

Solar Air Heating Systems Inventory Report

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1. Solar Air Heating Systems

Solar Air Heating Systems are active thermal collectors that convert incoming solar energy into heat, by using ambient air as the heat transfer medium. A solar air heating system known as the **SolarWall**, developed by Conserval Engineering (2009), has been widely implemented in the NWT. It is essentially a perforated dark metal cladding that captures the solar thermal energy to heat the incoming exterior air (Figure 1).

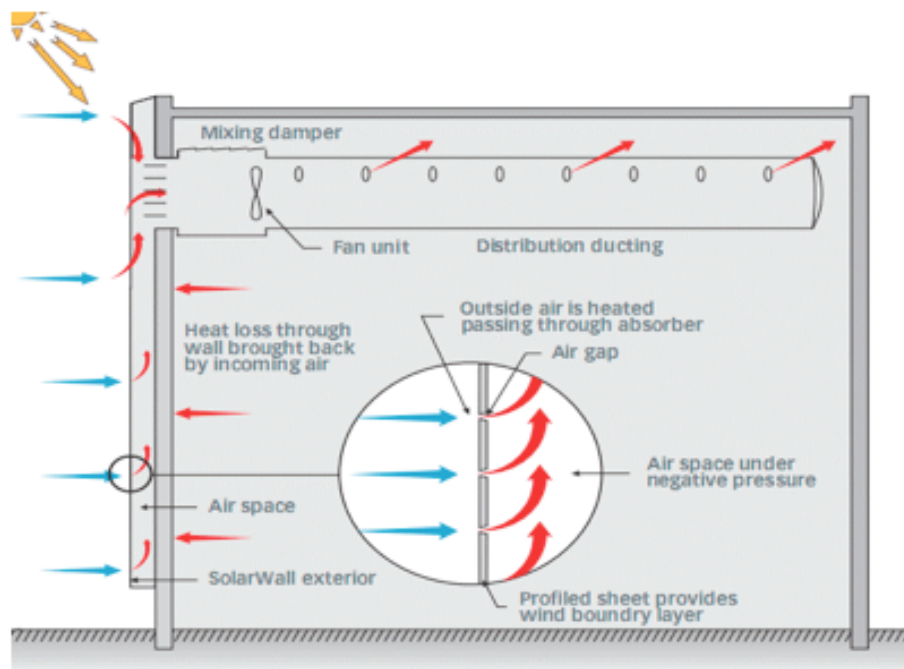


Figure 1. Schematic of a Typical SolarWall system (Conserval Engineering, 2009)

While liquid-based systems are often glazed collectors in an effort to minimize surface heat loss to the cold exterior, research has shown that Unglazed Transpired Solar Air Heating Systems such as the SolarWall system in Figure 1, exhibit very high performance at comparatively low cost. The term “transpired” simply indicates there are many tiny, well-distributed pores on the surface of the collector, comprising approximately 2% of the total wall area. There is an air cavity, ranging from 15 to 30cm in depth behind the cladding (Figure 1). Fans in that cavity create negative pressure and

draw in outside air through the tiny pores. The exterior air is heated as it is drawn through the dark metal cladding and rises to a canopy at the top of the wall. The pre-heated air is then ducted into the building to offset the ventilation heating loads.

Compared to their counterparts of liquid-based solar thermal collectors (for example, solar domestic hot water collectors), solar air heating systems are typically simple to install and essentially maintenance-free. In addition to the saving by obviating surface glazing, the SolarWall façade itself can replace the need for exterior cladding to further reduce cost.

Air, as heat transfer medium, has a lower heat capacity of air compared water or glycol. However, due to the distributed perforation on the surface of SolarWall that minimizes surface radiant and convective heat loss, such solar air heating system can achieve very high thermal efficiency. SolarWall systems can serve a variety of purposes such as pre-heating ventilation air, offset heat recovery defrost, supply to heat exchanger for space heating or hot water usage. For cold climate, solar air heating systems also have the advantage of being non-susceptible to freezing in comparison to liquid collectors.

By using solar radiation to preheat incoming air, the draw on traditional heating-fuel air heating is significantly reduced. At night, the air plenum and SolarWall also recaptures heat loss from the building envelope to the exterior, further contributing to overall energy savings. In summer months when air heating is not required, a bypass damper is controlled so that only air below a certain threshold temperature is ducted into the building, while the hot air is vented back out.

Due to the large air volume required during operation, SolarWall is particularly attractive to commercial or institution buildings with large ventilation requirements. The system offers to improve indoor air quality by bringing in a larger volume of fresh outside air than normal ventilation systems while keeping air heating costs low.

2. Inventory of existing SolarWall Installations in NWT

The Northwest Territories has abundant potentials for utilizing solar energy. For south-facing surfaces with latitude tilt, the annual average of mean daily global solar radiation of Yellowknife (Latitude 62.5°N, 14.4 MJ/m²) and Fort Smith (Latitude 60°N, 14.8 MJ/m²), are comparable to southern locations like Montreal (Latitude 45°N, 15.6 MJ/m²) and Vancouver (49.2°N, 13.3 MJ/m²) (Natural Resource Canada, 2007).

The challenge pertaining to solar utilization near the Arctic is the strong seasonal pattern of daily global radiation and its misalignment with heating loads (e.g. long daylight hours in the summer and almost no sunlight in the winter when heating load is the highest).

To investigate the suitability of such solar air systems for high-latitude remote locations, a study by Enermodal Engineering (1997) has deemed the SolarWall system economically feasible for applications in remote communities in the Northwest Territories. Consequently, a SolarWall facade was implemented in Fort Smith and monitored for a period of two years 2000-2002 (Enermodal Engineering, 2001&2002).

Compared to implementations in populated southern locations with existing grid infrastructure, the effectiveness of solar air heating systems in northern remote locations is compensated by the longer heating period, snow reflection of solar gain, displacement of higher energy costs and carbon footprint associated with transportation of imported fossil fuel.

This report surveys all the known existing SolarWall installations in the Northwest Territory, summarized in Table 1 and 2. The systems' sizes range from 26 m² to 200 m² and their installation dates vary from 1998 to 2011. Four out of six systems were implemented at or near the time of building construction (Original systems), while the other two systems were add-ons after the buildings were completed and occupied (Retrofit systems). Only one system is a residential application, while the rest are designed for institution or commercial buildings.



Table 1 Inventory of SolarWall projects in NWT

#	Location	Facility	Currently Operation Status	Time of Installation	Original or Retrofit	SolarWall Size	Façade Orientation	Usage for SolarWall Heated air
3.1	Yellowknife	Weledeh Catholic School	Functioning	1998	Original	200m ²	15° west of south	Pre-Heat Ventilation air
3.2	Yellowknife	Geoscience Building	Unknown	2003	Retrofit	53m ²	South	Ventilation, space heating, heat exchanger to hydronic heating to preheat glycols
3.3	Yellowknife	Private House	Not Functioning (Electrical fan control issue)	2009	Retrofit	~30m ²	SouthWest	Offset HRV and offset space heating
3.4	Fort Smith	Recreation Center	Unknown	2000	Original	150m ²	Southwest	Preheat air for HRV
3.5	Inuvik	Inuvik Correctional Center	Building unoccupied starting March 2011, SolarWall system maybe functional	May, 2005	Original	75m ²	Southwest	Preheat HRV fresh air, also sent to heat exchanger for in-floor heating
3.6	Inuvik	Aurora Research Institute	Functioning	2011	Original	~26m ²	35° west of south, Corrugation Horizontal	Fresh air preheat

Table 2 Summary of operational details for SolarWall installations in NWT

#	Location	Facility	Existing Monitoring System	Operational Problems	Other issues	Owner	Operating party (maintenance)
3.1	Yellowknife	Weledeh Catholic School	No; Honeywell control system	No issues; fan belt worn out and was fixed in May 2012;	Shaded partially	Yellowknife Catholic School Board	
3.2	Yellowknife	Geoscience Building	No; Control system unknown	Fan not turned on, lack of information due to personnel turnover	Shaded by a small hill with severe vegetation obstructions	Aboriginal Affairs and Northern Development Canada (AANDC)	Public works Federal
3.3	Yellowknife	Private House	No	Electric wiring of fan malfunctioned, control issue	Cost to fix fan is prohibitive at the moment, difficult to find skilled contractor/electrician	Pete Mount	
3.4	Fort Smith	Recreation Center	Yes, by Enermodal, until 2002	Unknown	Unknown	Town of Fort Smith	
3.5	Inuvik	Inuvik Correctional Center	No; Honeywell control system	No problems with SolarWall itself;	Serious foundation problems, building unlikely to be occupied again	Public works GNWT	Public works GNWT
3.6	Inuvik	Aurora Research Institute	No; Siemens Control system	No issues so far;	Occupants and Maintenance party are different groups	Aurora Research Institute	Public works GNWT

Site visits were conducted in Spring 2012 for all installations except the Fort Smith system. While some of the systems experience unique operational conditions, there are shared lessons that can be learnt from the diversity of SolarWall installations in NWT. For example, one design deficiency common among almost all the installations is the non-ideal orientation of the SolarWall façade. The non-south facing systems are disadvantaged from design, costing the same amount to implement but never able to use all the available incoming solar energy.

As shown in Table 2, two out of six SolarWall systems are currently functioning, while two systems are definitely not operational, and the state of the remaining two systems is unknown. Only one system (Fort Smith) was monitored from 2000 to 2002 by Enermodal Engineering as part of the follow-up mandates. At the time of survey (May 2012), none of the systems had any monitoring equipment to keep track of the energy saving or to detect potential operational abnormalities.

3. Individual Systems

3.1 Weledeh Catholic School – Yellowknife

The SolarWall system at the Weledeh Catholic School is currently the oldest (installed in 1998) and the largest (192 m²) in the territory. Constructed in a renovation process very close to the building completion, it can be considered as an original construction as part of the building.

The wall is oriented at 15° west of south and partially shaded in shoulder seasons. Despite a worn-out fan belt in May 2012 that was quickly fixed, this SolarWall system is currently functional with minimal maintenance required. Arctic Energy Alliance is currently monitoring the system to calculate energy savings. Monitoring started December 2012 and is currently waiting for the building automation software to be renewed for automated data trending. Online display should be operational by March 2013.



Figure 2. SolarWall at Weledeh Catholic School, Yellowknife

3.2 GeoScience Building, Yellowknife

Figure 3 shows the 53 m² SolarWall at the Yellowknife GeoScience building from afar (left) and close-up (right). It was installed as a retrofit in 2003 by the Aboriginal Affairs and Northern Development Canada (AANDC). Since then, vegetation in front of the solar collector has grown substantially. Though it is the only existing system that is designed to be south-facing, the building is located at the bottom of a small hill, with considerable shading on the SolarWall due to vegetation obstruction.

Maintained by Public Works and Government Services Canada, this SolarWall system was intended to serve multi-purposed usages such as ventilation, space heating, and to preheat glycol for hydronic radiant floor heating. However, the fan of the SolarWall has not been turned on for a while. No monitoring system is in place and little technical information was available concerning the design and operational state of the SolarWall system. Despite the interests expressed by the building occupants, there is a lack of awareness of the system. Although the status of operation is marked as ‘unknown’ in Table 1, this installation is most likely not functioning at the moment.



Figure 3. SolarWall at the GeoScience Building, Yellowknife

3.3 Private Residence, Yellowknife

As the only residential installation in this survey, the 45 m² SolarWall system occupied the entire south-west façade of a private house (*owned by Pete Mount*) in Yellowknife (Figure 4, left). There are also solar hot water collectors and photovoltaic panels mounted on the south-east roof. The SolarWall is designed to pre-heat air for the HRV system in the basement (Figure 4, right) or to directly offset space heating loads.



Figure 4. SolarWall façade on a private house, Yellowknife

According to the owner, the SolarWall hasn't worked at all since its installation in 2009 (retrofit). Though all the mechanical components are in working order, there is an electric control issue with the fan that draws the pre-heated air. Since it is a residential project, no commercial building control company was involved and the owner has been unable to find a skilled contractor for the job. The cost of hiring a qualified electrician to fix the fan wiring was prohibitive at the moment.

3.4 Recreation Center, Fort Smith

The investigation of the Fort Smith project (Figure 5) is solely based upon literature review, as no site visits were conducted. It is the most well-documented installation and the only system with past monitoring data (from April 2000 to March 2002).

Reports by Enermodal Engineering (2001, 2002 and 2005) shown that the combination of SolarWall and HRV contribute to 78% of total energy needed for ventilation air heating, 60% of which attributes to HRV alone while SolarWall is responsible for only the remaining 18%.

Estimated energy displacement by the SolarWall is up to 1542 litres of fuel oil annually, putting the payback period of just over 5 years. Combined with the capital cost and energy savings by the HRV system, the payback period for the ventilation system is estimated to be as short as three years. However, the reports do not provide details as for how the amount of energy saving were calculated from the monitoring data, or how particular variables were measured. The current state of the monitoring system is unknown and no reported data has been collected since March 2002.



Figure 5. SolarWall at Fort Smith Recreation Center, Fort Smith 60°N, Picture from Conservall Engineering (2010a, b)

While HRV is a very effective energy-saving system at low added cost, the installation of SolarWall required considerable capital costs with marginal energy savings in addition (18% out of the 78% total ventilation energy saving according to monitoring report). There are several reasons leading to the relatively low energy benefits pertaining to this system that couples SolarWall and HRV. Firstly, the wall is oriented significantly off south at an azimuth of 55° west, a permanent limitation for SolarWall performance. During operation, the controls of drawing solar heated air is often in ‘Manuel Operation’,

while the system would perform more effectively if thermostatically controlled (McCluskey, 2001).

Lastly, the thermodynamic laws dictate that HRV operates more efficiently when the temperature difference between cold exterior air and warm exhaust air is large. Therefore, preheating exterior air by SolarWall is only truly beneficial when it is offsetting the defrost load for the HRV, which has a temperature limit for exterior air intake. In other words, solar pre-heated air is limited to conditions when the exterior air needs defrost before entering HRV (very cold and sunny conditions), otherwise using solar pre-heated air instead of exterior air for HRV intake will in fact lower the HRV efficiency.

Ventilation air heating is the largest energy user for the Recreation Centre, which operates 14 hours a day, seven days a week. The SolarWall+HRV ventilation heating system has kept operating costs low, showcasing successful sustainable practices in the North (AEA, 2012). It would very interesting to continue the monitoring efforts in Fort Smith to facilitate feasibility studies of similar systems in the North.

3.5 Correctional Facility, Inuvik

Figure 6 shows the SolarWall system at the former Young Offenders Correctional Facility in Inuvik, installed by the NWT Department of Justice. The system is designed to preheat ventilation air for a heat recovery ventilator (HRV), heat glycol for in-floor hydronic heating, as well as to preheat water. Though there are no reported issues on the SolarWall itself, the system is not in operation as the building is currently unoccupied due to major foundation issues and it is unlikely to be re-occupied without significant work. At the moment, it is unknown whether the now-unoccupied building's SolarWall system is still functional.



Figure 6. Left: SolarWall at Female Young Offenders Correctional Facility, Inuvik; Right: Honeywell Building Control System Interface showing SolarWall controls

3.6 Aurora Research Institute, Inuvik

With funding from *the federal Arctic Research Infrastructure Fund*, the Aurora Research Institute's *Western Arctic Research Centre* has recently moved to a new facility with three renewable installations including a wind turbine, a photovoltaic system (solar electric), and a SolarWall façade (solar thermal).

Installed in 2011, the SolarWall façade is located on the penthouse at the back of the building 35° west of south (Figure 7, left). The building is maintained by GNWT Public Works and Services. The technician involved reports that the wall is only in operation for about 30% of the year, partly due to the non-optimal orientation.



Figure 7. Aurora Research Institute, Inuvik; Left: Back of building with SolarWall on the Penthouse; Right: Close-up of the SolarWall;

Like the Weledeh school system, the SolarWall at ARI is also on the immediate exterior of the mechanical room, making it a good candidate for monitoring. The Arctic Energy Alliance and the Aurora Research Institute has completed the preliminary proposal stage and is on schedule to install a monitoring system for this SolarWall system in March 2013. Ideally, all three renewable systems at the ARI will be monitored and real-time online display of renewable generation will be made available to the public in the near future.

4. Monitoring Plan

To evaluate the annual energy savings and determine the suitability for Solar Air Heating Systems in NWT, recent plans for monitoring have been carried out. Among all the six installations surveyed, the solar air heating systems at the Weledeh Catholic School (Yellowknife) and the Aurora Research Institute (Inuvik), are prioritized as monitoring candidates for the following reasons:

- Both systems are currently functional with no known operational issues;
- Owners and facility management of the buildings are very enthusiastic and cooperative about the monitoring project;
- They are the **oldest** and the **newest** SolarWall in NWT (Weledeh system is completed in 1998 while the ARI system in 2011);
- They are the **largest** and the **smallest** SolarWall collectors in NWT (Weledeh system is 192 m² while ARI system is 26 m²);
- They are located in **two different cities** and each building employs a **different control company** (Weledeh system uses Honeywell while ARI system uses Siemens control);
- Both are publicly accessible and they have education as a mandate. The results of the monitoring will be highly visible.

The monitoring system at the Weledeh has already been set up and is currently in operation; the monitoring for the Aurora Research Institute has passed the proposal stage and is scheduled to be implemented in March 2013. It would be very interesting to

compare the SolarWall performance at ARI (installed in 2011) with the SolarWall at Weledeh (installed in 1998) to determine the durability such solar thermal systems at high latitudes.

Similarly, it would be beneficial to renew the monitoring efforts at Fort Smith Recreation Center. With the available monitoring results of the same system back in 2000-2002, the new monitoring data could be used to track energy savings and to determine the durability and suitability of SolarWall+HRV systems in the North.

5. The Future of Solar Air Heating Systems in NWT

This report surveys all the known Solar Air Heating Systems (SolarWall) in Northwest Territories. At the moment, the current energy savings for all six systems discussed above are unknown. To address the lack of monitoring efforts and to revive continuing interests in the solar air heating systems in NWT, there have been recent monitoring plans in progress. The SolarWall at the Weledeh Catholic School in Yellowknife (3.1) is currently being monitored and its energy savings will be documented this year. The system at Aurora Research Institute in Inuvik (3.6) is schedule to implement monitoring systems in March 2013 to track its energy generation. In addition, it would also be very interesting, if possible, to renew the monitoring efforts at Fort Smith (3.4) to compare with the data from 2002.

Energy savings from SolarWall systems are comprised of two parts: directly used in the form of solar heated air, and the heat recaptured by the wall plenum at night. They can be calculated from carefully chosen sensors such as inlet and outlet temperature, volume flow rates, incident solar radiation, etc. Without on-going monitoring plans, there is no indicator of performance for such Solar Air Heating Systems in northern climate.

In fact, transpired solar air collector such as the SolarWall is very susceptible to high wind conditions (common in NWT) and its efficiency drops steeply with increasing wind speed. The seasonal misalignment (no sun in winter when heating is needed the

most, long daylight hours in summer when heating load is low) also poses a challenge on the feasibility of Solar Air Heating Systems. Lastly, only air within a certain temperature range is useful and not all the solar heated air can actually be used at all times. Therefore, feasibility and long-term suitability studies based on monitoring data are essential to determine the suitability of SolarWall-type solar air heating systems in the North.

Learning from the existing solar air heating systems in NWT would allow designers and planners to improve the performance of future installations. For example, the orientations of existing SolarWall are mostly non-south facing, some of them even with considerable shading. Mechanical, electrical or control issues with the fan directly result in the SolarWall not being used or under-used. Those are effective improvements that can be made for future installations at no or little added cost.

With the goal of achieving the best results energy-wise, the beauty of solar air heating system also lies in its simplicity (easy to installation and maintenance-free). Rather than focusing on slight increase in collector efficiency, a robust design that is resilient against human errors is perhaps more valuable. Lastly, it is recommended to make continuous monitoring plans mandatory for all future renewable installations.

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