

Residential Solar Opportunities in Dawson Creek

Solar Hot Water and Electricity Generation

Final Report

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February 2008



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A Report for the City of Dawson Creek

By:

Tim Weis P.Eng. • Matt Horne MRM

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About The Pembina Institute

The Pembina Institute creates sustainable energy solutions through research, education, consulting and advocacy. It promotes environmental, social and economic sustainability in the public interest by developing practical solutions for communities, individuals, governments and businesses. The Pembina Institute provides policy research leadership and education on climate change, energy issues, green economics, energy efficiency and conservation, renewable energy, and environmental governance. More information about the Pembina Institute is available at www.pembina.org or by contacting info@pembina.org.

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1 Introduction

Using the sun to heat buildings and water and generate electricity is becoming increasingly popular, even in northern counties like Canada. In fact Japan and Germany, both of which are located at latitudes similar to Canada are the world's two leading countries in photovoltaic installations. Solar energy systems are typically supported by government programs in order to reduce reliance on fossil fuels, reduce the risk of exposure to fluctuating energy prices, and to reduce local air and greenhouse gas emissions. Germany, Japan and California, all of who have the most supportive legislative framework for solar energy have all also become exporters of solar energy systems to the rapidly growing global demand. Appendix A provides some information on solar industries in British Columbia.

In addition to the direct environmental benefit, installing solar energy systems can also have a significant impact on that individual or community's relationship with energy. At an individual level, this can lead to changes in behaviour such as the purchase of energy efficient appliances and equipment, process changes, and support for other renewable energy projects. At a community level, the successful installation of one solar system can often give neighbors the confidence to install their own. Similar conclusions were reached by the National Renewable Energy Laboratory in Colorado with respect to small wind power.¹

The province of British Columbia has recently launched a program to achieve 100,000 solar roofs by the year 2020. The systems that will be used to achieve this goal are solar hot water heating (SWH) and solar photovoltaic (PV). The purpose of this report is to examine the technical potential, economic impacts, and environmental benefits of roof-mounted residential solar systems for the city of Dawson Creek.

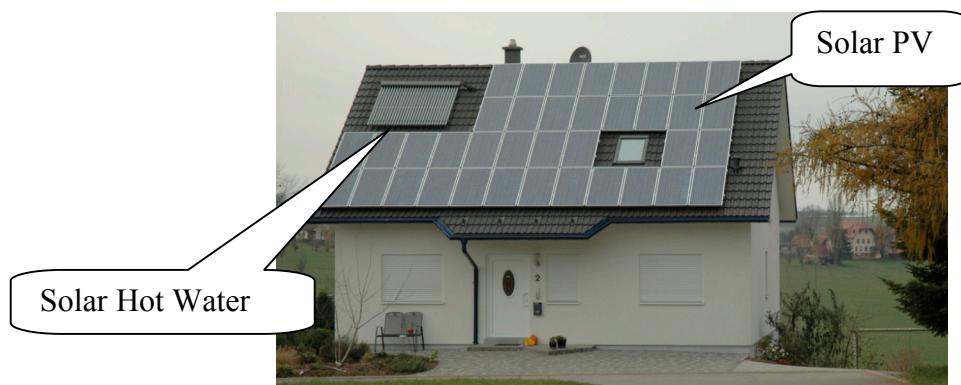


Figure 1: Home with solar hot water and PV systems (photo courtesy of Paul Gipe, www.wind-works.org)

Three opportunities that are outside the scope of this investigation merit mention, because they could all offer additional benefits to Dawson Creek residents:

- Other types of buildings such as apartment and commercial buildings can also benefit from both solar PV and solar water heating systems (as well as solar air heating).

¹ NREL. (2000). *Perspectives on an NWCC/NREL Assessment of Distributed Wind* (No. NREL/CP-500-28421): National Renewable Energy Laboratory.

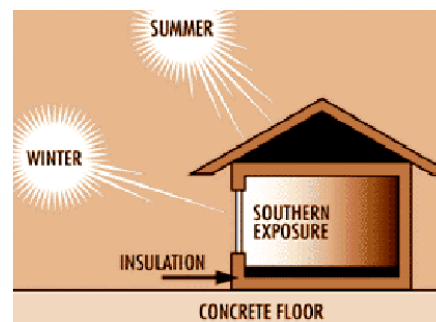
Typically the economics are even better for solar water heating for apartment buildings because of the economies of scale that can be achieved.

- Solar air heating systems, as shown in Figure 2, are a Canadian-developed technology that passively pre-heats air as it enters large buildings. The systems can pay for themselves in as little as 1-2 years when they are installed on new buildings and can often reduce heating costs by 30-40%. More information about other solar technologies can be found at: www.canren.gc.ca/tech_appl/index.asp?CaId=5&PgId=121. The solar air heating systems are manufactured by Conserval Engineering (www.solarwall.com) and are distributed in British Columbia through Astravan Distributors (www.astravan.com).



Figure 2: Recreation centre with Solarwall® in an Alberta First Nation.

- The orientation and design of a house can have a significant impact on energy use over the lifetime of the home. Designing homes and communities with passive solar heating in mind will allow each home to access as much free solar energy as possible. The term “passive” indicates that no additional mechanical equipment is used, other than what would typically be used in the construction of a building. Larger south-facing (within 30 degrees of due-south) are best because they allow the most direct sunlight to enter the home in the winter, and have awnings to prevent sunlight from entering the windows in the summer. An ideal ratio of window area to floor area is 8%. Window size on the north side should be minimized. **A home designed to optimize solar heating can meet 20-50% of its heating load with free solar energy without increasing the summer cooling needs.**²



1.1 Dawson Creek’s Solar Resource

Despite being in a northern climate, Canadian communities can still take advantage of solar energy, particularly in long summer days. However, even in shorter winter days, the sun offers a unique advantage in that it is strongest during the day when it is needed the most. For this research, the solar resource in the city of Dawson Creek was taken from the Natural Resources Canada solar resource maps³ and correlated with Environment Canada data from Dawson Creek.

² If passive solar is considered during the construction phase, there is very little (if any) extra cost associated. For more information, please refer to: the Canadian Solar Energy Society (www.solarenergysociety.ca), CMHC’s “Tap the Sun: Passive Solar Techniques & Home Designs” (www.cmhc.ca), and Advanced Building Technologies and Practices (www.advancedbuildings.org).

³ <https://glfc.cfsnet.nfis.org/mapserver/pv/municip.php?n=2324&NEK=e>

Because Dawson Creek is a northern community, the sun is low in the sky in the winter and as a result the average daily radiation from the sun, or ‘insolation’ that hits a horizontal plane in Dawson Creek is approximately 3.2 kWh/m²/day, which is slightly lower than a more southerly city such as Vancouver, whose annual horizontal insolation is close to 3.3 kWh/m²/day. The annual variations in Dawson Creek can be seen in Figure 3 below.

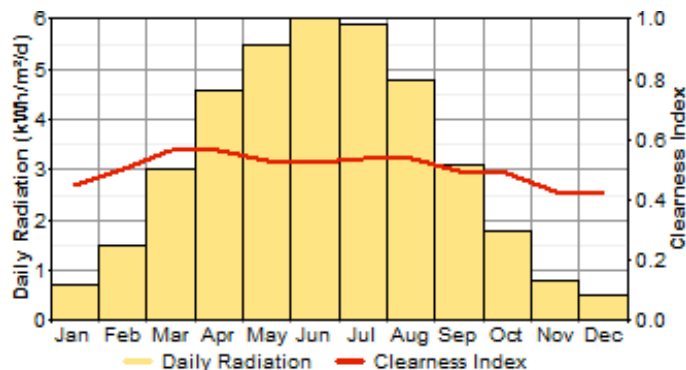


Figure 3: Dawson Creek insolation horizontal plane

By tilting up a solar panel properly this value is increased to 4.3 kWh/m²/day (see Appendix B for further detail), which is approximately 13% ‘sunnier’ than Vancouver. Typically the best orientation for fixed solar collectors is south-facing and on an incline approximately equal to the location’s latitude less 15 degrees. Slight modifications on the incline can improve either summer or winter performance.⁴ The solar potential map generated by Natural Resources Canada shown in Figure 4 below shows the solar potential for well-oriented static solar panels in British Columbia.

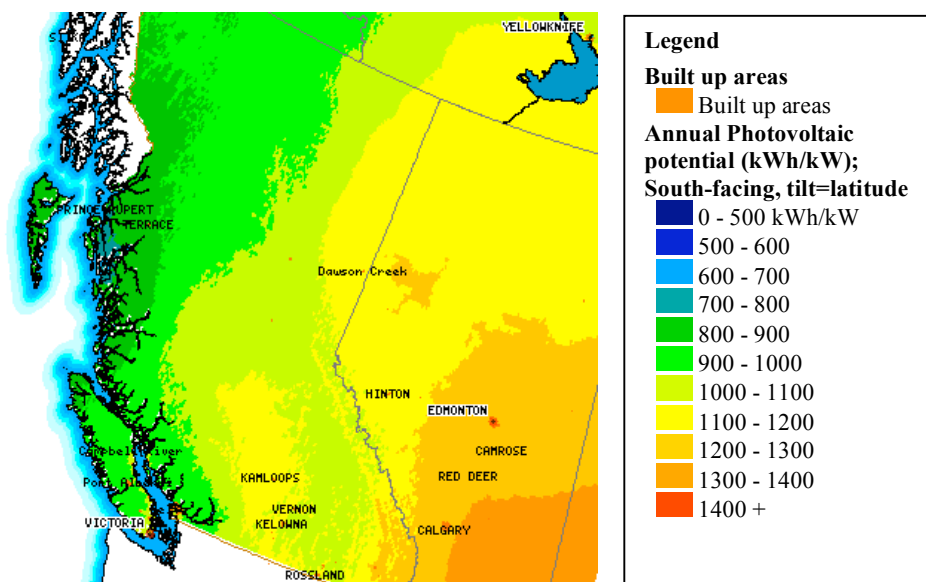


Figure 4: Solar potential for western Canada (source: https://glfc.cfsnet.nfis.org/mapserver/pv/index_e.php)

⁴ For further improved performance, systems can be designed to actively follow the sun from sunrise to sunset. In Dawson Creek 2-axis tracking systems could improve insolation rates by almost 50%; from 4.3 to 6.1 kWh/m²/day. Such systems are expensive to install and maintain and are not the norm in residential solar applications, and therefore only well-oriented static systems are considered for this report.

Dawson Creek can be seen in relative to Canada's best solar resource found in southern Alberta and Saskatchewan. Based on the amount of sun that Dawson Creek receives, and current technology, solar photovoltaic systems can be expected to operate at about a 13% capacity factor, which is good for a Canadian community and is in fact much higher than Berlin, Germany and Tokyo, Japan the capitals of the world's leading solar countries.

The capacity factor is the amount of energy that a system produced compare to how much it would produce if it operated at its full capacity 24 hours per day, 365 days per year. The capacity factor can sometimes be a misleading number as the sun is set for 50% of the day and there are cloudy days throughout the year, so even a perfect system in an ideal world would only be able to approach somewhere on the order of 30-40% capacity factors. In practical terms however, solar PV panels in Dawson Creek could be expected to generate 1,178 kWh per kW of capacity. This is over 30% more than 885 kWh per kW of capacity in Tokyo Japan, but about 13% less than Regina, one of the best locations in Canada where they can expect 1,361 kWh per kW of capacity (16% capacity factor).

Another advantage that Dawson Creek has is a snow cover during the winter months. The fact that snow is white means that it reflects the sun off the ground and allows significant amounts of solar energy that do not hit the panel directly to be reflected off of the ground on to the panels. This boost in winter months due to reflectivity is difficult to quantify in general terms as it depends on local conditions specific to the solar collector, but is a well known phenomenon and has been documented for the vertical solar panels integrated into the Federal government building in Yellowknife shown in Figure 5 below. The estimates in this report should therefore be considered as conservative.



Figure 5: LEED certified Greenstone building with integrated solar PV, Yellowknife, NWT

1.2 Residential Data for the City of Dawson Creek

Data provided by the city of Dawson Creek indicated that in 2007, there were approximately 3,500 single-family detached homes and 70 single-family attached, with almost all of them using natural gas for heating and hot water. It should be noted that although they are outside the scope

of this report, low and high-rise apartment buildings are well suited to solar systems, with the economics typically being more attractive than detached and row housing.

Energy consumption for a ‘typical house’ was derived from a HOT2XP model based on the current Canadian housing stock and new housing construction trends (based on publications from Statistics Canada, the Office of Energy Efficiency, and the Canadian Mortgage and Housing Corporation^{5,6,7}). The typical house modeled assumed a 135 m² floor plan, a fully insulated basement and 1980 construction with a typical occupancy of 2 adults and 2 children. While individual homes will vary from the model home, the variation is not significant for the purpose of this analysis. The results suggest that a typical home in Dawson Creek consumes 8,500 kWh of electricity annually and demands 4,720 kWh for domestic hot water heating purposes. Typical natural gas hot water tanks are on the order of 55% efficient, such that the annual consumption of natural gas is close to 8,585 kWh/yr for hot water purposes. At the time of writing this report the two-year average residential natural gas costs were 0.0374 \$/kWh⁸ and electricity rates were 0.0615 \$/kWh⁹.

Table 1: Typical residential annual energy consumption in Dawson Creek

Use	Energy	Consumption (kWh/yr)	Rate (\$/kWh)	Cost (\$/yr)	GHG (kgCO ₂ /kWh)	GHG (kgCO ₂ /yr)
Appliances	Electric	8,500	0.0374	318	0.032	270
Hot Water	Natural Gas	8,585	0.0615	530	0.188	1,610

⁵ Farm Financial Survey, 2005. Balance Sheet; Financial Structure by Farm Type, Financial Structure by Revenue Class; Capital Investments and Sales; by Region, 2004. Statistics Canada, Agriculture Division, Whole Farm Data Projects Section. Published by authority of the Minister responsible for Statistics Canada. January 2006. Catalogue no. 21F0008XIB. ISSN 1481-8213

⁶ Energy Use Data Handbook. 1990 and 1998 to 2004. August 2006. Energy Publications, Office of Energy Efficiency. Natural Resources Canada. Cat. No. M141-11/2004E. ISBN 0-662-43662-8

⁷ 2003 Survey of Household Energy Use (SHEU). Summary Report. December 2005. Energy Publications, Office of Energy Efficiency. Natural Resources Canada. Cat. No. M144-120/2003-1. ISBN 0-662-69565-8

⁸ PNG Dawson Creek historical pricing data provided by Alison Cormack, British Columbia Utility Commission, alison.cormack@bcuc.com

⁹ BC Hydro residential rate: 0.0615 \$/kWh. www.bchydro.com/policies/rates/rates757.html, effective Feb. 1, 2007. Accessed August 28, 2007

2 Solar Hot Water

Solar hot water (SHW) systems are a proven technology that has been used for several decades in Canada. Solar collectors absorb energy from sunlight and transfer the heat into a storage tank, either directly in cases where the water is unlikely to freeze, or through the use of an anti-freeze and heat exchanger in colder climates. Solar water heating does not replace the conventional water heater – it supplements it, and reduces the amount of traditional energy needed to heat the water. SHW systems are designed to be mounted on the roofs of houses and in Canada are ideally built facing south. As was mentioned earlier, the ideal slope of the collector is typically the latitude of the location less 15 degrees (0 degrees would be laying horizontal, and 90 degree would be vertically mounted). The latitude of Dawson Creek is 56 degrees, therefore hot water systems should be installed at angles as close to 41 degrees as possible. If the roof is not at the ideal angle, framing can be used to mount the system as is shown in Figure 6 below.

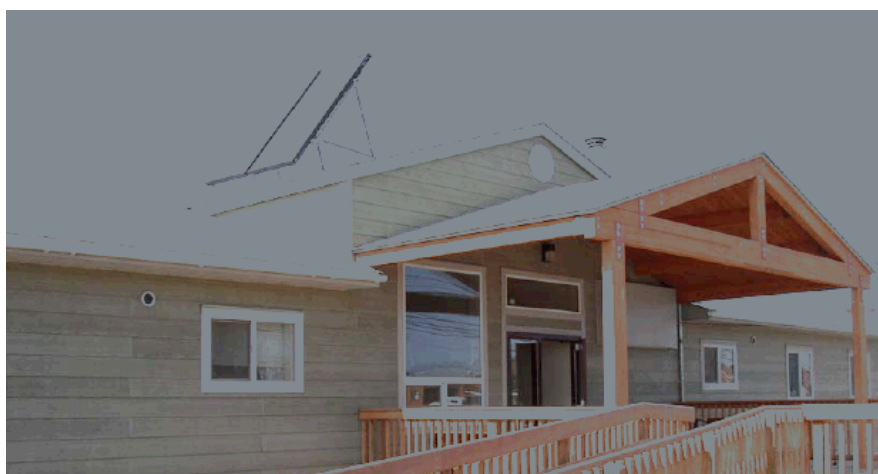


Figure 6: Solar hot water system in Wha Ti, NWT

Solar water heating is a mature technology common in many countries including those where some form of freeze protection is required. In the 1980s Canada supported a significant solar water heating industry, and while much of this support no longer exists, this period of development showed there were no major physical or technical barriers preventing the adoption of solar for water heating in Canada.

SHW systems can be added to a majority of homes in Canada. Houses in heavily wooded neighborhoods, or near tall buildings (such as apartments) will have less exposure to the sun and will not be able to benefit fully or at all from solar hot water systems. A typical domestic SHW heating system is typically 6 m² (2 x 2.97 m²), therefore this amount of roof space with southern exposure is required. The systems also typically require an additional water tank to store the pre-heated water. These are the only two technical requirements that would limit the uptake of solar hot water systems on any home in Dawson Creek.

2.1 Technology Assessment

A RETScreen™ (www.retscreen.ca) analysis for solar water heating was done for the city of Dawson Creek using an average installation costs of \$5,500 for typical 2 x 2.97 m² installation

(\$920/m² or 1,300\$/kW).¹⁰ Table 2 lists the model results from the RETScreen™ analysis for natural gas and electrically heated water assuming an annual operation and maintenance cost of 0.25% of installed costs. While it was estimated that 98% of homes in Dawson Creek use natural gas for hot water heating both natural gas and electric hot water heating scenarios are presented below for completeness.

Table 2: Solar hot water heating system results

Displaced Energy	Annual Solar Energy Delivered	Conventional System Efficiency	Annual Energy Savings	Displaced Energy Cost	Annual Savings	Annual GHG Savings
Electric	3,180 kWh	85%	3,740 kWh	\$ 0.062	\$ 232	0.12 tCO ₂
Natural Gas	3,180 kWh	55%	5,780 kWh	\$ 0.048	\$ 202	1.04 tCO ₂

A typical solar hot water system would be able to deliver a net amount of 3,180 kWh of renewable energy per year operating in Dawson Creek. The vast majority of hot water tanks in Dawson Creek are natural gas systems which typically have efficiencies on the order of 55%, therefore 5,780 kWh (21 GJ) of natural gas would be displaced every year. The few remaining homes in Dawson Creek that use electric hot water systems could expect to save 3,730 kWh per year assuming a standard electric hot water heating efficiency of 85%. At current prices both setups would have a simple payback period on the order of 25 years (assuming no increase in energy prices, a 0% discount rate, and not accounting for environmental benefits). While maintained systems can last longer than 30 years, this is nonetheless a longer payback period than most homeowners would consider without some sort of supporting policy.

Solar hot water heating systems can be installed on any roof with a good southern exposure. A 2004 report by the David Suzuki Foundation¹¹ estimated that 63% of homes in Ontario could be fitted with SHW heating systems. This number was calculated by the Canadian Solar Industries Association and was based on housing orientation and sufficient roof space (6 m²). These estimates are based on a random alignment of houses and there is no reason not to use these estimates for Dawson Creek¹² (or anywhere else in Canada). It can therefore be safely assumed that close to 60% of the current housing stock could install SHW systems. Table 3 shows the overall potential for residential solar hot water heating systems in Dawson Creek.

Table 3: Solar hot water potential of existing residential housing stock

Water Heating Type	Number of Houses	SHW Potential Houses	Annual Energy Savings	Annual Savings	Annual GHG Savings (tonnes CO _{2e})
Electric	71	42	157 MWh	\$ 9,161	5
Natural Gas	3,499	2,099	12,132 MWh*	\$ 424,884	2,184
Totals	3,570	2,141	12,289 MWh	\$ 434,045	2,189

* 43,676 GJ/yr of natural gas

¹⁰ Based on a recent Canadian Solar Industry Association report: *The Price of Solar Water Heating in Canada V2.4*, May 2006. Available for download at: <http://www.cansia.ca/downloads/report2006/C20.pdf>. Accessed Jan 15, 2007.

¹¹ David Suzuki Foundation (2004) *Smart Generation: Power Ontario with Renewable Energy*, ISBN 0-9689731-8-3. Available for download at: http://www.davidsuzuki.org/_pww370829/files/Climate/Ontario/Smart_Generation_full_report.pdf

¹² Communities including Perth, ON and Bathurst, NB have reached estimates that over 70% of existing houses could be retrofitted with SHW

Figure 7 shows the life cycle costs of energy from solar hot water heating depending on the installed cost (assuming a 20-year system life, a 0% discount rate, and constant energy prices). As illustrated, the installed cost (on the x-axis) would need to drop to about \$4,200 to be equivalent in cost with natural gas and to about \$4,500 to be equivalent with electricity prices (this does not account for environmental benefits). Installed costs can be expected to be declining as the technology evolves and becomes more mass-produced. While energy prices may also rise in the future, these predictions are difficult to make and therefore policy intervention is likely required to significantly accelerate deployment in the short to medium-term.

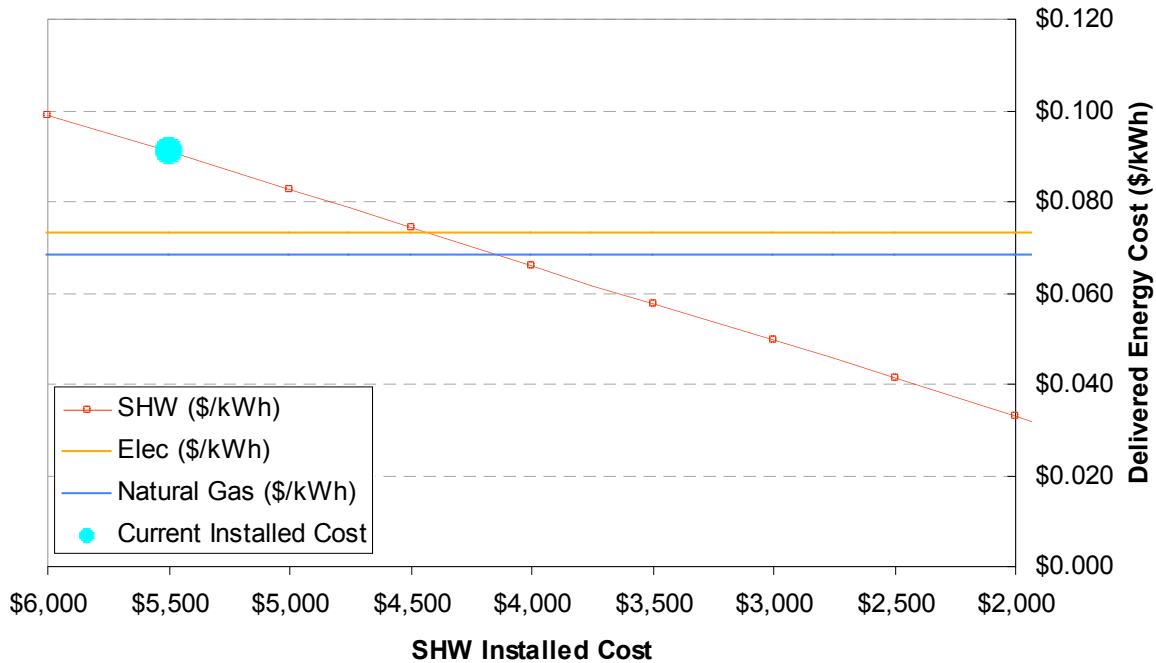


Figure 7: Hot water heating systems costs in Dawson Creek

A number of mechanisms could help reduce the installed cost of SHW systems to help accelerate their deployment. Houses that are made *Solar Ready* by virtue of ensuring that piping and controller wire are connected to the SHW potential location to the mechanical room at the time of construction, or even installing the systems during construction, can reduce costs on the order of \$200-\$800 in labour. Incentives through capital cost grants or production incentives could also be instituted either at a provincial or a municipal level. If successful, the increased installations that these policies should motivate will help create a stronger market for the technologies and cause costs to drop through economies of scale. In order to properly design an incentive, it would be important to re-visit some of the above economic assumptions in order to set an adequate level of incentive.

3 Solar Photovoltaics

Solar photovoltaic (PV), or solar electric systems are a rapidly growing industry with annual global installed growth rates on the order of 30% over the past 10-15 years as shown in Figure 8 below. The technology is mature and has been proven in extreme conditions including the Arctic and space. Nonetheless the technology is still rapidly improving to reduce capital costs and increase ease of installation. A recent Natural Resources Canada study found that the cost of solar PV dropped by over 50% from 1999-2005.¹³ Government programs have encouraged significant solar PV growth in California, Japan and Germany, who are installing PV at rates of 50, 350 and 750+ MW/year respectively. These countries are also the major global suppliers of the technology and have been largely responsible for the continuing price decreases.

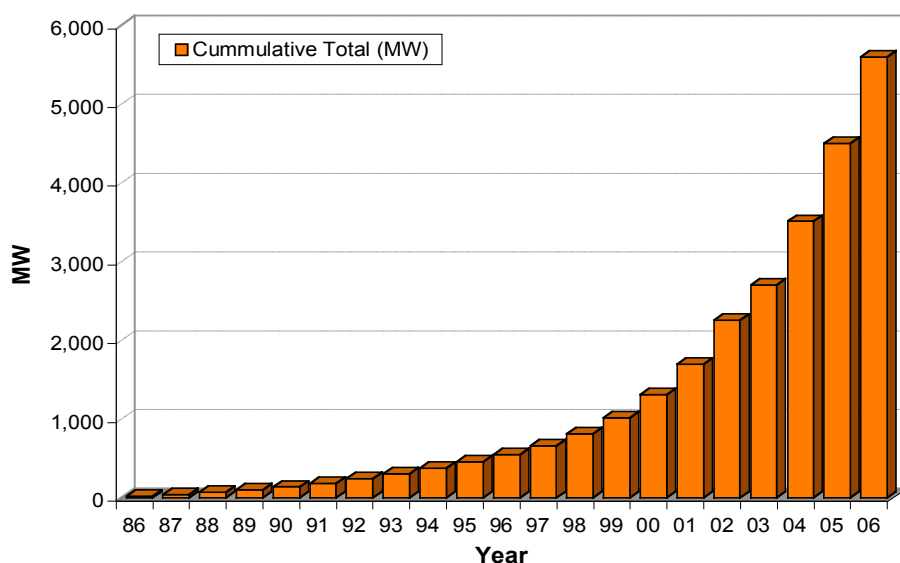


Figure 8: Global installations of solar PV systems

Like SHW systems residential PV systems are typically roof mounted, although they can also be mounted on building façades. While vertically mounted systems receive less direct sunlight, they are able to capture reflected sunlight from the Earth's surface, which is particularly useful in areas with frequent snow-cover.

3.1 Technology Assessment

A HOMER¹⁴ micropower simulation model was done for a model home in Dawson Creek. As BC Hydro allows for net metering, a battery storage system would not be required for residential solar PV systems. Nonetheless, inverters and other power control equipment are required and typical installed costs for solar systems are on the order of \$9,500 per kW. At the residential

¹³ NRCan, CETC-Varenes 2006 PV market survey.

¹⁴ www.nrel.gov/homer

scale there are very little economies of scale, such that a 3 kW PV system is close to three times the price of a 1 kW system.

Solar PV systems are modular, and therefore there is no standard systems size that can be associated with a residential system. A 3 kW system is representative of the typical rooftop capacity for a household (20 m²) and so it was modeled in this report along with a 1 kW system. As was mentioned in the introduction, houses could install both SHW and PV systems, however such systems are not explicitly modeled in this report. Such setups would not affect the economics of either system¹⁵, but would reduce the amount of roof space available for PV.

HOMER models hourly load data as well as the hourly production from a renewable energy system based on the local resource. For Dawson Creek, the model found that a 1 kW system would produce 1,160 kWh of electricity annually, which is approximately 13.5% of a typical home's consumption for household appliances (8,500 kWh/year).

The expected annual performance of residential solar PV systems in Dawson Creek is shown in Table 4 below. The results for 1 kW systems are shown for ease of multiplication; while 3 kW systems are shown as they are a typical residential size. Access to net metering means that the economics of a PV system are not affected by the actual power that is consumed by the home compared to how much of the electricity is sold to the grid. However, for the sake of interest the table also lists how much power is consumed directly in a typical home (without electric hot water heating) compared to how much of that power is sold to the grid (or net metered).

Table 4: Residential solar PV system results

System Description	Annual PV Output (kWh)	% of Home's Annual Use	Annual PV Used in Home (kWh)	Annual PV Net Metered (kWh)	Annual GHG Savings (tonnes CO _{2e})
1 kW PV	1,170	13.5%	1,160	10	0.03
3 kW PV	3,510	40%	2,300	1,210	0.11

While a 3 kW system was modeled as a typical installation, the International Energy Association's Photovoltaic Power Systems Programme (IEA PVPS) Task 7 report estimates that for every m² of ground floor area (footprint) of a home, 0.4 m² of roof space is "solar suitable", as well as 0.15 m² of façade space. This means that almost every home is capable of installing some sort of PV system based solely on its orientation, but many could also be larger than 3 kW. A "solar suitable" surface means it collects at least 80% of the maximum insolation for the area, so to use all of the "solar suitable" area would mean that some of the systems would operate up to 20% less efficiently than the model results listed below. Without doing a detailed study of the roofs in Dawson Creek, Table 5 below lists the PV potential using two approaches to illustrate the upper and lower bounds of potential:

- Using the IEA method described above with an assumed average number of floors of 1.44¹⁶ per home.

¹⁵ In 15% of cases where electricity is used to heat the water it would mean that more of the solar PV is net metered than is used directly in the home, but this has no overall economic impact

¹⁶ Natural Resources Canada, Office of Energy Efficiency, 2003. Survey of Household Energy Use (SHEU) 2003, table 2.1. Cat. No. M144-120-2003E

- Assuming the same percentage of homes that could install solar hot water systems (60%) could install 3 kW systems.

In addition to the energy savings and GHG reduction benefits, solar PV is also able to help meet peak demands in the grid because its output matches well when many electric demands are highest (see Appendix B for more detail).

Table 5: Solar hot water potential of existing residential housing stock

Method	PV location potential	PV density	Installed Solar Potential	kWh/kW	GWh/yr	Annual GHG Savings (tonnes CO _{2e})
IEA Method*	184,078 m ²	0.12 kW / m ²	21,656 kW	1,030	22.3	714
60% of homes	2,142 homes	3 kW / home	6,426 kW	1,170	7.5	241

* note: the IEA method calculation works out that every home could install an average of 6.1 kW

Figure 9 shows the life cycle costs of solar PV systems as the installed cost changes (assuming a 20-year system life, a 0% discount rate, 0.25% of capital cost annual O&M, and constant energy prices). As illustrated, the current installed cost (\$9,500 on the x-axis) would need to drop to about \$1,300 to be equivalent in cost with electricity prices (without accounting for environmental benefits). The installed costs have been declining as the technology evolves, but policy intervention will be required to significantly accelerate deployment in the short to medium-term. Incentives through capital cost grants or production incentives are the most likely policies to encourage solar PV, and they could also be instituted either at a provincial or a municipal level.¹⁷

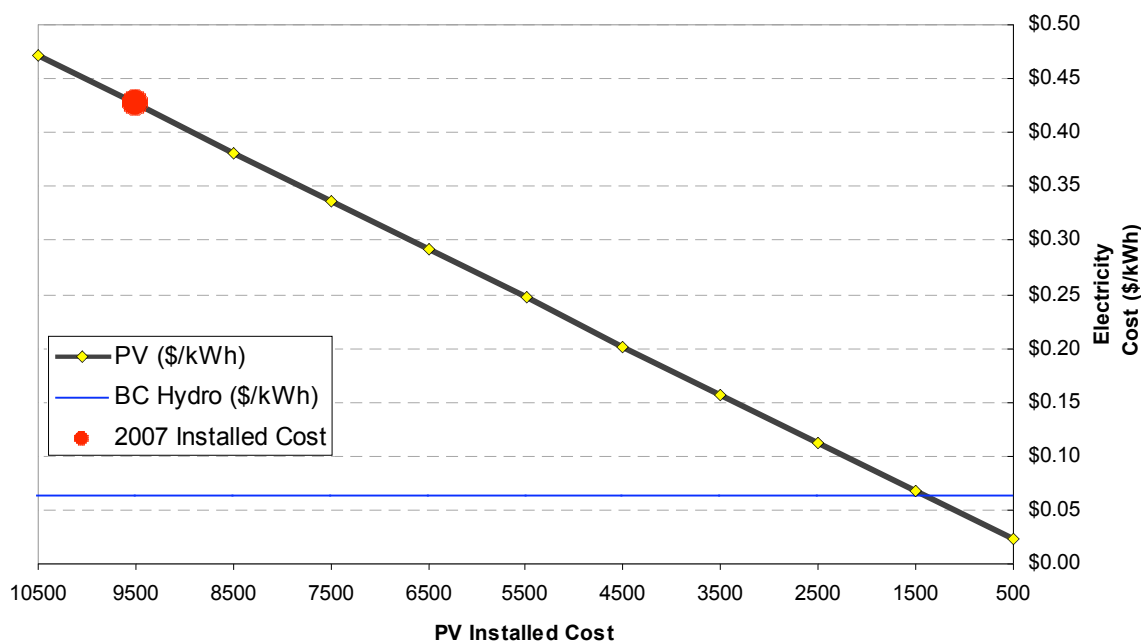


Figure 9: PV undiscouted electricity costs

¹⁷ Ontario recently set a feed-in rates for solar PV at 0.42 \$/kWh, which as can be seen in the figure is close to the pure cost of PV electricity in Dawson Creek. The Ontario Sustainable Energy Association is currently pushing to have this rates increased to 0.80 \$/kWh in order to account for debt financing of the equipment, to consider a discount rate had the investment in PV been invested elsewhere and to allow homeowners who invest in PV to make a modest profit.

4 Conclusions

The solar potential in Dawson Creek is good compared to many other Canadian cities. While it is not the best in Canada, it is better than in Tokyo, which has one of the highest per capita solar installation rates in the world. The average daily solar radiation is such that a 6 m² solar water heating system could be expected to collect 3,180 kWh of useful renewable energy and a 1 kW solar PV systems could generate 1,170 kWh/kW annually. Every 1 kW of solar PV that is installed in Dawson Creek could be expected to provides approximately 13.5% of the home's annual electricity use.

Solar hot water heating systems would reduce annual energy costs by \$232 and \$202 when coupled with electric and natural gas water heating systems respectively. Solar PV systems will reduce annual electricity costs by \$75 per kW installed. Current solar hot water heating systems average \$5,500 to purchase and install, while solar PV systems cost on the order of \$9,500 per kW. Both systems would expect to have annual operations and maintenance costs on the order of 0.25% of the installed costs.

A conservative estimate is that 60% of homes in Dawson Creek could install solar hot water systems, or an estimated 2,141 homes. If such an uptake occurred over 2,190 tonnes of CO_{2eq} emissions would be reduced annually. Potential residential uptake for solar PV in Dawson Creek is estimated to be between 6.4-21.7 MW, which would reduce annual greenhouse gas emissions by between 241 and 714 tonnes.

These numbers demonstrate the significant ability of solar hot water and solar PV systems to reduce the demand for grid electricity and natural gas in Dawson Creek, as well as the corresponding greenhouse gas emissions. However, the costs of installing these systems are high and the life cycle costs (not accounting for environmental benefits) are still higher than conventional options. As a result, the technical potential presented above is unlikely to be achieved without some sort of policy intervention (as evidenced by the low rates of penetration seen today).

While there are currently no Federal or BC programs to incent residential solar systems, it is possible for communities, such as Dawson Creek to lead the way in making such a transition. Appendix C gives an example of how Aachen, a city in Germany set in motion Germany's national advanced renewable tariff program, arguably the most progressive solar energy incentive program in the world. Policies that Dawson Creek could consider would be incentives to reduce the capital cost, production incentives, local improvement charges to finance systems, and bylaws requiring homes to be built solar ready or with a certain percentage of their energy needs being met by solar energy.

Appendix A

Solar Energy Suppliers in British Columbia

The following list is compiled from the Canadian Solar Industry Association's webpage (www.cansia.ca/directory). There may be other suppliers, installers and retailers in the British Columbia that are not members of CanSIA. They are listed in no particular order.

Company	Hot Water	PV
Xantrex Technology Inc. 8999 Nelson Way Burnaby, BC V5A 4B5 Telephone: (604) 422-8595 www.xantrex.com customerservice@xantrex.com		X
Day 4 Energy Inc. 101 - 5898 Trapp Ave. Burnaby, BC V3N 5G4 Telephone: (604) 759-3294 Fax: (604) 759-3295 www.day4energy.com info@day4energy.com		X
British Columbia Institute of Technology 3700 Willingdon Ave Burnaby, BC V5G 3H2 Telephone: (604) 456-1032 Fax: (604) 436-0286 www.bcit.ca/appliedresearch/pv/ Lou_Stamenic@bcit.ca		X
Taylor Munro Energy Systems Inc 7157 Honeyman St. #11 Delta, BC V4G 1E2 Telephone: (604) 946-4433 Fax: (604) 946-3804 www.taylormunro.com info@taylormunro.com	X	
Astravan Distributors Ltd. 123 Charles Street N. Vancouver, BC V7H 1S1 Telephone: (604) 929-5488 Fax: (604) 929-4883 www.astravan.com info@astravan.com	X	

<p>Canadian Solar Technologies Inc. 8459-110A Street Delta, BC V4C 2K5 Telephone: (604) 721-6565 Fax: (604) 507-9671 www.canadiansolartechnologies.ca info@canadiansolartechnologies.ca</p>	X	
<p>Analytic Systems Ware Ltd. #207-12448 82nd Ave. Surrey, BC V3W 3E9 Telephone: (604) 543-7378 Fax: (604) 543-7354 www.analyticsystems.com info@analyticsystems.com</p>		X
<p>Derrick J. Garland (Sole Proprietor) P.O. Box 170 Fort Langley, BC V1M 2R5 Telephone: (604) 617-6563</p>	X	X
<p>Carmanah Technologies Corporation Bld 4 203 Harbour Road Victoria, BC V9A 3S2 Telephone: (250) 380-0052 Toll-Free: (877) 722-8877 Fax: (250) 380-0062 info@carmanah.com www.carmanah.com</p>		X
<p>Rocky Mountain Solar Co. 6005 Brown Rd. Dunster, BC V0J 1J0 Telephone: (250) 968-4490 Fax: (250) 968-4410 royhoward@telus.net</p>	X	X
<p>Solarcrest 205A - 824 Johnson St. Victoria, BC V8W 1N3 Telephone: (250) 477-4060 Fax: (250) 477-4043 info@solarcrest.ca www.solarcrest.ca</p>	X	

Appendix B

Details of Solar PV Output

PV potential (kWh/kW)

	South-facing vertical (tilt=90°)	South-facing, tilt=latitude	South-facing, tilt=latitude+15°	South-facing, tilt=latitude-15°
January	64	60	64	53
February	80	80	83	73
March	108	121	119	117
April	97	128	118	132
May	81	122	106	132
June	76	121	103	134
July	78	122	105	134
August	82	117	104	123
September	81	99	94	99
October	80	85	86	80
November	61	60	63	53
December	56	52	56	45
Annual	943	1168	1101	1175

Mean daily global insolation (kWh/m²)

	South-facing vertical (tilt=90°)	South-facing, tilt=latitude	South-facing, tilt=latitude+15°	South-facing, tilt=latitude-15°	Two-axis sun- tracking	Horizontal (tilt=0°)
January	2.8	2.6	2.8	2.3	3.0	0.7
February	3.8	3.8	4.0	3.5	4.6	1.5
March	4.7	5.2	5.1	5.0	6.7	3.0
April	4.3	5.7	5.3	5.9	8.4	4.6
May	3.5	5.3	4.6	5.7	8.6	5.5
June	3.4	5.4	4.6	6.0	9.4	6.0
July	3.4	5.3	4.5	5.8	8.9	5.9
August	3.5	5.0	4.5	5.3	7.7	4.8
September	3.6	4.4	4.2	4.4	5.9	3.1
October	3.4	3.7	3.7	3.5	4.4	1.8
November	2.7	2.7	2.8	2.4	3.1	0.8
December	2.4	2.2	2.4	1.9	2.6	0.5
Annual	3.5	4.3	4.0	4.3	6.1	3.2

Source: <https://glfc.cfsnet.nfis.org/mapserver/pv/municip.php?n=2324&NEK=e>

While PV only generates power during the day, the electricity that is generated occurs during working hours as can be seen in Figure 10 below, which are the times of peak system demand. While residential demand tends to peak later in the day (close to dinner time), net metering allows residentially generated PV to reduce the needs for new generating capacity (or electricity imports) for BC. Both the generation capacity and the ability to provide power during peak consumption periods increase the overall electrical system efficiency. On site generation reduces imported power lines losses, and day-time generation will reduce the costs and size of transmission capacity into the city.

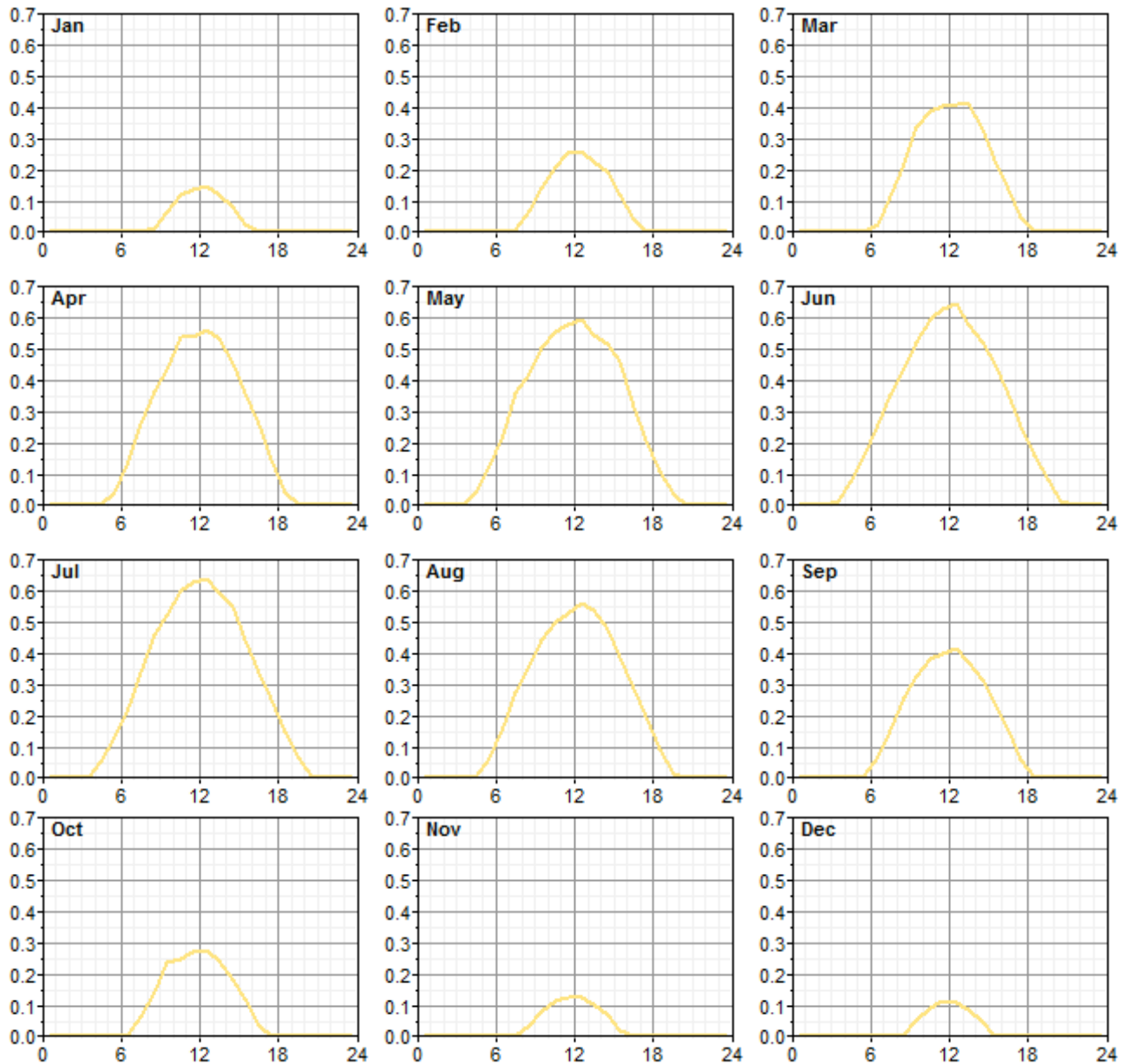


Figure 10: Average daily PV production for a typical residential 3 kW system

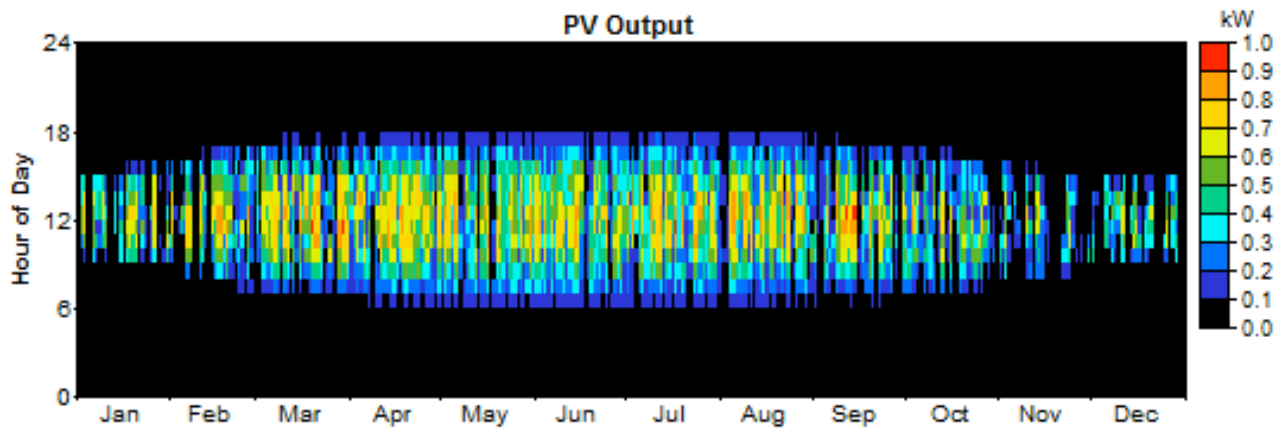


Figure 11: Annual expected solar PV generation per kW

Appendix C

The Aachen Solar Tariff Model

April 7, 2007

by Paul Gipe

www.wind-works.org

In the early 1990s the city of Aachen (Aix-en-Chapelle) Germany set the world of solar energy on its ear. Until that time development of solar PV depended entirely on direct and substantial subsidies. Then in June, 1993 Aachen's city council approved the first solar PV tariff that paid a profitable price for solar generated electricity.

Aachen calculated a tariff that would allow recovery of the "cost" of solar PV plus a modest profit. This principle is much like that used to determine the tariffs or electricity rates for regulated electric utilities.

The city did not base its tariff on the "value" of the solar electricity. This was--and is--revolutionary because solar PV is expensive and if rates are based on what it costs to install solar PV, the tariff will be much higher than that for other, cheaper, technologies. Aachen's city council took a bold move and said in effect, "we want solar and we're willing to pay what it takes".

At the time, solar generated electricity in Germany was paid 90% of the retail rate under Germany's 1991 electricity feed law, the *Stromeinspeisungsgesetz*.

Aachen determined that in addition to the feed law tariff, it was necessary to pay a citywide solar tariff of 2 DM/kWh (US\$1.28/kWh) for ten years. Shortly thereafter the Bavarian city of Freising followed suit.

Between 1994 and 1997, 30 Bavarian villages implemented a similar program.

Aachen and its sister cities established the principle of paying for the cost of generation for the generating technologies they desire--and not necessarily those that are the cheapest.

The Aachen model became the foundation for Germany's successful EEG, the Renewable Energy Sources Act (also known as the Act on Granting Priority to Renewable Energy).

Aachen's solar tariff and subsequent solar tariffs under Germany's EEG provided successful examples for the Ontario Sustainable Energy Association in proposing a solar tariff for Ontario.

<http://www.wind-works.org/Solar/TheAachenSolarTariffModel.html>

Appendix D

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