PHOTOVOLTAICS FOR THE NORTH: A CANADIAN PROGRAM

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ABSTRACT: Large seasonal variations in solar radiation and other adverse climatic factors have made the implementation of PV technologies challenging in Canada, especially in the North; however, through the development of new technologies adapted to cold climates and the development of expertise in this field, this challenge is being met. This paper reports on the experience and results of *PV for the North*, a Canadian program that started in 1993 in response to a need for PV systems better adapted to harsh arctic conditions and information on the technology. This five year program was initiated by the CANMET Energy Diversification Research Laboratory (CERDL), the Aurora Research Institute and the Nunavut Research Institute to address the various issues of importance in the particular context of Canada's north. The achievements of this program have been reached because of its complete range of activities: from market assessment to product development, to demonstration systems and information dissemination.

1. INTRODUCION

Canada's Northwest Territories communities are not linked to the North American electrical grid and 60% of their electricity is produced using diesel generators. This reliance on fossil fuel entails high financial and environmental costs. Increasing the use of renewable energy and energy conservation measures are the key to this region's sustainable development.

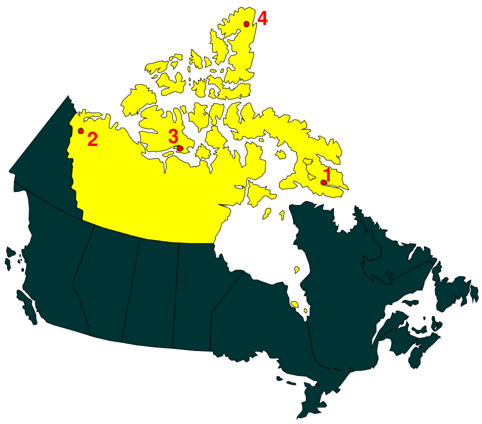

Figure 1: Map of Canada with yellow area outlining the Northwest Territories; specified project sites **1.** Iqaluit, **2.** Inuvik, **3.** Cambridge Bay, **4.** Tanquary Fiord.

The *PV FOR THE NORTH* program was initiated in 1993 by CANMET-EDRL and the Science Institute of the Northwest Territories (NWT), now known as the Aurora Research Institute (NWT-West) and the Nunavut Research Institute (NWT-East). This five-year program was aimed at increasing the penetration of PV technologies in Canada's north through technology development and transfer activities [1-3]. The program activities included:

1. Identifying and evaluating various markets in the Northwest Territories (NWT)
2. Stimulating PV markets through targeted technico-economic studies
3. Demonstrating and analysing the performance of PV systems operating in arctic conditions
4. Developing technologies better adapted to cold climate conditions
5. Transferring information and educating potential users and decision makers.

A summary of the key projects accomplished within each activity is presented in this paper. More detailed information is available by consulting the extensive list of references noted at the end of this paper.

2. PROGRAM ACTIVITIES

2.1 Market studies

Three market studies were completed during the PV for the North program. The first aimed at evaluating the overall technical potential of PV in the NWT [4]. Table 1 presents a summary of the findings and clearly showed that the largest market was the community diesel grid market. The near term markets were for radio or telephone communication sites, remote parks and fire towers. Several of these short term applications were the focus of technico economic studies described in section 2.2 of this paper.

Table I: Technical Potential of PV in NWT, Canada

Applications	Potential	Deployment
Diesel grids	17 MW_p	Long term
Communications	600 kW_p	Short to med. term
Remote residences	75 kW_p	Medium term
Remote parks	7.5 kW_p	Short term
Fire towers	7.5 kW_p	Short term

The second study focussed on quantifying the avoided cost benefit of PV on community diesel systems. This was performed based on the community electrical generation in Cambridge Bay, NWT [5]. The community's peak load is 1200kW and fuel costs CDN$0.80/l. The benefits were mainly due to reduced generator run time and fuel savings in the summer months. Without accounting for environmental benefits, for PV to be installed cost effectively on this community's diesel grid, the cost of turn-key PV systems must meet the value of the avoided cost benefit (CDN$2.63/Wp to CDN$4.25/Wp).

Table II: Estimated avoided cost benefit of PV on the local diesel grid in Cambridge Bay, NWT.

Benefit	Disc. Rate	Fuel Inc.	CDN$/$W_p$
Fuel Savings	7.5%	3.5% (infl.)	2.63
	7.5%	5.0%	3.04
	3.0%	3.5% (infl.)	4.25
600 kW_p PV, 1200 kW Diesel Grid Fuel Cost = CDN$0.80/l, Lubricant Cost = CDN$0.03/l O&M = CDN$7.50/h, Capital Cost = CDN$9.50/h			

In 1998, a third market study focussed on surveying residential and commercial users of small diesel or gas generators under 15 kW. The aim was to evaluate the potential, and user-willingness or barriers to converting these systems to PV or PV-hybrid systems [6].

2.2 Stimulate PV markets through targeted technico-economic studies

An extensive series of workshops and discussion with Northerners resulted in a series of targeted technico-economic studies that aimed at quantifying the benefits and costs of PV technologies and stimulating the market acceptance of PV technology in the north. Since these reports were viewed as an independent and honest assessment, they helped to convince decision makers to approve the conversion of the existing power system to use PV technology. Two of these studies for Parks Canada and NorthwesTel were particularly successful and, as a consequence, have been replicated in several other similar installations.

The first study was for the remote seasonal park facility located in Tanquary Fiord on Ellesmere Island (81°N) that operates four months every summer [7] (fig. 2). Due to the study, the facility was converted from a diesel generator to a PV-hybrid system that includes a 0.6 kW array mounted on a tracker, wind generator, battery storage and diesel generator. The system's performance was monitored and demonstrated that PV now supplies 45% of the energy requirements, with 23% from wind and only 32% from the generator. The tracker was optimised to take advantage of the summer's 24 hours of daylight. Reducing the generator run time from 18 hr/day to 2.2 hr/day greatly decreased the noise and fuel consumption at this fragile arctic site [8]. This installation has convinced other Park Wardens to convert seven other park facilities in Canada in the last 2-3 years.

Figure 2: PV-wind-diesel hybrid system using tracker to power Parks facility in Tanquary Fiord, NWT

In 1994, the second technico-economic study demonstrated that the conversion, from disposable potash batteries to photovoltaic, of small VHF telecommunication sites owned by NorthwesTel had a 1.1 year payback and would lead to savings of over CDN$500,000 over a 20 year life cycle [9]. PV for the North's involvement lead to a quick decision by NorthwesTel to convert 9 out of 11 VHF telecom sites to PV systems over the next two years [10]. In addition, this positive experience has convinced NorthwesTel to convert a first UHF site to a PV-hybrid system (1.5kWp PV array). This larger system, operating in extremely harsh conditions, is currently being monitored in order to evaluate the benefits of converting other diesel-cycle charge systems to PV-diesel hybrid systems. (Fig. 3)

Figure 3: PV-diesel hybrid system powering a mountain top UHF repeater, in Nahanni National Park, NWT.

2.3 Demonstrate and analyse the performance of PV systems operating in arctic conditions

Several demonstration systems were supported to demonstrate the reliability and monitor the performance of PV systems in the north. The first is a 3.2 kW_p PV array mounted on the façade of the Nunavut Arctic College (Fig. 4) in Iqaluit, NWT (64°N, 68°W). The system is connected to the local community grid that is powered by large diesel generators. It is currently monitored to validate PV simulation models and algorithms used to predict the performance of grid-tied applications [11,12]. The results have demonstrated that high latitude sites are not accurately modelled and has identified key improvements required. The requirements include accounting for low-light performance of PV modules and arrays, as well as improving the tilting algorithms that convert horizontal global irradiance measurements to vertical values. The analysis also indicated that higher inverter efficiency and lower self-power consumption during low-light or dark periods would improve the annual energy output of the PV systems [13, 14]. Continued monitoring of the performance of the Iqaluit PV façade and improvements to simulation and models will ensure that the energy performance of these systems can be accurately modelled in the future.

Figure 4: 3.2 kW_p PV array mounted on the façade of the college and connected to the local electric grid in Iqaluit, NWT.

Another demonstration system designed to perform R&D in Nordic conditions was installed at the Aurora Research Institute in Inuvik, NWT (68°N, 133°W). This includes a PV-wind-diesel hybrid test bench. The main features of the hybrid test facility are: a 360° tracker with 720 W_p PV array, a 850 watt wind turbine, a 5kW diesel generator, 23 kWh battery bank within an advanced insulated battery box with phase change material, and a system control and monitoring equipment. The goal is to evaluate different control strategies in order to optimise the benefits of small PV-hybrid systems [1,2].

2.4 Develop technologies better adapted to cold climate conditions

PV modules and components operating in cold climates need to be considered for northern installations. This has been the subject of some of the R&D work performed at CEDRL over the past four years [1]. One of the first products tested was TN-CONSEIL's PV panels that were adapted to accelerate the removal of snow and ice build up on PV modules. The adaptation kits are used to modify standard commercial modules. The principle of the technology is schematically presented in Figure 5. Modelling studies and field testing by CEDRL have demonstrated that two key features contribute to accelerating the snow and ice melt on the front face of the module: the absorption of solar radiation reflected on the back of the module and the insulating air space at the back of the panel, as shown in Figure 5 [15-18].

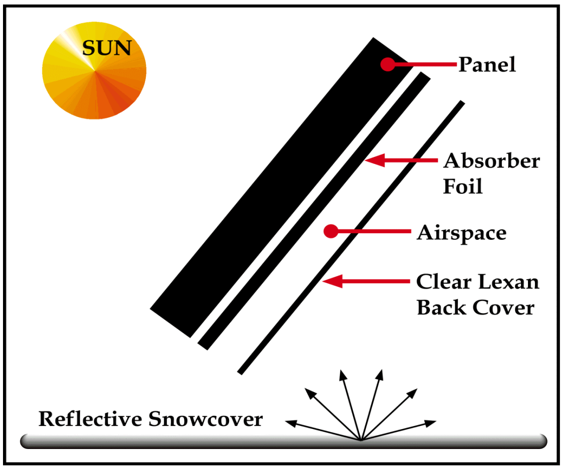

Figure 5: Schematic of passive solar snow-removal technology for PV panel.

Further research work is required to adapt PV modules to rime-prone sites. Rime is a dense, opaque ice build-up and is particularly difficult to remove or avoid at mountainous coastal regions. Results of field tests are not yet conclusive in this context.

In addition, battery testing and control optimisation has been the focus of some of the research work performed by CEDRL [1,18]. One result of this work is the development of an advanced battery enclosure and sizing software [19]. Since battery capacity decreases substantially when operating temperatures drop below 0°C, efforts were made to improve insulated battery enclosures. Optimisation of performance and costs were very important design criteria for the advanced battery box. By modelling and field testing comparative products, an optimal design was achieved. The test results presented in the Figure 6 demonstrated that batteries in the advanced battery enclosure with phase change material (PCM), not only ensured that the battery temperature did not fall below –5°C when the outdoor temperature reached -37°C, but also ensured that the summer time temperature did not increase above 22°C. Maintaining moderate battery temperature throughout the year makes the battery storage sizing of remote PV systems simpler. The added cost of the insulated enclosure will benefit application in harsh climates where reliability is important [20]. The result of the research has been commercialised by Soltek Solar Energy, under the trade name *Soltek Minus 40 Battery Enclosure*.

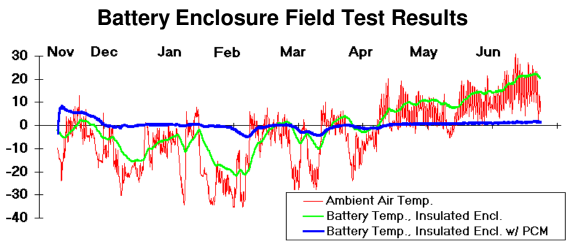

Figure 6: Comparison of battery temperature with and without PCM, Calgary, Canada.

Ensuring that PV components and systems are selected and designed for cold climate applications continues to be an important concern in Canada. The R&D activities of the PV for the North program sought to contribute to this field of research in a practical and cost-effective way.

2.5 Transfer information and educate potential users and decision makers.

Throughout the PV for the North program, targeted information transfer activities were conducted. These included:

- Training workshops in the NWT;
- Training Northerners at CEDRL's PV test facility;
- Publishing non-technical articles in magazines and newspapers;
- Preparing a video aimed at informing the public;
- Publishing technical papers and reports;
- Hosting an International *"Renewable Energy Technologies for Cold Climates" conference – RETCCC'98 held on May 4-6, 1998* in Montréal with proceedings to document the results achieved to date;

- Editing and contributing to a comprehensive book on *PHOTOVOLTAICS IN COLD CLIMATES* with international collaboration from the IEA PVPS member countries [21].

3. CONCLUSION

After five years, the PV for the North program has demonstrated tangible benefits and increased use of PV technologies in the North of Canada. Decision makers in the Northwest Territories are now knowledgeable of the advantages of photovoltaic technologies and their current market applications. Most of these applications are for small stand-alone power applications. In order to penetrate the largest potential diesel grid market, future installed systems cost reduction of PV systems is required.

The Photovoltaics in Cold Climates book, the proceedings of the Renewable Energy Technologies for Cold Climates Conference held in Montréal, and the many reports and publications are the legacy of the PV for the North program. These publications will contribute to increasing the understanding of issues related to PV applications in cold climates and at high latitude sites.

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