May 2011

Innovation Snapshot

Solar energy sector in the Toronto Region

"Solar energy stands to become a dominant part of the global energy mix. The biggest challenge in taking solar electricity mainstream is cost per watt."[1]

Dr. Nazir Kherani, Professor, Department of Electrical and Computer Engineering and the Department of Materials Science and Engineering, University of Toronto

Introduction

The growing concern over climate change is driving the demand for renewable and clean energy technologies. Both fundamental and applied research are crucial to meet this demand and to harness the power of natural resources through the development of innovative green technologies. Solar energy technologies are gaining in popularity because of incremental cost reductions and efficiency improvements. Solar systems can be divided into two major categories: solar photovoltaic systems (PV) and solar thermal. PV systems employ solar panels fabricated out of semiconductor devices to generate electricity from sunlight based on the photovoltaic effect. Solar thermal systems employ collectors to convert solar radiation into thermal energy, typically for applications such as heating of air or water and industrial process pre-heating.

Canadian Market at a Glance

The global PV industry has been growing rapidly. Installed capacity reached 23 GW in 2009, up from 16 GW in 2008.[2] Canada is widely seen as an emerging market. In fact, recent reports estimate that the Canadian market for solar energy products grew at an annual rate of approximately 25% between 1992 and 2006. The total installed capacity reached 94.5 MW in 2009, nearly triple that of 32.7 MW in 2008. Much of Canada's traditional solar capacity comes from stand-alone off-grid systems such as road signals, pipeline monitoring stations, telecommunications equipment, and remote homes, particularly in inaccessible areas or Northern regions with sparse populations. But this picture is changing quickly. The grid-connected segment jumped from 33% to 87% of the total between 2008 and 2009, mostly due to major incentive programs in Canada's most populous province, Ontario.[3]

Developments in Ontario

The key drivers for the implementation of green energy technologies in Ontario have been: (1) the desire to replace greenhouse gas-emitting technologies with those that draw on renewable resources, and (2) the deregulation and restructuring of electric power companies in the province that were intended to create a more competitive market.[4,5] PV systems are being deployed increasingly because technology advances have led to lower costs and higher conversion efficiencies.

Did you know…

- The first Canadian solar-powered community was built in Waterloo in 2002.
- The world's largest solar PV farm in Sarnia, Ontario can power more than 12,000 homes.
- Over 80% of Canada's generated energy came from emissions-free sources in 2009.

Table 1: Installed Capacity (North America)

	In 2009 (MW)	Total Cumulative Capacity (MW)
California	212	768
New Jersey	57	128
Colorado	23	59
Ontario	40	48
Florida	36	39

Source: www.renewableenergyworld.com

In an effort to combat climate change and build a green economy in Ontario, the province's political leadership has made commitments to sustainability and large-scale infrastructure spending. The **Green Energy Act (GEA)**, passed in May 2009, provides significant incentives for investment in renewable energy projects.[6]

The Ontario Power Authority has implemented the **Feed-in Tariff (FIT)** program (microFIT for projects 10 KW or less). As the first program of such immense scope in North America, the FIT program sets out rules, prices and contracts for project developers. This aims to make renewable energy projects affordable and to provide a return on investment in clean technologies. These incentives will help achieve one of Ontario's key energy objectives to eliminate coal-fired power generation by 2014.[7] The FIT program has generated international interest and has led to major announcements since inception. Ontario became North America's third-largest market and fourth in cumulative installed capacity in 2009 (Table 1).[8] Ontario's current capacity is estimated at 200 MW.

Natural Resources

Toronto Region's natural assets lend themselves well to photovoltaic and solar thermal installations. The region is strategically located in the midst of 25 million acres of farmland with a high annual PV potential. In fact, Southern Ontario receives a greater number of sunshine hours per year than regions that are recognized as the traditional leaders in solar energy technologies including Munich, Hong Kong, Paris and London (Figure 1).[9,10] The Great Lakes are the world's largest fresh water source and offer an abundant supply of water which is necessary for cooling of some solar energy systems. Toronto Region's electricity grid serves local IT and financial institutions as well as the most manufacturing-intensive region in Canada.

Industry and Labour Force

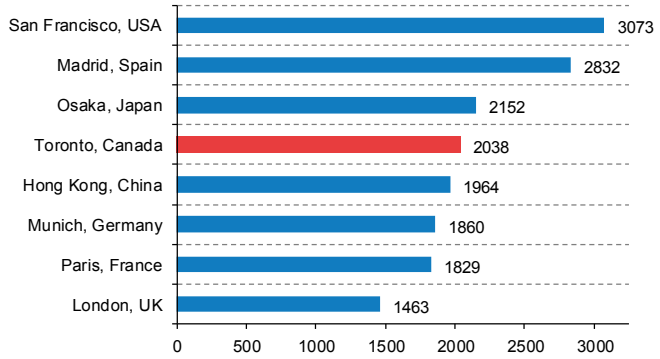
The Toronto Region is a growing hub for solar energy technologies with over 200 companies currently involved in related activities (Figure 2). Many are small- and medium-sized enterprises (SMEs) involved in designing systems and installing PV products for public and commercial needs. Examples of prominent companies are ARISE Technologies, ATS Automation Tooling Systems, GE Energy, Canadian Solar, and SkyPower Corporation.

The region boasts a growing industry with a highly-skilled and educated work force. There are an estimated 5,900 employees in the 210 companies. The region further employs 138,220 in related occupations such as electricians, electrical and civil engineers, and metal fabrication whose expertise would be undoubtedly of value to the growing solar industry.[11] Southern Ontario has a strong existing advanced manufacturing base that can support the growing solar industry with rich foundation in everything from high-quality machinery and die-and-mold making to automation systems and advanced materials. The developments in the green energy industry offer opportunities for local companies to diversify into emerging sectors and create jobs in construction, panel installation, operations, engineering, finance, IT and software.

Canadian Solar Industries Association (CanSIA)

The interests of the Canadian solar thermal and photovoltaic industries are represented by the **Canadian Solar Industries Association (CanSIA),** a national trade association with 650 industry members across Canada. CanSIA serves to raise the profile of the industry, promote the deployment of solar energy technologies, and carry out industry-specific research and education activities. The association released *Solar Vision 2025* in December 2010 which serves as Canada's road map for the industry. It envisions the widespread deployment of solar energy

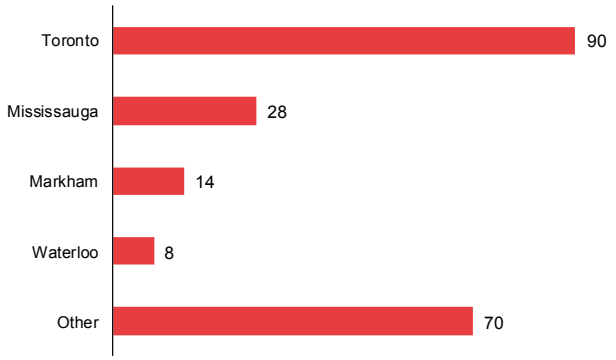
Figure 1: Sunshine Hours per Year (Competitive Cities)



Source: Yahoo! Travel Guide,[9] http://www.climatetemp.info[10]

Figure 2: Number of Companies by City in the Toronto Region

Total number of companies: 210



Source: TRRA analysis based on Industry Canada and Canadian Solar Industries Association members list

Figure 3: Industry Developments

Industry Highlights in 2010

January: Ontario signed a $7 billion green energy agreement – the largest of its kind in the world - with a Korean consortium led by Samsung C&T.

March: Bosch Solar Energy and Sustainable Energy commit to production of modules and inverters that would meet 2010/2011 FIT domestic content requirements.

October: Enbridge Inc.'s 80 MW solar PV farm in Sarnia was completed -making it the largest solar PV farm in the world.

October: The largest producer of crystalline silicon panels Suntech Power Holding Co. (Jiangsu, China) and Calisolar Inc. (US) signed a contract to build a silicon plant in Ontario.

October: Ontario closed four units of coal-fired generation, well before the 2014 deadline.

Recent Annoucements

Module manufacturer Solar Semiconductor (India) is setting up a production operation in Oakville.

Fronius International (Austria) will establish a solar inverter manufacturing site in Mississauga (estimated capacity of 50 MW/year).

Enphase and contract manufacturing partner Flextronics will establish a 100 MW micro-inverter production site. The plan is to double the capacity by the end of 2011.

Canadian Solar Inc. will set up its first North American solar module facility in Guelph (capacity 200 MW).

Eclipsall Energy Corp. is investing $10 million in 64 W solar panel manufacturing facility in the GTA.

Source: Karen Howlett, *Globe and Mail*,[16] Tyler Hamilton, *Clean Break*,[17] Government of Ontario,[18] Enbridge Inc.,[19] Reed Landberg, *Bloomberg News*[20]

technologies across the country and anticipates that the Canadian industry will employ more than 35,000 by 2025.[12]

The introduction of the FIT program has led to significant announcements and investment deals in Ontario's solar industry (Figure 3). The following are examples of players in the Toronto Region:[13,14]

Celestica (Toronto, Ontario) is one of five largest contract electronics manufacturers in the world with operations in Asia, the Americas and Europe. The company believes that the expertise accumulated from years of electronics manufacturing is transferrable to solar systems. It plans to launch a large expansion in green technology manufacturing with solar energy by early 2011. Celestica and Recurrent Energy, a subsidiary of Sharp Corporation, have started a joint venture to make crystalline silicon photovoltaic modules at Celestica's Toronto location.[15]

Founded in 2007, **Morgan Solar (Toronto, Ontario)** is a start-up that has developed a disruptive high-efficiency low-cost concentrated photovoltaic (CPV) solar module: Sun Simba HCPV. Morgan Solar has attracted funding from the provincial government, Sustainable Development Technology Canada, Iberdola Group (Spain's largest electrical utility), Turnstone Capital Management LLC, and Nypro Inc. of Massachusetts (global leader in injection moulding) for the development of its innovative technology. Manufacturing is underway for testing, demonstration and certification in Toronto, with systems planned for ground-mounted installation by late 2011.

SolGate (Woodbridge, Ontario) is the first large-scale PV panel manufacturer in the province with an annual production capacity of 25 MW. The company invested in advanced equipment for the production of polycrystalline solar modules and expanded its capacity from the original 6 MW. It entered into a distribution partnership with Sentinel Solar Corp., an Ontario company with expertise in the marketing, distribution and design of solar systems for commercial, agricultural and residential customers. Both companies are trying to take advantage of opportunities in the burgeoning PV market.

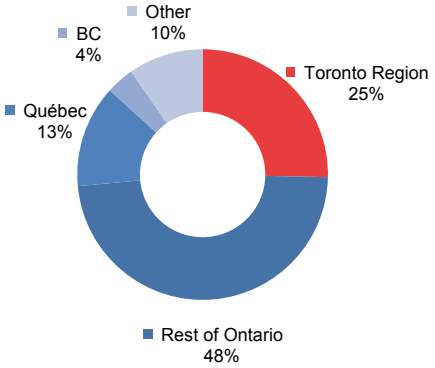
Photowatt (Cambridge, Ontario) is a subsidiary of ATS Automation Tooling Systems Inc., acquired as part of the French Photowatt Group in 1997. Photowatt has been active in advanced solar power technologies and production since the late 1970s. Photowatt Ontario was created in 2009 to serve the Ontario market in the area of solar modules, project development, maintenance and financing.

Table 2: Examples of Solar-related Research Institutes at Toronto Region Universities[24]

McMaster	Center for Emerging Device Technologies McMaster Institute for Energy Studies Brockhouse Institute for Materials Research
Guelph	Electrochemical Technology Centre Centre for Agricultural Renewable Energy and Sustainability
Toronto	Advanced Photovoltaics and Devices Group Institute for Optical Science Photonics Group
Waterloo	Centre for Advanced Photovoltaic Devices and Systems Power and Energy Systems Group Waterloo Institute for Sustainable Energy
York	Institute for Research and Innovation in Sustainability

Figure 4: Combined NSERC and CFI Funding (1999-2009)

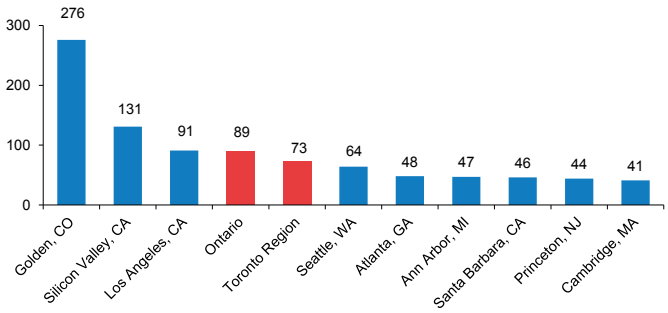
Total funding in Canada: $41,639,672



Source: TRRA analysis based on NSERC and CFI data, 2010

Figure 5: Solar PV Publications by North American Cities (1999-2009)

Total number in North America: 2,087



Source: TRRA analysis based on ISI Web of Knowledge, 2010.
(Note that the high number of publications in Golden, Colorado is due to the US National Renewable Energy Lab that produced 227 publications).

Research and Development in the Toronto Region

Innovation in solar energy technology is driven by cost reduction and efficiency improvements. Research and development are crucial to advance current systems and components.

The Toronto Region is a centre of advanced R&D. Local scientists are carrying out cutting-edge research in 22 solar energy-related research institutes and centers (Table 2). The expertise encompasses the entire solar value chain: thin films, photodetectors, PV energy conversion phenomena, refining processes for solar grade silicon, spectroscopy techniques, solar radiation modeling, distributed power and generation, and system design. Nanotechnology is expected to deliver efficiency improvements and the region is a hub of nanotechnology activity. In fact, 15 researchers are involved in solar nanotechnology such as nanocrystalline semiconductors, quantum dots, nanotube- and nanowire-based composite materials and fundamental phenomena.

Funding

Canada's main granting agencies invested more than $40 million in solar energy research across the country in the past ten years (Figure 4). Ontario received nearly 75% of the total NSERC (Natural Sciences and Engineering Research Council of Canada) and CFI (Canada Foundation for Innovation) funding for solar energy research and supporting infrastructure. With $5.3 million from CFI and $4.2 million from NSERC, the Toronto Region was awarded a quarter of the total Canadian funding. The University of Toronto and the University of Waterloo are major beneficiaries.[21,22]

The **Photovoltaic Innovation Network** is delivered through NSERC's *Strategic Network Grants* program, which channels funding into Canada's priority technology areas. The Network is headed by McMaster University and draws on the expertise of 29 top scientists and engineers from 13 universities and 20 government and industrial partners across Canada. With an investment of $8.8 million over five years, the Network is focusing on research that increases device conversion efficiency while reducing cost. The goal is to foster and accelerate large scale PV deployment in Canada.[23]

Scientific Publications and Patents

The Toronto Region is one of the top North American jurisdictions in the number of scientific publications related to the field of solar photovoltaics. It ranks among the top five in North America in the number of published articles (Figure 5). In fact, Toronto Region universities generate 36% of all Canadian publications.[26] Ontario is also the main contributor to Canada's international patent applications in the solar field and the Toronto Region accounted for over 50% of Ontario's patents between 1999 and 2009.[27]

Overview of Talent and R&D Expertise

The academic setting in the Toronto Region plays an important role in training talent and producing the future work force. With over 60 specific programs at seven local universities, the Toronto Region produces more than 3,400 graduates in solar energy-related engineering and science fields per year, such as environmental resource development and management, photonics engineering, and energy engineering.[28] Of all the degrees awarded, 83% were bachelor degrees, 14% were master's degrees and 3% were doctoral degrees.[29]

There are 86 experts performing research at related institutes in the Region. Below are profiles of a few prominent experts in the area:

Professor **Siva Sivoththaman** currently holds the Ontario Research Chair for Renewable Energy Technologies and Health. He is a leading expert in semiconductor materials, electronic devices, and fabrication technologies for PV applications. Dr. Sivoththaman received the Ontario Premier's Research Excellence Award in 2002. He served as the first Director of Canada's largest co-operative undergraduate degree program in nanotechnology, and is now the Director of the Centre for Advanced Photovoltaic Devices and Systems (CAPDS).[30]

Professor **Nazir Kherani** leads the Advanced Photovoltaics and Devices Research Group at the University of Toronto. The group focuses on semiconductor and nanostructured materials and devices with expertise in the areas of high-efficiency silicon PV, photonic crystals, optical coatings, photonic materials, and micro power sources. Dr. Kherani received the 2006 Early Researcher Award and the 2008 Ontario Research Foundation Excellence Award for his contributions to PV research.[31]

Rafael Kleiman, Professor in McMaster's Department of Engineering Physics, holds the Canada Research Chair in Micro Electro Mechanical Systems. He is heading a number of high-profile solar energy-related projects. Dr. Kleiman is leading a $4.1 million project funded by the Ontario Centres of Excellence and ARISE Technologies to develop high efficiency silicon-based multi-junction solar cells. He serves as the Director of the Centre for Emerging Device Technologies at McMaster University. He is also the Scientific Director of the Canada-wide NSERC Photovoltaic Innovation Network.[32]

Ted Sargent, Professor of Electrical and Computer Engineering at the University of Toronto, holds the Canada Research Chair in Nanotechnology. He has received numerous awards for his scientific accomplishments. Dr. Sargent was named one of the world's top young innovators by MIT's Technology Review in 2003 and stayed at MIT as Visiting Professor in Nanotechnology and Photonics the following year. He was also honoured in the *2005 Scientific American 50* for his contributions to flexible PV cells. This is a list that recognizes leading voices in science and technology from the past year.[33]

Innovation in the Toronto Region

The growing importance of solar energy technologies and recent developments in the provincial solar industry have spurred innovation in the field:

- Morgan Solar has been recognized with the Canadian Energy Innovation Award for its **disruptive high-efficiency and low-cost concentrated photovoltaic solar module, the Sun Simba**. The company is setting an industry standard with the highest reported optical concentration, yet a simple and compact design.[34]

- Professor Ted Sargent and his group at the University of Toronto invented **spray-on solar paint**, taking advantage of properties of nanosized semiconductor crystals in solution which can be sprayed or painted onto a variety of surfaces. This was the first solar cell capable of utilizing invisible, infrared rays emitted by the sun.[35]

- Brighton, Ontario-based company GreenWorks Solar Power partnered with experts from Durham College to develop a **unique and robust computerized control system for two-axis solar tracker mechanism.** The systems were designed for solar panel installations on unused farm fields and are capable of withstanding Ontario winters.[36]

- University Toronto professor Nazir Kherani is working with ARISE Technologies (Waterloo, Ontario) to develop a prototype of a **high-efficiency silicon photovoltaic solar cell**. Dr. Kherani's team is processing these cells by depositing nano-thin films at low temperatures, a process that increases the efficiency of available systems by 50%.[37]

Conclusion

The combination of a strategic location, academic expertise, a qualified work force, and the existing advanced manufacturing base, the Toronto Region offers tremendous opportunities in the solar PV industry.
The plan to shut down all coal-fired plants in the near future will necessitate alternative sources of energy, while the Green Energy Act provides strong incentives for investments in renewable energy technologies.

Canada and particularly Ontario are widely recognized as emerging markets with significant developments in 2009 and 2010. Ontario has experienced impressive growth and is now the fourth-largest solar market in North America in terms of installed capacity. In fact, the province currently has more than 200 MW of solar capacity derived from over 4,600 solar projects.[38] Multiple ventures are underway and have been in the planning stages since the implementation of the Act in 2009.

"Ontario was a global leader in telecom, but now that has slowed down… All the people, all this research...is finding a new home. I really believe Ontario can make itself a global hub in solar photovoltaic technologies… We have the ability to play, catch up, and to succeed."[25]

Dr. Rafael Kleiman, Professor of Engineering Physics and Director of McMaster's Centre for Emerging Device Technologies

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