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] and the ecoENERGY Technology Initiative[3].

In 2009, the Province of Ontario, Canada's second largest province, through the passage into law of the Green Energy Act, adopted an aggressive green energy policy that includes a powerful Feed-In Tariff (FIT) [4] program launched in September 2009. The provincial government delegated the responsibility for its implementation to the Ontario Power Authority (OPA). The FIT program replaced the province's highly popular Renewable Energy Standard Offer Program (RESOP)[5], which underwent review in 2008. As part of the FIT launch process, all renewable energy supply projects that have been approved under RESOP and are in commercial operation will continue according to their RESOP contracts. As of the third quarter of 2009, the OPA had 1,422 MW of renewable energy supply capacity of which 525.4 MW are from PV power generation projects under the RESOP Program (Table 1). Of these, Canada's first three large-scale PV parks of 23.4 MW by enXco/ EdF-EN Canada[6], 20 MW by Enbridge[7] and First Solar and 9.1 MW (Figure 1) by Skypower Corporation[8] have achieved commercial operation in 2009 and became eligible for RESOP contract payments of 0.42 CAD/kWh for a 20-year power purchase agreements.

As of the fourth quarter of 2009, the RESOP Program was replaced by the FIT Program and RESOP contract holders whose projects were not in commercial operation were given an opportunity to rescind their RESOP contracts and apply for a FIT contract.

Table 1: Ontario Power Authority RESOP Contracts Capacity in 2009[9] (MW)

RE Source	In Commercial Operation	Under Development	Total
Solar PV	**54.3**	**471.1**	**525.4**
Wind	67.6	671.3	738.9
Water	17.7	53.2	70.9
Bio-Energy	26.1	60.9	87.0
TOTAL	**142.3**	**1279.9**	**1,422.2**

Figure 1 : SunEdison's and SkyPower Corporation's 9.1-megawatt (MW) First Light Solar Energy Park in Stone Mills, Ontario, and the largest solar energy park built to date in Canada.(Photo credit: Dave Turcotte, CanmetENERGY))

The Canadian Solar Buildings Research Network (SBRN)[10] continues to be in the centre of Canada's R&D into solar buildings by innovating solar energy production and efficiency of its use in commercial, institutional and residential buildings in Canada. The network pools 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 is the development of the solar-optimized buildings an integrated advanced technological system that approached net-zero annual total energy consumption. The efforts of the network experts are providing in-depth analyses to Canadian stakeholders on the optimization of low and net-zero energy homes for Canadian climatic conditions, and are supporting innovation in the construction industry in order to accelerate the adoption of low and net-zero energy solar homes.

In 2009, the Government of Canada invited Canadian residential developers, planners, designers and municipalities to develop and showcase neighborhoods that are more sustainable and energy-efficient than most existing communities under the new EQuilibrium ™ Communities Initiative[11]. The initiative, which is funded and led by NRCan and the Canada Mortgage and Housing Corporation (CMHC), builds on the success of the EQuilibrium™ Sustainable Housing Demonstration Initiative launched by CMHC in 2006, and is supported by NRCan's CanmetENERGY expertise. It provides leading-edge teams with an opportunity to be at the forefront of bringing to market energy-efficient, sustainable and profitable clean energy technologies integrated into buildings and neighborhoods that benefit consumers, the environment, and the economy. Also in 2009, a number of the EQuilibrium™ houses moved beyond the demonstration stage when they were purchased and occupied, and are now starting a one year monitoring phase to verify their actual performance. Performance data from the PV systems installed on these homes will be available online for a minimum of one year with a live feed from Fat Spaniel Technologies site[12]

NATIONAL PROGRAMME

Research and development

NRCan's CanmetENERGY is responsible for conducting photovoltaic RD&D activities in Canada that facilitate the development and deployment of PV energy technologies throughout the country. Efforts undertaken by CanmetENERGY, such as the coordination of various research projects, participation in international committees on the establishment of standards, and producing information that will support domestic capacity-building, 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 photovoltaics, participating in joint projects with industry, developing software to assist in feasibility studies, as well as developing information and training tools.

As of September 2009, a new PV Innovation Research Network with a focus on solar cells has been formed in Canada. This research network, funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) at 1 million CAD per year over the next 5 years, will bring 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 to develop and transfer to the Canadian industry innovative PV technologies. 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 a new cross-agency collaboration with the Business development Bank of Canada to support research partnerships with industry in the field nanomaterial that includes 2.9 million CAD over three years[13].

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: from where electrical power was generated in large power plants, sent to the consumption areas through transmission lines, and delivered to the consumers through a passive distribution infrastructure, to a distributed and dynamic power generation and smart grid infrastructure. CanmetENERGY is responsible for delivering on the R&D mandate of the Grid Integration of Renewable and Distributed Energy Resources (DER) [14] – 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, with the aim of promoting the grid integration of clean power including photovoltaic.

CanmetENERGY is also conducting research into the optimal integration of solar Photovoltaic/Thermal (PV/T) technologies and systems into net zero energy homes, with the aim of developing simple models to predict the electrical and thermal yield of PV/T systems. This work is aligned with Canada's mandate to conduct innovative R&D in the building technologies that are essential for achieving marketable near- and net- zero houses of the future. This work is undertaken in collaboration with other federal delivery organizations such as CMHC and the Solar Buildings Research Network.

DEMONSTRATION

Alstonvale Net Zero Energy Solar Smart Home, Hudson, Quebec

The Alstonvale Net Zero Energy Solar Smart House[15] (ANZEH) under construction in the city of Hudson, Province of Quebec, is one of 15 winners chosen in 2007 by the Canadian Housing Mortgage Corporation's (CMHC) nationwide EQuilibrium Initiative[16], a sustainable housing program launched in 2006 and geared towards mitigating emissions of carbon dioxide from the housing sector. The ANZEH strives towards net-zero energy consumption by minimizing the energy requirement of the house through a high performance building envelope, reduced energy demand loads, and aggressive use of passive heating and passive cooling techniques, as well as generating on-site sufficient energy, through renewable resources through a roof-integrated 8.4 kW photovoltaic array and solar thermal panels (Figure 2). The scope of the ANZEH, however, has evolved to broader and more ambitious objectives than other EQuilibrium projects. It will attempt to generate all the energy required for the household's domestic as well as local transportation energy needs, by storing excess PV generated power into an electric-drive vehicle, in an effort to demonstrate the attainability of a more encompassing net-zero energy lifestyle. NRCan's CanmetENERGY is leading this R&D work with the home builder.

Figure 2: The Alstonvale Net Zero Energy House, Hudson, Quebec, Canada. (Photos credits: Sevag Pogharian)

Team North and Team Alberta 2009 Solar Decathlon Competition

Canada was represented by two university teams in U.S. Department of Energy 2009 Solar Decathlon competition: *Team North* (the "*North House"*, Figure 3a) bringing together students from University of Waterloo, Ryerson University and Simon Fraser University and *Team Alberta* (the "ENMAX SolAbode" Figure 3b) consisting of University of Calgary, SAIT Polytechnic, Alberta College of Art and Design and Mount Royal College students. Team North greatly impressed by finishing in fourth position of the general ranking. The team performed consistently throughout the whole competition by finishing in the top 5 of 7 of the 10 tests they had to compete in and by obtaining the second position in the communications test. Team Alberta also distinguished itself by achieving the 6th rank in the global competition and getting the 5th position in the home entertainment and comfort zone challenges. The U.S. Solar Decathlon is an excellent opportunity that provides architecture and engineering students with hands-on experience in innovative design that target net-zero energy solar optimized homes.

Figure 3: Canada's two entries in the 2009 US DOE Solar Decathlon Competition, the North House (a), and ENMAX SolAbode (b) - marketable solar powered home that makes use of the latest in high-performance architecture energy management technology while building Canada's next generation of leaders in sustainable engineering, business and design. (Photos credits: Team North and Team Alberta)

The T'Sou-ke First Nation Solar Power Project, Sooke, British Columbia

In 2009, the T'Sou-ke First Nation, a native community in Sooke on the southern end of Vancouver Island became the largest solar energy producing community in the Province of British Columbia. The T'Sou-ke solar project is a suite of solar options for producing hot water and electricity. The PV component consists of three models: 62 kW grid-connected array atop the band's canoe shed providing the electricity needs of the community or for sale to BC Hydro, the provincial utility; a 7 kW grid-connected system on the band hall for emergency battery back-up in case of a power outage; and a 6 kW system on the bands' fisheries office that will require some form of backup such as diesel, propane or another renewable technology. The T'Sou-ke First Nation solar project is being held up as an energy autonomy model for other aboriginal communities across the province, particularly those that are off grid and reliant upon diesel generators for electricity.

Figure 4: The T'Sou-ke First Nation Solar PV Project, BC's largest solar system. (Photo credit, Sia Vojdani)

IMPLEMENTATION

Ontario's Feed-In Tariff (FIT) Program

Ontario's FIT program launched the third quarter of 2009 and managed by the Ontario Power Authority is North America's first comprehensive guaranteed pricing structure for electricity production from renewable fuels sources including solar PV, bioenergy waterpower and wind. The FIT 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 a home or small business installations (referred to as the "microFIT Program")[17]. 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 applicants are paid a fixed price of up to 0.802 CAD per kWh for the electricity they generate for a 20 years contract.

As of December 2009, under the FIT program, the OPA received about 1000 applications with approximately 8,000 MW of potential generating capacity[18]. Of this, approximately 2,500 MW will be awarded contracts under the first round of contracts. Under the microFIT program, the OPA received about 1, 200 applications representing 8.6 MW of generating capacity of which about 1,166 are solar PV projects totaling 8.382 MW.

Table 2: Ontario Power Authority Feed-In Tariff Price Schedule for Solar PV (CAD)[19]

Application type	Size Tranches	Contract Price (¢/kWh)	
Any type	≤ 10 kW	80.2	microFIT
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	

Net-Metering in Canada

Electric power generation in Canada is a provincial jurisdiction. Canadian electricity customers who want to install renewable energy technology generating systems at their sites and interconnect them to their local utility grid may do according to their local distribution company's requirements. Net metering regulations have been put in place in several provinces that establish rules for the flow of electricity between utilities and distributed PV systems. The implementation of these regulations is challenging, requiring 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 (BC Hydro, Toronto Hydro, and Hydro Quebec Distribution).

Interconnection standards and codes

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 requirements across the country. This included the development of harmonized national interconnection standards, the conduct of research and field-testing addressing concerns raised by electricity distributors, and the implementation of changes in the Canadian Electrical Code[20]. In the installation of the distributed generators in Canada, PV Systems must be installed in accordance with all applicable general rules of the Canadian Electrical Code to Part I and II for low voltage installations at load centers such as residences and commercial buildings, with Part III for medium to high voltage of the electricity distribution and transmission systems. Continuing concern during the electricity network interconnection "impact assessments" by utilities delays projects and leads to additional costs to large scale PV projects planned in Ontario.

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 is a key issue to ensure that systems are inter-operable with utility networks. This effort was completed in 2009 with the final approval and publication of the IEC 61850-7-420 Ed.1 standard for basic communication structure, including photovoltaic device and system logical nodes.

Federal Programs in support of technology demonstration to market commercialization

Sustainable Development Technology Canada (SDTC)[21] - an arms-length foundation that operates as a not-for-profit corporation, established by the Government of Canada in 2001 to support the development and demonstration of innovative technological solutions continued in 2009 to invest 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.

INDUSTRY STATUS

There is nearly 350 solar photovoltaic companies (sales companies, wholesalers, product manufacturers, project developers, private consultants, systems installers and industry associations) operating in Canada many of which are members of the Canadian Solar Industries Association[22] and Énergie Solaire Québec[23]. The majority of these companies are also participating in the Province of Ontario's new Feed-In Tariff Program (and its precursor the Renewable Energy Standard Offer Program). The FIT Program continued to attract to renewable energy project developers and product manufactures to the Province in 2009. Under 'new content rules', any developer wishing to participate in the FIT Program must show that the equipment and labor used to install the system consist of 40 percent 'Ontario' content for projects less than 10 kW in size. Above that threshold the required local content is 50%.

In 2009, Canadian Solar Inc.[24] (a vertically integrated provider of ingots, wafers solar cell and modules and specialized solar products) announced its intentions to establish a manufacturing facility in Ontario that will create 500 jobs to take advantage of the province's FIT Program that mandates local content. Also, ATS Automation Tooling Systems Inc.[25], the parent company of Photowatt International[26] announced in 2009 that it has established Photowatt Ontario Inc. at its site in Cambridge, Ontario as part of its plan to lead the Ontario solar energy market. Phottowatt Ontario offers turnkey solar project development, installation and solar products. Another development in 2009 is the Government of Ontario[27] and Korea-based Samsung C&T Corporation[28] - led consortium announcement of a 7 billion CAD green energy investment for 2,500 MW of solar (500 MW) and wind (2000 MW) energy generation in the Province. This investment is expected to triple Ontario's renewable solar and wind energy generation and lead to manufacturing facilities being constructed in Ontario. The Province's Green Energy Act is creating the appropriate business conditions to attract investments to grow the solar industry in Ontario.

MARKET

Growth in the Canadian sector has been consistent over the past 17years, with capacity growing by more than 22% percent annually between 1993 and 2009 The Ontario FIT (and RESOP)program offering 0.443 - 0.802 CAD per kilowatt-hour for PV electricity production is paving the way for a steep uptake for grid-connected PV. Provincial policies supporting "net-metering" of PV power have encouraged a number of building integrated PV applications throughout Canada during this period. The PV market and industry in Canada is continuing to grow, despite the low price for conventional energy. A sustainable market for remote and off-grid applications has developed over the last 17 years in Canada and continues to accounts for about 75% of total PV installed without the FIT component. This is an unsubsidized market that is meeting the remote power needs of Canadian customers particularly for transport route signaling, navigational aids, remote homes, telecommunication, and remote sensing and monitoring.

The Canadian total PV power installed capacity increased by 211% to about 102 MW in 2009 with nearly 52.5 MW attributed to the three large-scale PV parks installed in Ontario. In 2009, the PV module market in Canada was 67.3 MW compared to 6.94 MW in 2008. In terms of total domestic and export modules sales by Canadian-based industry this represents approximately 42 MW, an increase of 48% over the previous year of which 81% were for on-grid applications (distributed), and 19% for off-grid applications (residential and non-residential). Module prices (weighted average) have gradually declined from 11.09 CAD in 1999 to 3.31 CAD in 2009. This represents an average annual price reduction of slightly over 10% over the ten-year period.

FUTURE OUTLOOK

The Feed-In Tariff Program (and RESOP) is viewed by the Canadian PV industry as a major step towards developing a competitive, strong Canadian solar industry. By the end of 2009, the RESOP had exceeded its 5-year target with 525 MW power purchase contracts signed with the OPA of which 54.3 MW being in commercial operation to date and the balance expected to become operational in

the next few years. The FIT program addressed many of the concerns regarding the delays and interconnection obstacles identified by the industry during the review process of the RESOP. The tremendous initial response to the microFIT program signals a strong support for residential solar rooftop applications in Ontario. Based on its popularity, this market niche is expected to grow substantially in 2010 beyond the announcement of a 700 solar rooftop projects announced by the Province of Ontario to date.

The federal government is investing in research activities to develop and test photovoltaic electricity generation forecasts relevant to electric utilities, PV system developers, owners and operators. Such forecasts are important to improve the cost-effectiveness of large scale integration of PV systems into electricity grids and to the development of load control strategies for PV integrated into buildings and building clusters. The federal government is also leading the R&D investments into activities to better understand the technical interconnection challenges of high penetration levels of PV in electricity grids. This work will be undertaken in collaboration with an international group of experts and stakeholders to better address the emerging field of PV integration in smart grids in Canada.

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[1] http://canmetenergie.rncan.gc.ca/eng/index.html
[2] http://www.nrcan-rncan.gc.ca/eneene/science/perdprde-eng.php
[3] http://www.nrcan-rncan.gc.ca/eneene/science/etiiet-eng.php
[4] http://www.fit.powerauthority.on.ca
[5] http://www.powerauthority.on.ca/sop/Page.asp?PageID=861&SiteNodeID=209
[6] The firm behind the project is enXco and EdF-Energie Novelles group. The Canadian operation is known as EdF-EN Canada. http://www.enxco.com/
[7] http://www.enbridge.com
[8] http://www.skypower.com
[9] Information extracted from OPA, *"A Progress Report on Electricity Supply, Third Quarter 2009".* 10.9 MW of solar PV capacity reached commercial operation in Q3 of 2009 and reported in the OPA report, and 20 MW achieved commercial operation in Q4 of 2009.
[10] http://www.solarbuildings.ca
[11] http://www.ecoaction.gc.ca/equilibrium-eng.cfm
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[16] http://www.ecoaction.gc.ca/equilibrium-eng.cfm
[17] http://www.microfit.powerauthority.on.ca.
[18] No breakdown of the solar PV generating capacity given.
[19] http://www.fit.powerauthority.on.ca
[20] http://cetc-varennes.nrcan.gc.ca/fichier.php/codectec/En/2007-172/2007-172e.pdf
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[28] http://www.samsungcnt.com/pr/board_view.asp?fnum=131&fidx=1805&fpart=eng