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DRAKE LANDING SOLAR COMMUNITY: FINANCIAL SUMMARY AND LESSONS LEARNED

Bill Wong[1] and Lucio Mesquita[1]

[1] CanmetENERGY/Natural Resources Canada, Ottawa (Canada)

Summary

Drake Landing Solar Community is a Canadian solar district heating system with seasonal thermal storage. The demonstration project, designed to achieve over 90% solar fraction, was commissioned in the summer of 2007, reaching its 12th year of operation in 2019. The demonstration project successfully illustrated the technical feasibility of solar seasonal energy storage with a high solar fraction in a northern climate. Over the course of this project, from design, to construction, to commissioning, to operation and performance monitoring, much has been learned about this technology application in Canada. Through our on-going performance monitoring project, a number of learning points were identified that could inform the development and implementation of future similar projects. This paper will review the project financial results, key learning points and discuss design improvements (what we would do differently), stakeholder engagement for future projects.

Keywords: solar district heating, seasonal heat storage, borehole thermal energy storage, BTES, Drake Landing, high solar fraction, monitored performance, financial results, learning points.

1. Introduction

Residential and commercial/institutional buildings were responsible for 22% of energy use related GHG emission in Canada in 2016 (NRCAN, Emissions, 2018), most of it due to space and water heating. Because of that, significant efforts have been undertaken in recent years in developing more energy efficient building envelopes and mechanical systems, and in the inclusion of a larger share of on-site renewable energy technologies in those buildings. In 2004, CanmetENERGY spearheaded the Drake Landing Solar Community (DLSC) project, in the Town of Okotoks (latitude 50.73N, longitude 113.95W), located approximate 20 km south of Calgary. DLSC, the first community size solar seasonal energy storage project in North America, demonstrated the effective integration of the borehole thermal energy storage (BTES) technology with a locally available renewable energy resource - the sun, in delivering more than 90% of the community's space heating needs.

The Drake Landing Solar Community, which supplies heat to 52 single-detached houses, has been operating for 12 years as of July 2019 and, although it has been technically successful, its relatively small size does not lead to economic feasibility under current economic conditions in Canada. This first-of-its-kind technology demonstration project in North America revealed a number of learning points for system designers and renewable energy project developers. This paper will discuss in detail a number of key learning points from the DLSC project. The authors will also highlight the implementation cost for the DLSC project, financial challenges with the operation of systems involving innovative technologies and how to better manage such issues in future projects.

2. System Description and Performance Summary

A large-scale solar seasonal storage project is currently in its thirteenth year of operation in Okotoks, Alberta. The Drake Landing Solar Community (DLSC) is a community of fifty-two modern detached homes that derive most of their heat requirements from solar energy, using borehole thermal energy storage (BTES) to store heat collected in the summer, for use in the winter. DLSC is the largest solar seasonal thermal energy storage system of its kind in North

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America and is designed to have the highest annual solar fraction (90%) of any solar-based seasonal storage system in the world. Thermal energy is stored in 35,000 m^3 of soil and rock under a corner of the neighborhood park; the heat is transferred to and from the earth by water flowing through U-tubes in 144 boreholes, each 35 meters deep.

A schematic diagram of the system is shown on Figure 1, and more details on its design and early results of operation can be found elsewhere: McClenahan et al. (2006), Wong et al. (2006), Sibbitt et al. (2012, 2015) and Mesquita et al. (2017).

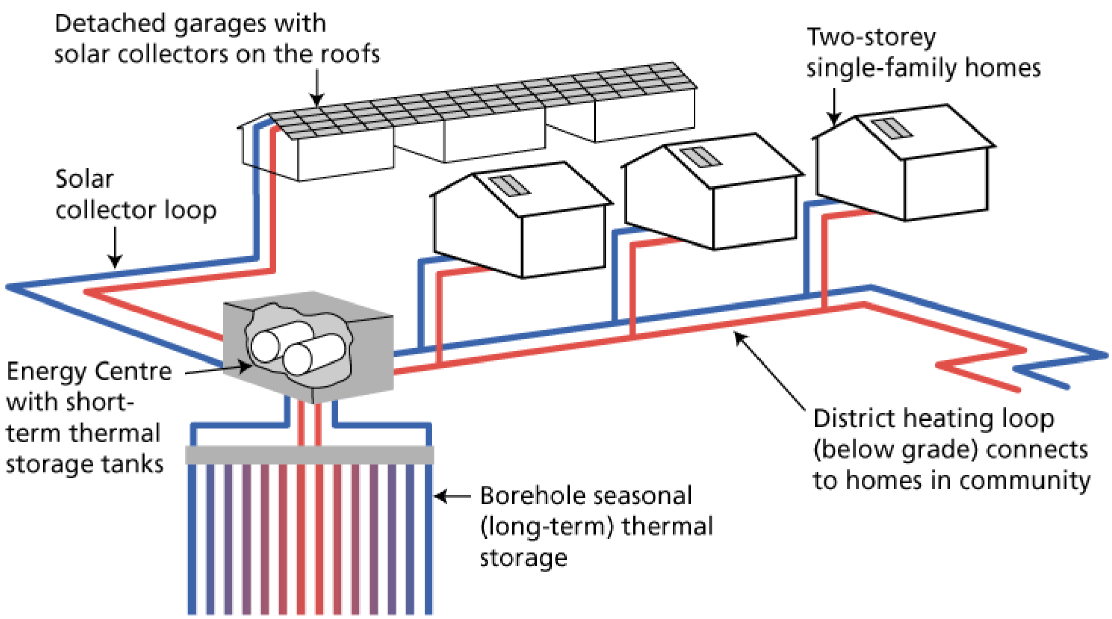

Fig. 1: Schematic diagram of the solar seasonal storage heating system at Drake Landing Solar Community

Each DLSC home has a detached garage behind the house, facing onto a lane (Figure 2). Each garage has been joined to the next garage by a roofed-in breezeway, creating 4 continuous roof structures, as seen on Figure 3. On those roof structures, 2293 m^2 (gross) of flat-plate solar collectors were installed.

The houses are located along two streets running east-west. Six different house models were available to buyers, with an average above-grade floor area of 145 m^2. The houses were built to meet Canada's R-2000 performance standard (NRCan, R-2000, 2018), with upgraded building envelopes, including higher insulation, low-e argon filled double panel windows and improved air tightness and construction details. The R-2000 standard requires the homes to be built with energy performance (space heating and domestic hot water), amongst other non-energy related conditions, to be below 50% of that for of a local code built home. The higher standard was estimated to reduce the space heating requirement to a range between 57 GJ and 72 GJ for the 52 homes in various models. The average domestic hot water (DHW) requirement was 18 GJ with water efficiency measures. Using renewable energy technologies home heating energy requirements were further reduced by 90% and 50% for space heating and DHW, respectively. Space heating is supplied to the 52 houses through 4 parallel branches of a 2-pipe district heating system. An integrated air handler and heat recovery ventilator, incorporating fans with electronically commutated motors and a large water-to-air heat exchanger, supplies forced-air heating and fresh air. An independent, 2-collector, solar domestic hot water system, backed-up with a high-efficiency gas-fired water heater, supplies service hot water.

Fig. 2: View of houses with adjoined garages and houses street view

A seasonal borehole thermal energy storage (BTES) field was installed under a corner of a neighborhood park and covered with a layer of insulation beneath the topsoil. The BTES is composed of 144 boreholes, each 35 m deep and radially plumbed in 24 parallel circuits, each with a string of 6 boreholes in series. Each series string is connected in such a way that the water flows from the centre to the outer edge of the BTES when storing heat, and from the edge towards the centre when recovering heat, so that the highest temperatures will always be at the centre. Figure 4 shows the borehole field under construction and currently, as a landscaped park.

Fig. 3: Aerial view of Drake Landing Solar Community

The heat source for this BTES project is solar thermal energy. The solar collection system consists of 798 conventional, flat-plate solar thermal collectors mounted on four rows of interconnected garage/carports located behind the homes. The Energy Centre building is located in the southwest corner of the neighbourhood park, and is the heart and brains of this innovative, solar energy based BTES heating system. Table 1 summarizes the performance since the project inception.

Tab. 1: Key measured performance indicators for the first 11 seasons of operation

Year of Operation	2007 2008	2008 2009	2009 2010	2010 2011	2011 2012	2012 2013	2013 2014	2014 2015	2015 2016	2016 2017	2017 2018
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Heating Degree-Days (18°C ref.)	5274	5393	5069	4911	4515	4579	5304	4860	4134	4756	5103
Incident Global Irradiation (GJm^{-2})	5.82	6.07	5.49	5.45	5.67	5.55	5.55	5.41	5.48	5.06	5.57
Collected Solar Energy (GJ)	4469	4391	4275	4059	4428	4328	4287	4340	4356	3917	4416
Collector Efficiency	34%	32%	34%	33%	34%	34%	34%	35%	35%	34%	35%
Energy into BTES (GJ)	2609	2713	2499	2263	2518	2566	2459	2684	2675	2275	2550
BTES Efficiency	6%	21%	35%	54%	36%	51%	56%	42%	32%	54%	47%
Solar Energy to District Loop (GJ)	1670	1790	2026	2456	2049	2434	2781	2393	2266	2553	2719
Total Energy to District Loop (GJ)	3036	2964	2545	2859	2119	2494	3033	2501	2266	2745	2928
Solar Fraction	0.55	0.60	0.80	0.86	0.97	0.98	0.92	0.96	1.00	0.93	0.93
All Pumps Electricity Consumption (GJ)	53	54	53	52	52	52	51	51	79	78	109

A 100% solar fraction performance was observed in 2015/16. This was followed by 2 years with solar fraction of 93%. Preliminary estimate for the 12th year's (2018-2019) solar fraction is 92%.

Fig. 4: Borehole field under construction and currently, as a landscaped park

3. Project Implementation Cost Summary and Analysis

The DLSC implementation cost summary breakdown is presented in Table 2. All figures are presented in 2007 Canadian dollars to reflect the actual costs (Total project cost of CAD$ 7,146,000) at the time of project implementation. Assuming an average annual escalation rate of 2%, the total project cost in 2019 would be approximately CAD$ 9M.

Tab. 2: DLSC project costs (CAD$)

Task	Description	Final Project Cost	
1	Detailed design and planning	$	510,000
2	Solar energy collection system	$	1,001,000
3	Thermal energy storage system	$	880,000
4	Energy centre building	$	650,000
5	Home heating system and R-2000	$	440,000
6	District heating loop	$	1,130,000
7	Solar domestic hot water system	$	200,000
8	Garages for collector mounting	$	1,460,000
9	System commissioning	$	215,000
10	Performance monitoring system	$	460,000
11	Project management and outreach	$	200,000
	Total	$	7,146,000

Tab. 3: DLSC project extra costs (CAD$)

Additional construction management fees	$	155,500
Energy consultants and home energy modelling	$	255,000
Additional energy centre costs	$	40,000
Collector loop repair and protection	$	63,500
Total Extra Costs	$	514,000

The grand total cost, including project extra costs, for DLSC implementation was CAD$7,660,000. From a technology point of view, Table 2 includes items that were not directly a part of the solar seasonal thermal energy storage heating system. Direct technology cost is approximately CAD$4,616,000, excluding home heating equipment, home energy efficiency upgrades, solar domestic hot water equipment, garage construction, project management, stakeholder outreach and system monitoring equipment cost. It should be noted that the direct technology cost also includes CAD$1,130,000 for the community district heating system.

Innovative technology demonstration requires commitment and significant financial resources. In the case for DLSC, key stakeholders and government funding agencies supported the project while the project technical team resolved many unexpected challenges. Several important cost lessons could be taken from the DLSC implementation. The following three points will be presented from the cost perspective.

3.1 Challenges in obtaining firm price quotations

The DLSC project was the first time that a large (community scale) solar thermal project was implemented in Canada. Advanced solar thermal technology experience and installation capacity was only available in limited regions in Canada at the time of DLSC implementation. In the early 2000's there was a very small penetration of residential rooftop solar thermal domestic hot water systems into the Calgary area market. The plumbing and home construction trades were not familiar with the solar thermal technology nor trained to perform the installations. As a result, the construction management company hired to do the job for the DLSC provided a high cost estimate for the installation of the four banks of solar thermal collectors (total 798 collectors) and this cost was well above what was available in the budget. Although the higher cost estimate was not welcomed by the project team, one could understand the issues faced by the construction company with very little prior solar thermal experience and could not fault the company for taking a very conservative approach in cost estimation. A different approach is required in order to contain the project cost.

The project team and the construction company agreed to proceed on a time & materials basis for the first bank of collectors while the project team provided training to the construction crew. The construction crew took the necessary time to learn how to perform the work safely and effectively for the first bank of collectors. The cost was relatively high. However through this experience the construction crew understood the technology and was able to refined the installation procedures. The construction company was then able to provide a firm quote for the installation of the remaining three banks of collectors at a significantly lower unit cost which resulted in achieving a more reasonable total solar thermal collector system installation cost for the project.

3.2 Utilize existing market capacity from complementary sectors

In the case of the solar thermal collector installation, the work involved considerable effort and time on the roof. Working with heights on a steeply pitched roof (45-degree pitch angle) is not a typical working environment for the plumbing trades. This made it more challenging for the trades to get comfortable on rooftops and performing efficiently at the onset of the project. For the construction of the borehole thermal energy storage system (which consisted of 144 vertical boreholes to a depth of 35 meters), a local drilling company was hired to perform the work. With a few practice boreholes for inserting the U-tube and installation of the thermal grouting, the job was quickly completed on schedule and on budget against a firm quote. It was important to note that drilling technology and the drilling industry in Alberta was very strong from the production of conventional energy in the province.

The drilling contractor’s performance and their efficiency in carrying out the BTES field construction work was a pleasant surprise as the project team did not realize the synergistic opportunity at the time of project development. This kind of cross-sectoral skills transfer would be very beneficial in the development of innovative energy technologies and the implementation of a demonstration project for the first time.

3.3 Expect the unexpected

An unexpected consequence of of a minor design change in the collector design impacted negatively on the DLSC project at a critical juncture before the solar thermal collectors could be commissioned. From the commissioning test of the first bank of solar collectors the project team discovered the inter-connecting component (a short piece of bellow) between the adjacent collector headers underwent plastic deformation during high temperature excursions in the collector system fluid. As a result of this plastic deformation (well outside the working range for elastic bellow movement) the entire batch of installed connectors had to be replaced. The project team and the supplier worked together to determine the root cause of the problem and worked to finding a solution to correct the situation.

The conclusion of a thorough review of the scenario pointed to the possibility in the insufficient rigidity (or being too soft) of the rubber grommet used to secure the header pipe penetrating through the small opening on the sides of the collector metal frame that allowed a larger longitudinal misalignment between the two adjacent header pipes. In addition, in some areas of the roof, the adjacent collectors mounted on the surface of the roof were not well aligned due to variations in residential roof construction.

The larger longitudinal misalignment then allowed the bellow device to bow rather than absorbing the expansion linearly along the longitudinal axis of the header pipes, as shown on Figure 5. The collector manufacturer tested a series of grommets having different stiffness in a set of test collectors subject to high temperatures in an attempt to re-enact the bowing of the bellow-type of inter-connecting device. The findings conformed the hypothesis and determined the stiffness required to hold the header pipes in alignment while still flexible enough to allow the installation of the header pipes through the collector frame without undue difficulty. Based on this review and testing, the production of solar collectors was put on hold pending the shipment of a new order of grommets to be made to the new specifications.

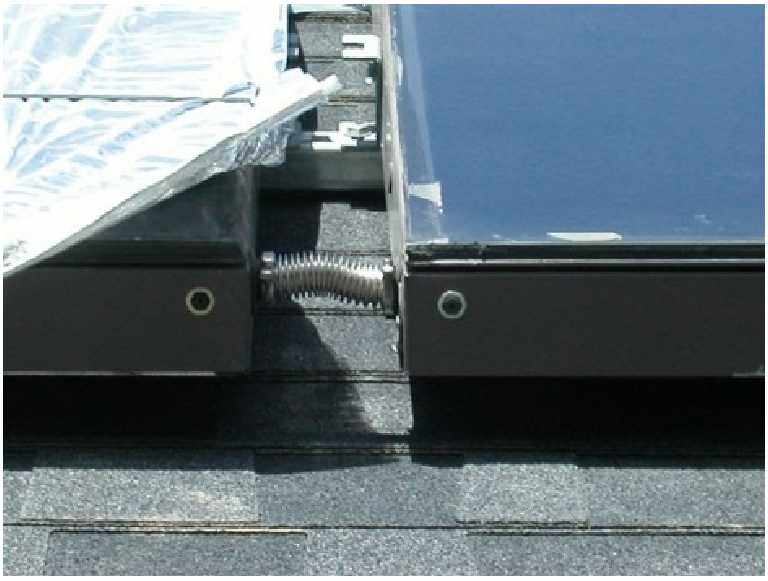

Fig. 5: Bowed bellow device between collectors.

The grommets were produced in a plant in southern China through a global supply chain in the production of the solar thermal collectors. A 100-year typhoon happened to hit the southern China village where this plant was located and completely destroyed the facility. Apparently the batch of grommets extruded for this order was just finished and packaged ready for shipment. To the project team's good fortune, even though the plant was completed destroyed, the staff was able to find the package in the after-math of the storm and shipped the new grommets to Canada.

The resulting 3 months delay in the construction led to a serious water management issue in the short term thermal energy storage tanks and a significant cost increase to drain the large water tanks, clean the biofouling deposits throughout the tanks, piping system and the heat exchangers.

The unexpected issue with the grommet led to the redesign of the collector with new parts, the supplier was hit by a unexpected typhoon, the ensuing delay then caused the biofouling.

4. Major Learning Points

Innovative technology demonstration projects offer great opportunities for shared learning on project implementation and technology improvements. The journey of the DLSC technology demonstration is no exception. There were many design, implementation and operation learning points. Five areas for learning from the DLSC project are highlights below for discussions.

4.1 Solar thermal collector system scale-up

The solar thermal collectors deployed for the DLSC project came from a collector manufacturer specialized in the design and installation of a solar domestic hot water (SDHW) system in Canada. The collector had a new design with a number of innovative features that provided improvement in efficiency and cost reduction. The selection of the solar thermal collector was based on its the cost-effectiveness after an international tender process. The collector was originally designed for smaller residential roof-top SDHW systems. For the SDHW application, there was no requirement for the bellow-style inter-connecting fitting between collectors in a two-collector SDHW system. However, for a larger community-scale solar thermal collector system, the inter-connection between adjacent collectors and thermal expansions control became an important design consideration. At that time, the DLSC project team (and the Canadian solar thermal industry) was short on experience in roof-integrated large size solar thermal collector systems . The design of the bellow-style inter-connecting device was reviewed and accepted as the standard design for the DLSC system. In retrospect, additional time should have been built into the project schedule for a larger scale field test system (such as an array of 10 or 20 collectors) to be installed and tested subject to a range of anticipated operating conditions. Design deficiencies might have been discovered and improvements sought before full-scale implementation. As a result of this design deficiency the bellow connectors and the grommets in approximately one-third of the collectors already installed on the roof had to be replaced by new bellows and a stiffer grommet at extra cost.

4.2 Solar thermal collector maintenance and market capacity

At the time of the DLSC project initiation and implementation, the price of natural gas in Canada was relatively high. A number of government incentive programs (at both the federal and provincial levels) for solar thermal hot water systems were in place. The solar thermal market was relatively strong with the promise that the strength in the demand and market capacity growth would continue. However shortly after the commissioning of the DLSC system, the price for natural gas in Canada (and North America) started to drop. Government policy change resulted in the termination of solar thermal support program and incentives. The SDHW technology was no longer competitive. A gradual decrease in photovoltaics (PV) system cost on top of the slow SDHW market attracted many of the solar thermal suppliers to switch to the PV technology in Canada. It became increasingly difficult to find installers and plumbers for routine, as well as emergency services, for the DLSC solar thermal system. The impact was higher service cost and delays in scheduling qualified trades for service and maintenance work on site. Such global level change in the energy landscape might be rare and would certainly be out of the control of the project team. However, the robustness in the design of innovative technologies and the ease for transferrable skills from other trades or field of service should be considered for new demonstration projects.

4.3 Borehole thermal energy storage system water chemistry issue

The DLSC borehole thermal energy storage system (BTES) and the short-term thermal storage (STTS) tanks are connected. Water is circulated throughout the STTS tanks, the BTES loop and the piping system that connects the BTES and STTS tanks to the two heat exchangers in the system (one for receiving heat from the solar thermal collector loop and a second heat exchanger for delivering heat to the district loop). The design of the BTES/STTS water system consisted of: open atmospheric STTS tanks for simpler operation management, carbon steel piping for potential high fluid temperature from the solar collector loop or the back-up natural gas boilers, and circulation pumps designed for closed circuits for lower cost.

After several years of operation higher than expected levels of corrosion product has been found in the system and a reduced system flow rate in the BTES system has been observed. Although the DLSC system operated well even under these conditions and continued to deliver high solar fraction performance in recent years, there has been an increase in pumping electricity usage and the long-term positive trend in performance may be at risk. The water chemistry question was not addressed sufficiently by the DLSC project team at the time of project implementation as there were many other pressing issues at the time and there was a concern that if the water was heavily treated with anti-corrosion additives and a leak in the BTES piping occurred, there could be potential groundwater contamination risk. For innovative technology demonstration projects, one still needs to pay close attention to conventional engineering design challenges, such as basic water chemistry and water system management.

Fig.6: Pump impeller volute with corrosion deposits.

4.4 Controls and monitoring system equipment life cycle and support considerations

The implementation of the DLSC project included a comprehensive set of sensors and instrumentation with the capability for data acquisition and storage. This data acquisition and storage system supports an operational control and fault detection system, as well as a system performance monitoring system. The performance monitoring system has provided invaluable data throughout the demonstration project to the project team and other interested stakeholders. The trend analysis on parameters and the comparison between the actual system performance with design performance revealed opportunities for improvement in system modification and operation. This contributed to the high solar fraction observed over the past 12 years.

While the instrumentation and data acquisition system has performed well over the project period the electronic hardware is also aging. Periodic component replacement and control programming changes required the services of the control system vendor technicians. Within a limited research budget the expenditures on control system maintenance is not always easy to rationalize for a relatively small technology demonstration project. In the DLSC project case, the control system is supported by a commercial vendor and project team members and researchers were not able to make any control logic changes or implement new algorithms. This turned out to be a constraint in carrying out some of the research work. As the project moves into its second decade of operation, the life cycle consideration of the control system is starting to enter the discussion. In hindsight, perhaps the option for a more "open" control system (such as a PLC) would have facilitated easier programming changes by researchers as well as enabling a broader base for technical support. It is recognized that a PLC would have required higher upfront implementation cost, which is probably always a challenge for an innovative technology demonstration project.

4.5 Cold climate system start-up and operation – Murphy's Law applies

The DLSC system is designed to operate and deliver heat for comfort reliably to the 52 homes in cold nights in Alberta

Canada where ambient temperature could reach as low as -40 Degrees Celsius. Towards the end of March 2006, the first bank of solar thermal collectors had been installed and the collector piping system was cleaned and flushed. Other sub-systems were also being installed and being commissioned. This included a new control system.

The mishap started with the mechanical contractor not wanting to drain the collector piping system after cleaning and flushing but decided to keep the collector loop circulation pump running throughout the night as the local overnight temperature was forecasted to drop just below zero degrees Celsius. At the same time the controls engineer was testing the control algorithm and implementing the program. The collector loop pump was operating and fluid was circulating as the mechanical contractor and the controls engineer left late in the evening for the day. For reasons not clear to the project team, an automatic control valve in the collector loop closed during the night which led to a blockage in the collector loop circulation. The overnight ambient temperature dropped down to -3 degrees Celsius for a short period of time. Next day, the construction crew discovered leaks from a number of collectors and the piping network due to freeze damage. While the damage was limited and repaired, the incident took considerable time and effort to resolve. The testing to identify the leaks, repairing the leaks and the steps required to ensure piping integrity added significant cost to the project. Out of the first bank of collectors (just under 200 collectors), only 12 collectors had to be replaced. Had the sub-zero temperature lasted for a longer period of time, the damage could have been much worse.

5. Considerations for Future Technology demonstration Projects

There were many positive learning outcomes from the DLSC project that contributed to its success. These positive learning points should be noted for future innovative technology demonstration projects. These include the following positive learning points:

5.1 Strong team approach to project implementation

The DLSC project team included the various disciplines of engineering, the homebuilder, the community developer, municipal planners, utility partner and government researchers. The project team was formed based on the understanding that the technology being tried was new and this project gave all team members the opportunity to learn and contribute. There was no one individual claimed superior experience above others. Each team member brought specialized and unique knowledge to the project with great respect for other team members' contribution. This atmosphere promoted a positive working environment with open and honest working relationships throughout the project.

5.2 Facilitated integrated design process

The land development timeline was fixed and tight with home construction scheduled to take place with or without the solar seasonal thermal energy storage project. The tight schedule necessitated the project design team to work closely together and resolve issues in "real time" rather than the more traditional "silo" style of design for commercial construction projects. From the start of the design phase to the end of commissioning, weekly teleconference calls were held every Friday morning involving all project team members. Each call usually took two to three hours to complete in order to cover deep technical discussions, key design decisions and action items. Several in-person technical workshops were held at a number of critical junctures during the project. This integrated design process was critical to meeting the development schedule and in the successful completion of the DLSC project.

5.3 Feasibility phase study technical tour

Meaningful engagement of the key stakeholders relevant to the DLSC project was a critical component of the feasibility study. During the feasibility study a project team technical tour through three European countries (Sweden, Germany and the Netherlands) was planned and conducted to provide a "first-hand" view for the key stakeholders on what is possible to achieve in solar seasonal thermal energy storage. The homebuilder, the community developer, planners, municipal engineer and all members of the stakeholder group came away with a sense of confidence inspired to create the DLSC project. The technical tour provided a strong foundation for the project team to begin the challenging design process for a high solar fraction project in Canada. Excellent discussions took place during the tour and in fact, some of the key design decisions started to form during the trip.

5.4 International technical steering committee

The success of the DLSC demonstration project was in part due to the active involvement and invaluable guidance provided by a technical steering committee consisted of experts from across Canada and leading European researchers in solar seasonal thermal energy storage. The international connections were made through Canada's participation in the International Energy Agency Solar Heating & Cooling Technology Collaboration Program. The connection continued through the technical study tour and the relationship was strengthened during the design and construction phases of the project. The project team kept the technical steering committee informed of key design issues and sought advice. A two-day design review workshop was held towards the end of the design phase for the steering committee members to check on the design and provide final recommendations before construction. The meaningful involvement of the technical steering committee brought tremendous benefit to the project, however it also required more time and patience to work through the design issues and for the project team to listen to the committee members for their opinions.

5.5 The expert use of modelling tools and simulation software

The design of the DLSC energy system leveraged on the broad experience from members of the project design team and the many sage technical advice from the steering committee members. One key element in the DLSC project was the utilization of a transient thermal energy modelling and simulation tool to study the solar seasonal thermal energy storage system in support of design decisions. The entire DLSC energy system was modelled and simulations were conducted to test the various design options and in the selection of critical system parameters. The successful outcome of the DLSC technology demonstration project – a first of its kind in North America – is a testament to the power and usefulness of such modelling and simulation tools when used by modelling experts in consort with the relevant field experience in the project team. Following the commissioning of the DLSC project, a full year of measured system data was used to calibrate the model for enhanced accuracy in the simulation. The calibrated model has been used for many feasibility studies in Canada and abroad with confidence in predicting system performance as well as used as a design tool for other locations.

5.6 Strong government support

An innovative technology demonstration project would not happen on its own without the strong support from multiple levels of government. In the case of the DLSC project the combined support from the Canadian federal government, provincial government (the Province of Alberta) and the local government (the Town of Okotoks) was instrumental to the success of the project. Without the strong alignment in objectives from the multiple levels of government it would have been difficult for the project to materialize.

A number of important points should be considered for future projects involving highly innovative technologies. The following topics were not considered as a top priority for the DLSC technology demonstration project during implementation. However, after 12 years of successful operation for the DLSC, these topics are emerging as questions that needing some consideration.

- Project exit strategy for a smooth transition out of technology demonstration;
- Project designed to take into account of technology/component life cycle, include the flexibility for potential "plug-and-play" technology enhancement;
- Knowledge transfer and local sustainability for innovative technologies (including low maintenance cost); and
- Earlier engagement and more frequent consultation with the homeowners in the community for a greater community participation.

For future technology demonstration projects coupled with a strong research focus, discussions on some of the softer issues should be considered.

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