical product safety and quality. The Canadian sub-committee to the IEC TC 82 actively participates in the development of PV standards. It collaborates with the Canadian Standards Association to make recommendations on international standards adoption. To date Canada has adopted the international IEC61215 and IEC61646 standards that define the test and qualification requirements for crystalline and thin-film solar PV modules. It has initiated a process for the joint adoption of the IEC 61730 for PV module safety, in collaboration with Underwriter's Laboratory and the Canadian Standard Association, that would replace the current ULC-1703 PV module safety standard.

NRCan's CanmetENERGY, in partnership with key industry players and associations, has championed a national effort to address the delays and avoid multiplication of regional grid interconnection requirements across the country. This included the development of two harmonized national interconnection standards, CSAC22.2 no.257 and the CSA C22.3 no.9. CanmetENERGY conducts research and field-testing addressing concerns raised by electricity distributors to update and improve the electrical code. Distributed generation installations of PV systems must be installed in accordance with all applicable general rules of the Canadian Electrical Code: Part I and II for low voltage installations at load centers such as residences and commercial buildings and Part III for medium to high voltage of the electricity distribution and transmission systems.

This national effort has been expanded to address future Smart Grid applications. The Standard Council of Canada and NRCan's CanmetENERGY have established a Canadian Smart Grid Technology and Standards Task Force in support of a global effort to harmonize requirements. As an example of its commitment to the International Electrotechnical Commission, Canada provided support for the development of an international standard for electricity network communication and distributed energy resources. This was a key issue to ensure that systems were inter-operable with utility networks, and was reflected in the first edition of the IEC 61850-7-420 Ed.1 standard for basic communication structure, including photovoltaic device and system logical nodes.

IMPLEMENTATION

Ontario's Feed-In Tariff Program

Ontario's Feed-In-Tariff program [6], managed by the OPA, is North America's first comprehensive guaranteed pricing structure for electricity production from renewable fuels sources including solar-PV, bioenergy, waterpower and wind. The incentive program is divided into two streams, one targets the small, medium and large renewable energy projects generating more that 10 kW of electricity (referred as the "FIT Program"), and the other targets very small renewable projects generating 10 kW of electricity or less, such as home or small business installations (referred to as the "microFIT Program") . Prices paid for renewable energy generation under FIT and microFIT programs vary by energy source and take into account the capital investment required to implement the project. Under the program, solar PV enter into a 20 year contract to receive a fixed price of up to 0.802 CAD per kWh for the electricity they generate (Table 1).

Table 1: Ontario Power Authority Feed in Tariff Rates for Solar PV (CAD)

Application type	Size	Contract Price (¢/kWh)	
Rooftop	≤ 10 kW	80.2	micro-FIT
Ground-mounted	≤ 10 kW	64.2	
Rooftop	10 - 250 kW	71.3	FIT
Rooftop	250 - 500 kW	63.5	
Rooftop	> 500 kW	53.9	
Ground-mounted	10 kW - 10 MW	44.3	

As of December 2010, the OPA received, under the FIT program, 3656 applications representing about 4886 MW of PV generating capacity (Table 2). Under the microFIT program, the OPA received 18176 applications representing 166 MW of generating capacity (99% of which was for PV, Table 3) [13]. Given limited transmission capacity and an extremely large number of applications, a transmission planning process, known as the Economic Connection Test (ECT), was created to facilitate generator investment in new transmission "enabler" lines (Fig. 2). A comprehensive regulatory evaluation of these new electricity network investment proposals would be conducted by the Ontario Energy Board (OEB) [14], the province's regulatory authority. A map tool showing the locations of PV projects that have been offered contracts by the OPA under the FIT Program, or are awaiting ECT, is also available from the OPA website [15].

Normally required to pass a series of connection tests before being offered a contract (or capacity to connect), the OEB created exemptions for small projects connected within the distribution system. Known as "capacity allocation exempt", these projects have "no more than 250 kilowatts of rated generating capacity where the facility is connected to a less than 15 kV line" and "500 kW or less of rated generating capacity where the facility is connected to a 15 kV or greater line" [16].

Net-Metering in Canada

Electric power generation in Canada is a provincial jurisdiction. Canadian electricity customers who want to install renewable energy generating systems at their sites and interconnect them to their local utility grid may do so according to their local distribution company's requirements. Net metering regulations have been put in place in all provinces that establish rules for the flow of electricity between utilities and distributed PV systems. The implementation of these regulations requires the installation of new equipment (e.g. proper meters) and new billing systems. Some utilities have developed and implemented programs that streamline the application process specify net metering requirements and set out approved tariffs (for example, BC Hydro and Hydro Quebec).

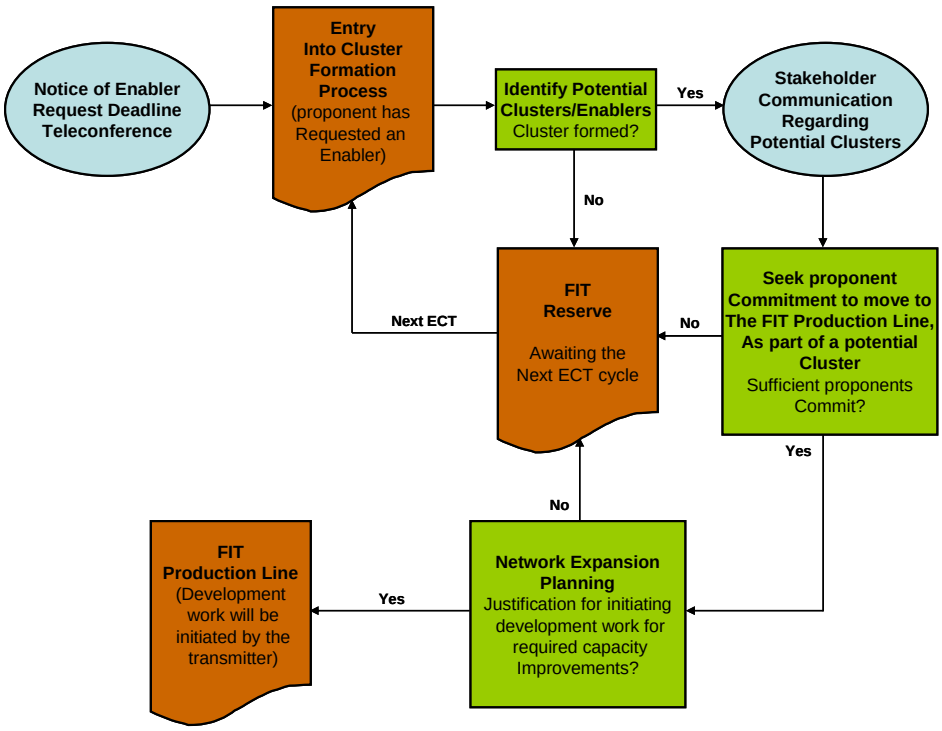

Figure 2: Process for identifying FIT project "clusters" that are awaiting connection and new "enabler" transmission network infrastructure projects (Ontario Power Authority)

INDUSTRY STATUS

There are over 440 solar photovoltaic companies operating in Canada, many of which are members of the Canadian Solar Industries Association [17] and Énergie Solaire Québec [18]. The majority of these companies are participants in Ontario's FIT Program, since developers must show that the equipment and labour for system installations consist of 40% 'Ontario' content for projects less than 10 kW in size, and 60% for larger installations.

Table 2: Summary of Progress in the FIT Program in the province of Ontario [13]

FIT	Applications	Awaiting ECT	Offered Contracts	Executed Contracts
Number	3656	72	1376	1119
Capacity (MW)	4886	592	911	856

Table 3: Summary of Progress in the "microFIT" Program in the province of Ontario [13]

MicroFIT	Approved	Executed
Number	18176	2619
Capacity (MW)	166	21

In 2010, several companies announced major investments in Ontario that would lead to new "green jobs" in Ontario; they included Siemens [19], Fronius [20], ATS Photowatt Ontario [21], Canadian Solar Inc. [22] and a Korea-based Samsung C&T Corporation-led consortium [23]. The Province's Green Energy and Economy Act [24], released in 2009, is continuing to create the conditions necessary to attract investments in the solar industry in Ontario. In addition, Canada has three companies that are suppliers of feedstock materials for solar PV markets: Bécancour Québec produced approximately 182 tonnes of silicon last year; 5N Plus had a significant increase in Cadmium Telluride production that is exported for the fabrication of thin-film CdTe modules; and Calisolar, who acquired 6N Silicon, has an estimated production capacity of 2000 T/yr.

MARKET

Growth in the Canadian PV sector has been consistent over the past 18 years, with capacity growing by more than 22% percent annually between 1993 and 2009. The Ontario feed-in-tariff program is paving the way for a steep uptake for grid-connected PV. Provincial and Territorial government policies are now all supporting "net-metering" of PV power and have encouraged a number of building integrated PV applications. The market uptake has been low for net-metering applications due of the low price of electricity in most regions of Canada. A sustainable market for remote and off-grid applications has developed over the last 18 years in Canada and accounted for 75% of total PV installed in 2009, however this is expected to be only 50% in 2010 due to the large growth of grid-connected applications in the province of Ontario.

Employment in PV-related areas in Canada grew by about 30% in 2009 to 2700 jobs. These positions included those in manufacturing, sales and installation, R&D, and other positions in the PV-value chain including company R&D, as well as utility PV dedicated labour (IEA-PVPS NSR2009: R&D 100; Manufacturing 1975; Other 625). The main increase was in the manufacturing sector as new companies have set up manufacturing bases in Ontario to enable them to satisfy the FIT Program Ontario content requirements.

The national survey completed in 2009 showed a significant decrease in PV module prices (weighted average) to 3.31 CAD per watt. Compared to 11.09 CAD in 1999, this represents an average annual price reduction of slightly over 10% over an 11-year period. The Canadian total PV power installed capacity is expected to double, reaching an estimated capacity of 200 MW in 2010, compared to 94 MW that was in operation in 2009. As expected, a large fraction of this growth is in the grid-connected market segment in the province of Ontario.

FUTURE OUTLOOK

The Feed-In Tariff Program in the province of Ontario is viewed by the Canadian PV industry as a major step towards developing a competitive, strong Canadian solar industry. The FIT program addressed many of the concerns regarding the delays and interconnection obstacles identified by the industry during the review process. The tremendous initial response to the microFIT program signals a strong support for residential solar rooftop applications in Ontario.

The federal government is also leading the efforts of a technical study group to better understand the technical interconnection issues for high penetration levels of PV systems in electricity grids. This work will be undertaken in collaboration with the International Energy Agency PVPS Task 14 and Canadian stakeholders to better address the emerging field of PV integration enabled through smart grid infrastructure in Canada.

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