ERA-FUNDED PROJECT REPORT

LARGE SCALE BUILDING INTEGRATED SOLAR PV DEMONSTRATION IN PRODUCTION HOUSING

NON-CONFIDENTIAL FINAL REPORT

LANDMARK GROUP OF COMPANIES
OCTOBER 2018

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FINAL OUTCOMES REPORT

LARGE SCALE BUILDING INTEGRATED SOLAR PV DEMONSTRATION IN PRODUCTION HOUSING

PROJECT INFORMATION

CCEMC Project number: E120089

Project title: Large Scale Building Integrated Solar PV Demonstration in Production Housing

Company name: Landmark Group of Companies

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Project completion date: July 31st, 2018

Total CCEMC fund: $1,385,360

Submission date: October 31, 2018

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EXECUTIVE SUMMARY

Solar photovoltaic (PV) power generation has long been acknowledged as a clean energy technology with vast potential. The objective of ERA-funded Landmark Building Integrated Solar PV project is to develop, validate and demonstrate a cost-effective solar PV solution and a business model for integrating solar PV into production housing. By the end of July 2018, Landmark completed the installation of 199 residential solar PV systems with total installed solar PV capacity of 895 kW and achieved all milestones outlined in the Amended Contributions Agreement.

Based on the experience gained from this project and a study of solar PV adoption in other jurisdictions, we identified the four main barriers that prevented the wide adoption of solar PV technology in Alberta housing market. Firstly, although the levelized cost of electricity (LCOE) went down substantially in the last five years to 8.5¢/kWh for residential PV system today, it still much higher than the grid electricity price in Alberta (5¢/kWh). The electricity generated by the distributed solar PV system are mostly used by users in the community, but the solar PV system owners do not get any credits for savings in demand transmission service (DTS) charges. Thirdly, most homebuyers do not have the financial capacity to make large initial investment needed for solar PV system, while no financing mechanism is available in Alberta for individuals to make such investment in renewable energy. Also, no mechanism today to reflect the fair value of solar PV in the value of the property.

Alberta economy slowed down in late 2014 had significant impacts on the housing market. Landmark group experienced a remarkable drop in both the new home sales and the percentage of new homebuyers who would invest in solar PV. Despite harsh market conditions, Landmark still maintained its commitments to the project and supported industry's efforts in NetZero Energy Homes. The unique business model of Landmark and SolarMax Power Inc. ("SolarMax") is proven to be effective in reducing the hardware costs and the soft costs related to marketing, system design and customer acquisition. Energy profile information and the interactive solar PV calculator developed by Landmark and its research partner helped the potential solar PV buyers to better understand the true value of roof-top solar PV systems and simplified the selling process, thus improving customers' purchasing experience of solar PV system. The recent increase of solar PV incentive and proposed PACE program will help Albertans to overcome above mentioned barriers, but their impact is limited due to relatively low return of investment on residential solar PV.

The funding from the project has supported 199 residential solar PV systems with 896 kW of installed generation capacity. The total annual solar PV generation of the project is estimated to be 1,082 MWh. Using the electricity grid displacement and grid usage factors published by Alberta Government, the direct GHG emission reduction of the project is 690 tonnes of CO_2e per year and 16.3 kilotonnes of CO_2e during their 25-year life span. Landmark will continue its commitment on residential solar PV and further explore the best approach to integrate distributed micro-generation and net zero energy or highly energy efficient homes on community level.

PROJECT DESCRIPTION

Solar photovoltaic (PV) power generation has long been acknowledged as a clean energy technology with vast potential. In the past two decades, research and development have significantly improved the efficiency and reliability of PV systems. Because of these globe efforts, the costs of solar PV modules have drop by over 50% between 2008 and 2013. Driven by the rapid reduction in cost and government incentives, the solar PV industry has experienced explosive growth in the past two decade globally.

The objective of ERA-funded Landmark Building Integrated Solar PV project is to develop, validate and demonstrate a cost-effective solar PV solution and a business model for integrating solar PV into production housing. Impacted by Alberta's economic recession, the progress of the project was slower than expected. Meanwhile the provincial government launched the Residential and Commercial Solar Program (RCSP) in 2017. To provide continuous supports for housing industry in Alberta to adopt solar PV technology and to avoid possible overlaps of this project and RCSP, ERA and Landmark signed the 3rd Amendment to the project Contribution Agreement in January 2018, extending the project end date to March 31st, 2018 and adjusting the project work plan to include the following 11 tasks:

1. Research on the best practices of integrating solar PV into new house construction and evaluation of the available solar PV products.
2. Integrating 400 kW solar PV systems into the design of highly energy efficient homes with different house models, orientations and in various geographic regions
3. Solving application issues associated with the PV micro-generation systems.
4. Installation of 400 kW solar PV (designed in Task 2) on NetZero and Highly Energy Efficient new homes
5. Establishing strategic relationship with major solar PV module manufacturers and long-term partnership with the installation contractors
6. Assessing the market acceptance of solar PV systems installed in Task 4 and conducting a profitability study based on sales data.
7. Developing a generic solar PV system design and integrating solar PV into Landmark's homebuilding processes.
8. Measuring the performance of 20-25 solar PV systems installed at homes with different orientations, roof configuration and in various geographic regions.
9. Developing green marketing strategies for solar PV systems on highly energy homes and integrating solar PV into Landmark sales process.
10. Design and construction of 495 kW solar PV on highly energy efficient solar homes for refining the process and large-scale demonstration
11. Project reporting and knowledge dissemination.

In the adjusted project plan, the total solar PV installation was reduced to 895 kW, which would generate 1,080 MWh of electricity annually and reduce GHG emissions by 16.3 kilotonnes in their 25-year life span.

PROJECT OUTCOMES AND LEARNINGS

The project officially started in November 2013 with a thorough scan of the best practices in residential solar PV technologies and products. The focus of the study was on reducing balance of system (BOS) costs[1]. Table 1.1 listed six technologies were reviewed. Integrated bonding, rail-less mounting systems for pitched roofs and PV module level power electronics were identified as most promising technologies for residential applications.

Table 1.1: Reviewed Solar PV Technologies and Products for Residential Applications

Technology	Description	How it Reduces Costs	Available Products
Integrated Bonding	Bonds solar modules directly to solar racking rails.	Eliminates the needs for separate bonding parts and procedures	Mounting System Inc.; IronRidge
Rail-less Mounting	System for mounting solar modules to pitched roofs without rails.	Uses less material than a traditional flush mount system with rails.	Zilla – Phantom; DynoRaxx
Module Level Electronics	Micro-inverters and DC optimizers	Removes the electrical roadblocks of traditional system design and enables more modules to be installed on roofs.	SolarEdge; SolarBridge Technologies;
Building-Integrated PV	PV materials are used to replace conventional building materials in parts of the building envelope.	Provides savings by replacing traditional building materials	PowerHouse – Dow

[1] Balance of System (BOS) encompasses all components of a photovoltaic system other than the photovoltaic panels. Soft BOS costs are the non-hardware portion of the BOS costs. It includes expenses of customer acquisition, project design, permitting, sales tax, installation labor, overhead, profit and other residual soft costs.

Product Integrated Solutions	A manufacturer combines at least two products.	Supply of a single product instead of two or more.	
Pre-Assembled Solutions	A manufacturer or installer pre-assembles components of a system.	Assembly work is completed rapidly with quality control in a controlled setting.	The Raq – Sader Power; Instant Connect- Andalay Solar

At the same time, Landmark solar division worked with the drafting department to pre-design solar layouts for top selling home models. For each base house model, on average four roof designs were developed to accommodate different orientations, architectural requirements and plan options and to maximize the number of solar PV panels installed on the south-facing roof. After three-month preparation, developing a marketing and sales plan, working with sales. estimating and accounting teams to finalize execution details and training the sales people, Landmark launched a solar PV promotion program in March 2014. For a limited time, any new homebuyers would receive two 250-Watt solar PV panels at no cost, on the condition that they purchase a 2-kW or larger solar PV system for their new homes. Due to the supports from the project, Landmark was able to provide these early adopters a very competitive price of $2.2/Watt.

Due to issues in building permit application and architectural approvals, the offer could only be taken by homebuyers who are purchasing homes before construction start, which accounts for only 22% of the total sales of the Landmark Group. Although the promotion only targeted a small fraction of the market, the result was encouraging. In the first three months, over 70% of qualified Landmark customers decided to take the offer and purchased a roof-top solar PV system, and in the six months of promotion, 54 solar PV systems were sold with total solar PV generation capacity of 155 kW. By completing the installation of these solar PV systems, 12 Landmark highly energy efficient solar showhomes in Edmonton and Calgary and 3 external solar PV projects for other builders, we fulfilled installation requirements of project Milestones 2 and 3 (240 kW) at the end of 2014.

In October 2014, solar PV became a standard option to all Landmark customers who were buying single-family or free hold duplex new homes. To enable this move, Landmark's solar division developed sales material (see Figure 1.1), procedure and homeowner guide, and conducted a group-wide sales people training. In the following months, the sales were stable, but not in the speed we had expected. A slowing housing market was part of the reason, and there were also some internal and external issues preventing us to achieve a higher market penetration. One major reason was the costs. As most of installed solar PV systems were small, with an average installed capacity of 2-3 kW, the costs of installation and job management were high and the provision of solar generation measuring devices also added costs. Landmark solar PV division had to increase the selling price after the promotion period, which had significant impacts on the sales.

To reduce the costs of solar panels and BOS, Landmark solar division established a long-term collaborative relationship with several major solar PV component manufacturers. Table 1.2

summarized the Landmark's such efforts in 2014 and early 2015. Meanwhile, a strategy partnership was formed between Landmark and SkyFire Energy, the largest solar installation contractor in Alberta. We also worked with KVR Electric Ltd. to investigate the feasibility of using electrical contractor for solar PV installation and establishing an in-house installation workforce. We hoped that integrating solar PV installation with Electrical Final would reduce the installation costs, save construction time and simplify construction coordination.

Figure 1.1: Landmark Solar Sales Sheet – Lazy Roof vs Solar Roof (2014)

Table 1.2: Efforts of Establishing Collaborative Relationships with System Component Manufacturers

Equipment	Manufacturer	Products	Relationship
Solar Module	Canadian Solar	Poly- and Mono-crystalline modules	Establishing a preferred pricing through their distributors.
Solar Module	JA Solar (U.S.A.)	Mono-crystalline modules	Establishing a preferred pricing through their distributors.
Inverter	Enphase Energy	Microinverter with integrated ground delivers	Establishing a preferred pricing through their distributors.
Inverter	ABB Power One		A direct-supply relationship on batch purchase of 500kW or more.
Inverter	APS America	APS Inverter	Establishing preferred pricing through their distributors.
Racking	Schletter		A direct-supply relationship and collaboration in the development of a new technology solution for slop roof installation.
Racking	Kinetic	K-Rack system	Establishing a preferred pricing through their distributors.

Alberta's solar PV industry experienced extremely tough time in 2015. Due to low crude oil prices, Alberta economy slowed down in late 2014 and so did the housing market, which had significant impacts on the project progress. Landmark saw a remarkable drop in both new home sales and the percentage of new homebuyers who would invest in solar power. Future uncertainty prevented home buyers from investing extra money on solar PV. At the same time, the Alberta grid electricity price continuously went down from 8₵/kWh in late 2013 to below 5₵/kWh in mid-2015. The cost of solar PV modules, on the other hand, increased by $0.5/Watt due to combined effects of weak Canadian dollar and a new import tariff on Chinese-made products[2]. With low adoption rate, Landmark had to take a market-driven approach for solar PV installation. The installation target of project Milestone 4 (160 kW) took 10 month to accomplish, and the overall project schedule was delayed by about 12 months.

In contrast to the solar PV sales and installation, the research on solar generation and household energy consumption measuring want well in project year 2. Over 100 solar PV systems installed by Landmark across the province were equipped with either Solar-Log Monitoring Systems or Enphase Enlighten Systems. A research team led by Dr. Mustafa Gul at the University of Alberta had developed

[2] In March 2015, the Canada Border Services Agency (CBSA) put in place provisional duties ranging from 9% to 202% on nine specific Chinese solar PV panel exporters, and a duty of 286% on all other Chinese solar PV exporters.

a data warehouse to collect real-time solar PV generation data from these systems and started to analyze the data using artificial neural network technology (see Figure 1.2).

- Alberta, Canada
- 2010 Up-to-date
- 113 houses

City	Houses	Area
Lakeland County	1	Lakeland
Edmonton	45	Edmonton
Sherwood Park	5	
Leduc	1	
Beaumont	2	
Red Deer	7	Red Deer
Sylvan Lake	1	
Calgary	12	Calgary
Cochrane	15	
Airdrie	1	

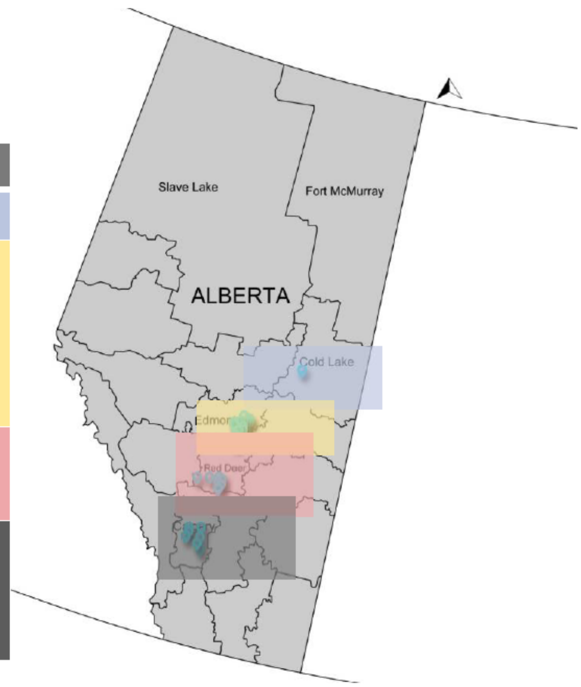

Figure 1.2: Highly Energy Efficient Solar Homes Monitored at the end of 2015

The primary goals of measuring the energy performance of solar PV systems and highly energy efficient solar homes were twofold:

- Developing a design tool for residential roof top solar PV system in Alberta to accurately forecast solar PV generation and assess the impacts of design factors on solar PV's performance, and
- Investigating the interaction between solar PV generation and house electricity consumption to optimize solar system design.

To achieve the second goal, we installed eGauge energy measuring systems in 12 occupied highly energy efficient solar homes to measure both the energy consumption and solar PV generation. Figure 1.3 was a snapshot of the measuring results of an eGauge system.

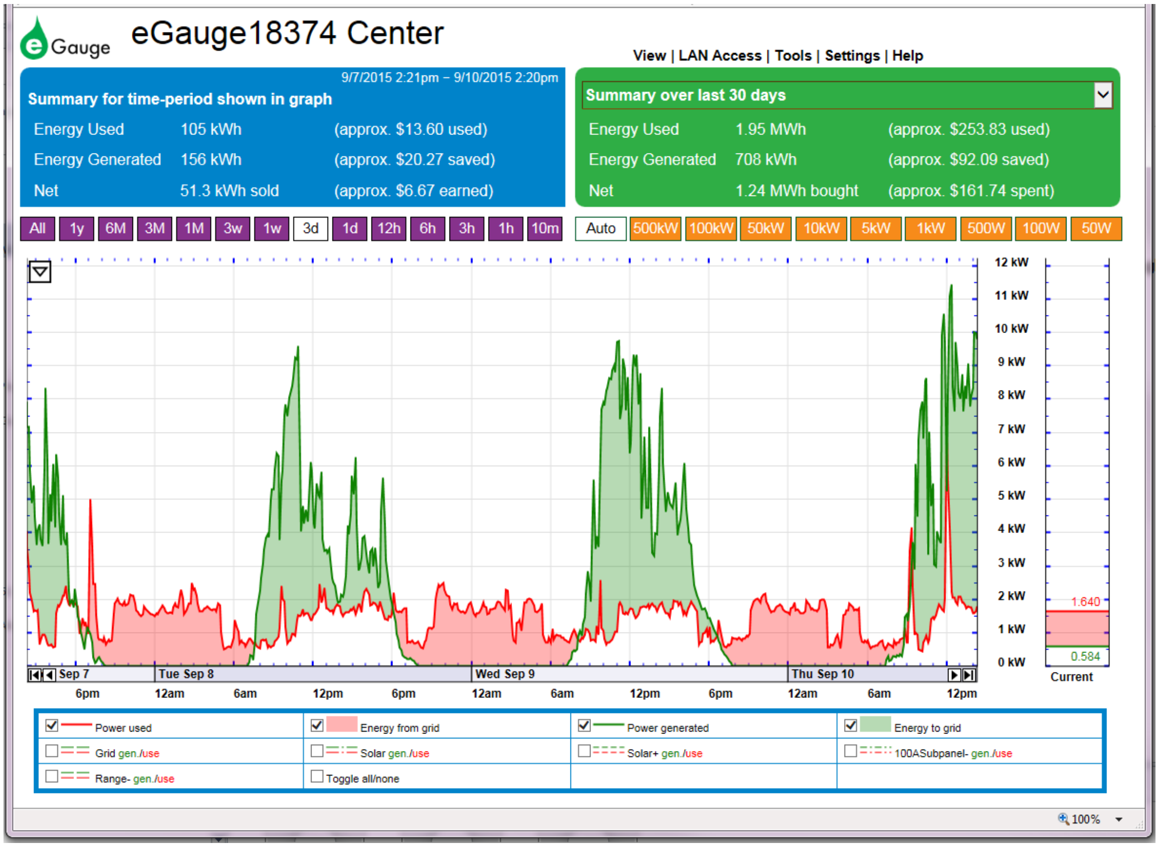

Figure 1.3: Energy Consumption and Solar PV Generation Measuring (eGauge System)

In early 2016, the research team presented the preliminary research results to the project management team. Below were a few conclusions from their study:

- In the year 2014 and 2015, the PV generation factor of Edmonton was about 1400 kWh/kW per year, while the generation factor of Calgary was 1500 kWh/kW, 12% more than the commonly used 1,250 kWh/kW for Edmonton and 1,265 kWh/kW for Calgary;
- The peak outputs of solar PV generation was 1.54 kW/kW and the peak electricity loads of a household with natural gas space and domestic water heating systems was about 8.4 kW. This means when a house is equipped with 5.5kW or larger solar PV system, the outputs of solar power is the determining factor for sizing the electrical service.
- The optimal installed position of solar PV panels in Alberta would be facing south and at a tilt angle of 50˚, but compared to orientation, the impact of tile angle was minor. A solar PV panel installed at 20˚ tilt angle could get 92% of the maximum outputs, while a panel facing east would get only 73% of the maximum outputs.
- A solar PV panel installed flat would lose 24% of its generation capacity and a vertical installed panel facing south would lose approximately 20%, better than a panels facing east or west.

Alberta's economy continued at bottom in 2016 and after the grid electricity price hit historical low in 2015, it went down further 15% in the first quarter of 2016. The project team had done an economic analysis on the investment return of residential solar PV systems and found that even with the supports from ERA (about $1.5/w), the costs of solar power was well above the level needed for reaching grid parity, which was considered to be the point at which an energy source would become a contender for widespread market acceptance. As shown in Figure 1.4, when the electricity price was at 5¢/kWh, the total revenue or savings from a 10-kW roof-top solar PV system would be $14,450 in 25 years, lower than the initial investment of $20,000. Despite the adverse market conditions, SolarMax, the solar division of Landmark, continued to actively promote solar PV solutions to residential customers. The installation target of Milestone 5 (160 kW) was achieved in May 2016.

The growth of micro generation in Alberta remained a very slow pace in 2017. The average floating rate of grid electricity to residential users was as low as 3.69 ¢/kWh. Even with the funding supports from the project, the cost of solar power is almost two-times higher comparing to the cost of purchasing electricity from the grid. To keep solar PV solution competitive, Landmark focused on improving customers' purchasing experience. In late 2016, SolarMax obtained the energy retailer license. This enabled it to provide solar PV system owners full services, from solar PV system design, installation and MG registration to energy measuring and metering, and a variety of integrated power options. In addition, SolarMax provides 1 ¢/kWh premium for solar power exported to the grid when a customer signs up a fixed pricing package with the company.

Rooftop Solar PV in Edmonton

	Inputs	
System $/W	$3.50	$/Watt
System Size	10	kW
System Cost (not incl GST)	$35,000	Total Cost before grant
CCEMC Funding	$1.50	$/Watt
Total Funding mount	$15,000	$
Final System Cost	$20,000	Cost to Customer
Output Multiplier:	1.25	AB avg kWhr/kW/yr
Annual Output	12,500	kWh per year in Year 1
Annual Inflation	0%	
Annual maintenance cost:	$50	
Insurance	$0.00	annually
Solar derate losses	0.50%	%/yr

Economic:

Electricity Price	$0.05	$/KWh
Government FiT Incentive	$0.00	$/KWh
IRR	-3%	
Simple Payback		Years

Year	Output kWh/year	Revenue/Saving from PV Power	Cash Flow	Cumulative
1	6,250	$312.5	-$19,688	-$19,688
2	12,500	$625	$575	-$19,113
3	12,438	$622	$572	-$18,541
4	12,375	$619	$569	-$17,972
5	12,313	$616	$566	-$17,406
6	12,250	$613	$563	-$16,844
7	12,188	$609	$559	-$16,284
8	12,125	$606	$556	-$15,728
9	12,063	$603	$553	-$15,175
10	12,000	$600	$550	-$14,625
11	11,938	$597	$547	-$14,078
12	11,875	$594	$544	-$13,534
13	11,813	$591	$541	-$12,994
14	11,750	$588	$538	-$12,456
15	11,688	$584	$534	-$11,922
16	11,625	$581	$531	-$11,391
17	11,563	$578	$528	-$10,863
18	11,500	$575	$525	-$10,338
19	11,438	$572	$522	-$9,816
20	11,375	$569	$519	-$9,297
21	11,313	$566	$516	-$8,781
22	11,250	$563	$513	-$8,269
23	11,188	$559	$509	-$7,759
24	11,125	$556	$506	-$7,253
25	11,063	$553	$503	**-$6,750**
Total	289,000	$14,450		

Figure 1.4: Economic Analysis of a 10-kW Residential Roof Top Solar PV System in Alberta

The interactive slope-roof solar PV calculator developed in 2016 was also proved to be an effective decision-making tool to improve the customer experience of solar PV system purchasing, as well as to size the solar PV system in NZEH design. In the past, Landmark sales representative had to meet a potential customer at least three to four times to discuss the layout of the solar PV panels, the size of the system, the estimated costs and predicted power generations before the customer knew the whole picture and made the decision. With a simple Excel tool shown in Figure 1.5, the sales person can sit with the customer who is interested in solar PV, look at the house blueprint, and have a quick estimate on the numbers of solar PV panels, annual solar power generation and the efficiency of the solar PV system. Coupling with a SolarMax's price sheet, the customer then has all information that he/she needs to make the decision.

PV Panel Capacity	260	W/panel
Based on	PVWatts	
Annual Generation Factor	1,350	kWh/kW

Annual Generation (kWh)	**11,030**
Annual Generation (kWh/kW)	**1,250**

Roof 1		Roof 2		Roof 3	
Number of panels	16	**Number of panels**	10	**Number of panels**	8
Orientation	S	**Orientation**	SW	**Orientation**	SE
Tilt Angle	30	**Tilt Angle**	20	**Tilt Angle**	60
Capacity Factor	0.97	**Capacity Factor**	0.87	**Capacity Factor**	0.9

Figure 1.5: The User Interface of Slope-Roof Solar PV Calculator

The Alberta housing market remained in the valley in 2017. In addition to 562 kW of solar PV systems installed before May 2016 (Milestones 2-5) and 160 kW installed in the time period between June 2016 and August 2017 (Milestone 6), Landmark had completed the installation of 24 residential solar PV systems with total installed capacity of 174 kW between January 2017 and March 2018 (Milestone 7). Overall, 199 residential solar PV systems with 896 kW of generation capacity were installed reaching the amended project goal of installing 895 kW of solar PV systems.

SCIENTIFIC ACHIEVEMENTS

To support the design optimization and evaluate the actual performance of Solar PV systems, a research team led by Dr. Mustafa Gul at the University of Alberta has been work closely with Landmark in the past three years. A NSERC Collaborative Research and Development (CRD) project was initiated by Landmark to support one Ph.D. and two M.Sc. students working on researches related to residential solar PV implementation in Alberta. Their research works were conducted mainly in the following four areas:

1) Investigating the long-term performance of solar PV systems in local climatic conditions and developing a solar PV output forecast tool for Alberta;

2) Studying the energy profile of net zero and highly energy efficient homes and identifying load and generation patterns for different house types based on climatological, social, and cultural conditions;
3) Developing a design framework to optimize solar PV system design and maximizing the on-side load match; and
4) Developing a web-based optimization tools for flat and sloped rooftop solar PV systems.

By the project end date, the research team has published three journal papers and three conference papers. The project scientific results were also shared at Solar Energy Society of Alberta (SESA)'s Seminar Series (Jan 19, 2018, Edmonton). One Ph.D. student and one M.Sc. students completed their programs based on their work conducted during the project.

Journal Papers

- *Predicting the Energy Production by Solar Photovoltaic Systems in Cold-Climate Regions,* International Journal of Sustainable Energy, accepted
- *Energy Performance and the Discrepancy of Multiple NetZero Energy Homes (NZEHs) in Cold Regions*, Journal of Cleaner Production, 2018.
- *Load-match-driven design of solar PV systems at high latitudes in the northern hemisphere and its impact on the grid*, Solar Energy, 2017

Conference Papers

- *'Load-match-driven Design Improvement of Solar PV Systems and Its Impact on the Grid with a Case Study*, SusTech: 5th Annual IEEE Conference on Technologies for Sustainability, 2017, Phoenix, AZ, US.
- *Economy of Residential Photovoltaic Generation and Battery Energy Storage in Alberta, Canada*, 2017 IEEE Electrical Power and Energy Conference (EPEC 2017), 2017, Saskatoon, SK, Canada.
- *Solar photovoltaic optimization for flat rooftops in cold regions,* 4th Annual IEEE Conference on Technologies for Sustainability, 2016, Phoenix, AZ, US.

Student Thesis

- *Integrating Solar PV Systems into Residential Buildings in Cold-climate Regions: The Impact of Energy-efficient Homes on Shaping the Future Smart Grid.* Ph.D. Theses, Hadia Awad, 2018.
- *Design optimization of grid-tied solar Photo-Voltaic (PV) systems for flat roofs,* M.Sc. Theses, Salim, K M Emtiaz, 2017.

GREENHOUSE GAS AND NON-GHG IMPACTS

The GHG benefits resulting from the completed project include direct GHG reduction from the electricity generated by the 199 residential solar PV systems (895 kW of generation capacity) that were funded by the project, and the indirect impact to support the efforts of housing industry in building highly energy efficiency homes. As mentioned in the previous section, due to high unemployment rate and net out-flow of population caused by economic recession, the Alberta housing market has seen slow sales and high inventory resulted from the building boom before 2015. To survive in this slow buyer-market, all homebuilders are cutting non-essential features like energy efficiency and trying to compete on price to increase their market share. Virtually, there was no market for residential solar PV. SolarMax was the only solar PV solution provider in new home market supporting NZEHs built in Alberta (by Landmark and other builders) since 2015. The technical solution and marketing strategies developed under this project and the funding supports from ERA enable Landmark to continuously support the adoption of solar PV in the residential sector and keep the industry's momentum for NZEHs.

In the full project proposal, the annual solar PV generation was calculated according to the PV Map published by NRCan, but during the Contribution Agreement execution process, the annual solar PV generation was re-calculated using NREL's PVWatts software[3] and the GHG emission reduction was estimated using GHG emission factor indicated in Government of Alberta's Memorandum (2011) Notice of Change for Emission Factor for Increased Grid Electricity Usage. The estimated annual solar PV generation of the proposed 1.6 MW system was 2,012 MWh and the total GHG reductions by 2050 was 30.8 tonnes of CO2e.

To evaluate the actual performance of solar PV, energy measuring device was installed at every solar PV system installed by Landmark/SolarMax to collect the real-time solar PV generation data. A research team led by Dr. Mustafa Gul at the University of Alberta developed a database to store and analyze the data from over 150 residential roof-top solar PV systems. Artificial Neural Network (ANN) technique was used to develop a solar PV output forecast model to better estimate the actual performance of roof-top solar PV systems in Alberta. As shown in Figure 2.1, the developed tool provides a better estimate on daily and monthly outputs of the solar PV, but for yearly forecast, PVWattes Calculator has the best accuracy.

Following the same methodology used during the Contribution Agreement execution process, , the direct GHG emission reduction of the project is calculated as shown in Table 2.1. The total annual

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[3] PVWatts Calculator is an online tool developed by National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy (DOE) to homeowners, small building owners, installers and manufacturers throughout the world to estimates the energy production and cost of energy of grid-connected photovoltaic (PV) energy systems. (https://pvwatts.nrel.gov).

generation of 714 kW of solar PV systems in Edmonton, 15 kW in Red Deer and 166 kW in Calgary is 1,082 MWh. Using the electricity grid displacement and grid usage factors published by Alberta Government[4] the direct GHG emission reduction of the project is 690 tonnes of CO2e per year and 16.3 kilotonnes of CO2e during their 25-year life span. Appendix A includes the simulation results from NREL's PVWatts Calculator and the assumptions used in the calculations. The life span of the solar PV system is based on the warranty offered by solar PV module manufacturers. This estimate is very conservative. The solar PV panel will not lose its generation capacity suddenly after 25 years, and many case studies proved that the actual life of solar PV panels are much longer. The calculation also considered possible PV degradation and assume the efficiency loss of solar PV systems is 0.5% per year, a rate used by the solar PV industry and multiple government renewable incentive programs in U.S. and Europe.

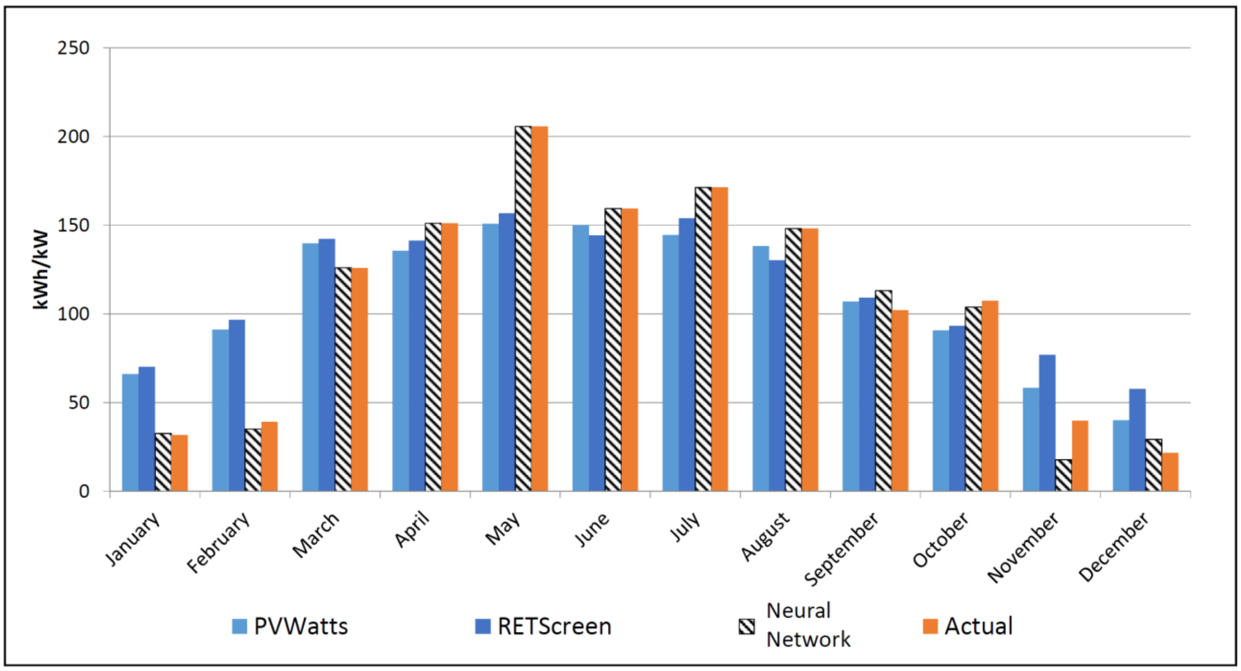

Figure 2.1: A Comparison of Monthly Solar PV Generation Forecast and Measured Data
(A typical roof-top solar PV system installed in Edmonton, south-facing with an 30° tilt angle)

[4] Alberta Environment and Sustainable Resource Development (2015) Carbon Offset Emission Factors Handbook (https://open.alberta.ca/dataset/dd23dec0-e408-49b7-8bdc-151cc1ce58f5/resource/18f3a5f5-6370-467b-be5a-664330014723/download/2015-carbonemissionhandbook-mar11.pdf)

Table 2.1: Direct GHG Emission Reduction of the Project

Year	Annual PV Generation (MWh)	Efficiency Loss	GHG Reductions (0.64 t/MWh)	Σ reductions (tonnes CO2e)
2014	0	0.0%	0	0
2015	0	0.0%	0	0
2016	1,082	0.5%	692	692
2017	1,077	0.5%	689	1,381
2018	1,071	0.5%	686	2,067
2019	1,066	0.5%	682	2,749
2020	1,061	0.5%	679	3,428
2021	1,055	0.5%	675	4,103
2022	1,050	0.5%	672	4,775
2023	1,045	0.5%	669	5,444
2024	1,039	0.5%	665	6,109
2025	1,034	0.5%	662	**6,771**
2026	1,029	0.5%	659	7,430
2027	1,024	0.5%	655	8,085
2028	1,019	0.5%	652	8,737
2029	1,014	0.5%	649	9,386
2030	1,009	0.5%	646	10,031
2031	1,004	0.5%	642	10,674
2032	999	0.5%	639	11,313
2033	994	0.5%	636	11,949
2034	989	0.5%	633	12,581
2035	984	0.5%	630	**13,211**
2036	979	0.5%	626	13,837
2037	974	0.5%	623	14,461
2038	969	0.5%	620	15,081
2039	964	0.5%	617	15,698
2040	959	0.5%	614	**16,312**

OVERALL CONCLUSIONS

Photovoltaic power generation has long been acknowledged as a clean energy technology with vast potential. Solar PV panels draw upon the planet's most abundant and widely distributed renewable energy resource – the sun, and directly convert sunlight to electricity without any environmental emissions during operation. In the past two decades, PV systems have experienced exponential growth around world, from being niche market applications into a mature technology used for mainstream electricity generation. According to International Renewable Energy Agency (IRENA)'s report[5], cumulative global installed PV capacity grew from 6.1 GW at the end of 2006 to 291 GW at the end of 2016. At the same time, the costs of PV systems rapidly declined. Between 2010 and the 2016, solar PV module prices decreased by over 80%. Nowadays, the costs of solar PV modules range between $0.45 and $0.65 USD.

As solar PV technology has matured, balance of system (BoS) costs, which include costs of BOS-components, customer acquisition, permitting, inspection and interconnection, installation labor and financing, contribute more and more to total system costs. NREL's residential PV system cost benchmark provides the best reference for the cost structure of solar PV. As shown in Figure 3.1, from 2010 to 2017 there was a 61% reduction in the total installed costs of residential PV systems. Approximately 61% of that reduction can be attributed to hardware costs (module, inverter, and hardware BOS), as module prices dropped 86% over that time period. An additional 18% can be attributed to labor, which dropped 73% over that time period. And the final 21% attributable to other soft costs, including PII, sales tax, overhead, and net profit.

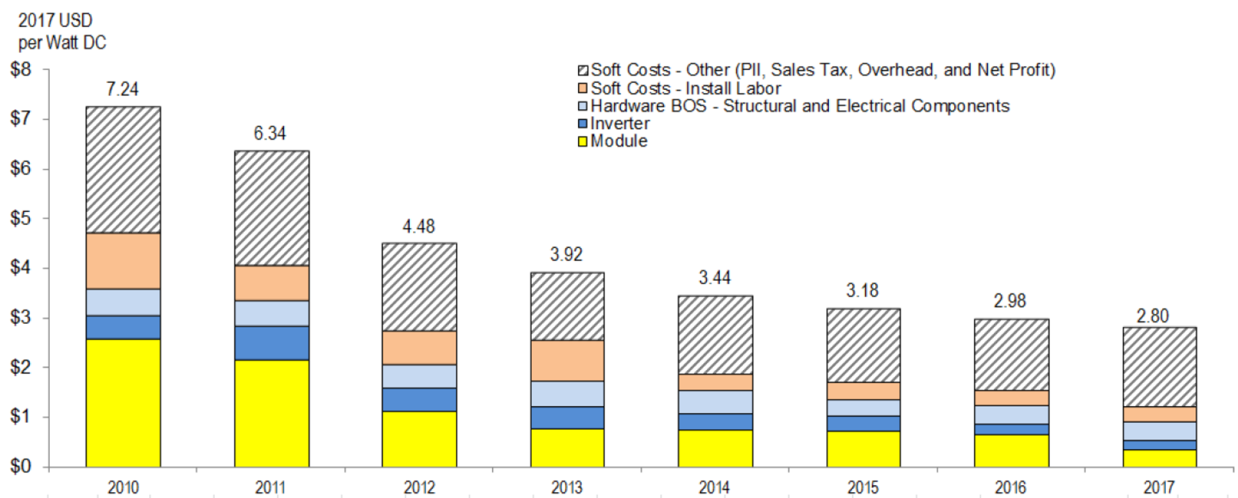

Figure 3.1: NREL Residential PV System Cost Benchmark Summary (inflation adjusted), (Q4 2009–Q1 2017)

In Alberta, the current installed price of residential roof-top solar systems is at the same level of the price in the U.S., around $3.5 CAD per DC watt, while Landmark is providing a more competitive price to our customers at around $3.2/watt, depending on the size of the system. With the rebates from Alberta government's Residential and Commercial Solar Program ($0.75/watt) and the City of Edmonton's Residential Solar program ($0.15/watt), the final price for Landmark customers to install solar PV system on their properties is as low as $2.3/watt. In fact, in Milestone 7, the average sale

[5] IRENA (2018) Renewable Power Generation Costs in 2017 (https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf).

price of our solar PV package was below \$2.0/watt, the target price of this ERA funded project. However, only a small percentage of new home buyers considered installing solar PV on their homes, in spite of all the efforts in marketing and incentives from the government. Based the experience in the past four years working on this project and a study of the adoption of solar PV in other jurisdictions such as California, where actually has the most expensive residential solar PV market with total installed costs of \$4.5/watt USD, we identified the following four main barriers that prevented the wide adoption of solar PV technology in Alberta housing market.

- The attractiveness of solar PV to customers largely depends on levelized cost of electricity (LCOE). Although the LCOE of residential systems went down about over 50% in the last five years to 8.5¢/kWh today, it is still much higher than the grid electricity price in Alberta, which is at historical low of less than 5¢/kWh.
- Despite the electricity generated by the distributed residential solar PV system are mostly used by users in the neighborhood and save WSPs the demand transmission service (DTS) charges (3¢/kWh) that they have to pay AESO for grid electricity, the solar PV system owners normally do not get any credits for this saving. Currently each WSP in Alberta has its own way of referring to the DTS charges and policy for DTS credits, a common policy has the potential to help residential solar PV to achieve grid parity.
- Solar PV system requires significant initial investment and most homebuyers do not have the financial capacity to make such an investment even they would like to. No financing mechanism is now available in Alberta for individuals to invest in renewable energy.
- The return of a solar PV system will last for 25 years or longer. However, there is no mechanism today to reflect the fair value of solar PV in the value of the property. The homeowners who invest in the solar PV have to take the risk that they cannot recover the investment when they sell their homes.

Landmark's experience proves that the integration of solar PV to high energy efficient homes, particularly NetZero or Near NetZero Energy Homes, can substantially reduce the costs of getting homes to solar ready and the soft costs of marketing, customer acquisition and inspection. SolarMax's business model, which combined functions of solar PV system integrator and electricity retailer, enables the company to deliver end-to-end turnkey solar PV systems as well as a full commissioning and operation service such as micro-generation registration, metering and system maintenance.

Sales and marketing was another area having great influence on the market penetration of Solar PV in the housing market. The interactive solar PV calculator (Figure 1.5) developed in 2016 simplified the selling process, thus improving customers' purchasing experience of solar PV system. Based on the feedback from our salesperson, these tools were very effective in getting homebuyers attention on Landmark's solar PV options and facilitate their decision-making process.

In mid-2018, Alberta Residential and Commercial Solar Program has increased the incentives levels of residential solar system to \$0.90/watt. Meanwhile, the residential electricity retail rate went up substantially in 2018 and is now higher than 6.8¢/kWh (rate cap). Today residential solar PV is economically viable in Edmonton area, with a simple payback of about 20 years (Barrier 1). The proposed Property Assessed Clean Energy (PACE) program is expected to provide an alternative financing mechanism to help Albertans make clean-energy improvements (Barrier 3) and eliminates the issue that the initial investor may not be able to recover its investment when the ownership of property/solar PV system changes (Barrier 4).

NEXT STEPS

Landmark installed the first residential solar PV system on its first NZEH in 2012. Since then, over 200 solar PV systems were sold and installed on new homes built by Landmark and other builders across Alberta. As the only solar PV solution provider focusing on new home market, SolarMax supported the construction of 24 NZEHs in the last 4 years using the project funding.

The integration of solar energy systems to residential buildings will continue to be an important way for housing industry to mitigate the GHG emissions. Alberta is now at turning point towards building energy efficiency and renewable energy. Alberta’s Climate Leadership Plan was launched in November 2015 and as a result, an economy wide carbon levy comes in force on January 1st, 2017. It is expected that the carbon pricing will raise $9.6 billion between 2017 - 2022, all of which will be invested in the green economy, including $3.4 billion for renewable energy, $2.2 billion for green infrastructure and $645 million for energy efficiency. In this context, Dr. Mustafa Gül and his research team at the University of Alberta, in collaboration with Landmark, initiated a strategic research in late 2017 on community energy system that consists of distributed micro-generation and a combination of NetZero energy and highly energy efficient homes. As shown in Figure 4.1, the research is based on the existing work of energy measuring at over 150 residential roof-top solar PV systems and 18 highly energy efficient homes, and aims at developing a simulation tool to assist community smart grid design by considering load match, grid interaction and energy storage.

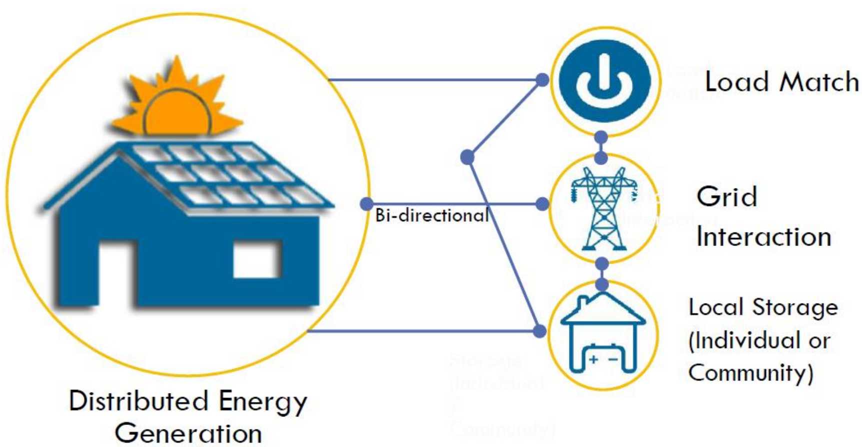

Figure 4.1: Research Scope

A fundamental problem of current electricity grid is that it was designed and built for one-way power flow and sized to accommodate consistent loads of multiple users whose peak demands occur at different time points. However, NZEHs with electrical air source heat pump for space heating and domestic water supply consume 2.5 – 3 times of electricity that a typical home does and a large portion of the ramped demand occurs at the same time in the winter, particularly cold days with temperature below -15°C. On the other hand, a large roof-top solar PV system, on average 14 kWp, can cause significant outward electricity flow in the summer to the power network, further adding dynamic complexity to the problem. As NZEHs and roof-top solar PV gain more market penetration, it is critical for residential project developers and utility providers to have necessary tool to take the challenge and better design and manage the smart micro-grid at community level.

Built on the efforts of this project in evaluating the real performance of residential solar PV systems and understanding the energy profile of NZEHs and highly energy efficient homes, the objectives of this research initiative are:

- Developing house minute-by-minute energy profile models using actual house consumption and generation data;
- Analyzing the load and grid-interaction patterns of homes with different characters in more detailed level;
- Designing the grid simulation model using the Monte Carlo approach to estimate the agregative impacts of infrequent events such as drying clothing and charging electrical vehicles; and
- Developing a generic community micro-grid simulator that accounts for large-scale application of NZEHs and residential solar PV systems.

Community solar is another area that Landmark is exploring right now. In response to a request from the City of Edmonton, SolarMax conducted a feasibility study early this year on installing a 140-kW solar PV system at the to-be-developed Twin Brooks First Place site. The purpose of the study is to explore an overall approach for multi-family complexes of shared ownership to pursue a community solar model designed to meet aggregate consumption and the possible mechanisms available in the Alberta regulatory context. Following the discussion with the City of Edmonton, the following three potential approaches were analyzed, and five models were evaluated in terms of regulation compliance, technical easiness and economic viability.

- Approach I (baseline scenario): A conventional single roof-top solar PV system on each townhome unit, connecting to the unit's electrical panelboard and being owned by the homeowner.
- Approach II: A large solar PV system tied into one meter, owned and operated by the condo board and interconnected to the electricity grid under the Micro-generation regulation.
- Approach III: A large solar PV system tied into one meter, owned and operated by the condo board and interconnected to the electricity grid under Distributed Generation regulation.

After consulting various stakeholders in the solar PV implementation process, we concluded that the conventional single system (Approach I) is the simplest method of installing solar PV systems in a residential site. The existing regulations and government incentive programs in Alberta are designed based on this approach. WSPs and retailers are familiar with this type of micro-generation application and have no technical issues to interconnect the small single-household solar PV systems to the electricity distribution network and to manage the billing process.

There is no clear way for a large community solar PV system to meet the requirements of the current Micro-Generation Regulation framework. The 2016 Micro-generation Amendment Regulation allows a micro-generating system to serve adjacent sites on the conditions that the aggregated sites are owned by the same customer, connected to a single electric distribution system feeder, and using the same retailer. In an interview with AESO and Alberta DOE, both clearly state that a condo board and each homeowner would be considered as individual end-users, which prohibits the condo board to own the solar PV system and use solar power to offset homeowners' loads. The largest barrier need to be overcome is how to design an ownership structure that allows the system to meet the regulation's requirements of load matching and site ownership. Though community solar may not be applicable to regular free-hold or condo projects, like Twin Brooks First Place, it can be used at rental project, in which all houses in the community are owned by a single owner. In collaboration with SevenEightyseven Condo Inc., Landmark is going to further explore the community solar approach and planning to install a 40-kW solar system at Webber Greens affordable rental project. Figure 4.2 illustrates the concept of the community solar PV system.

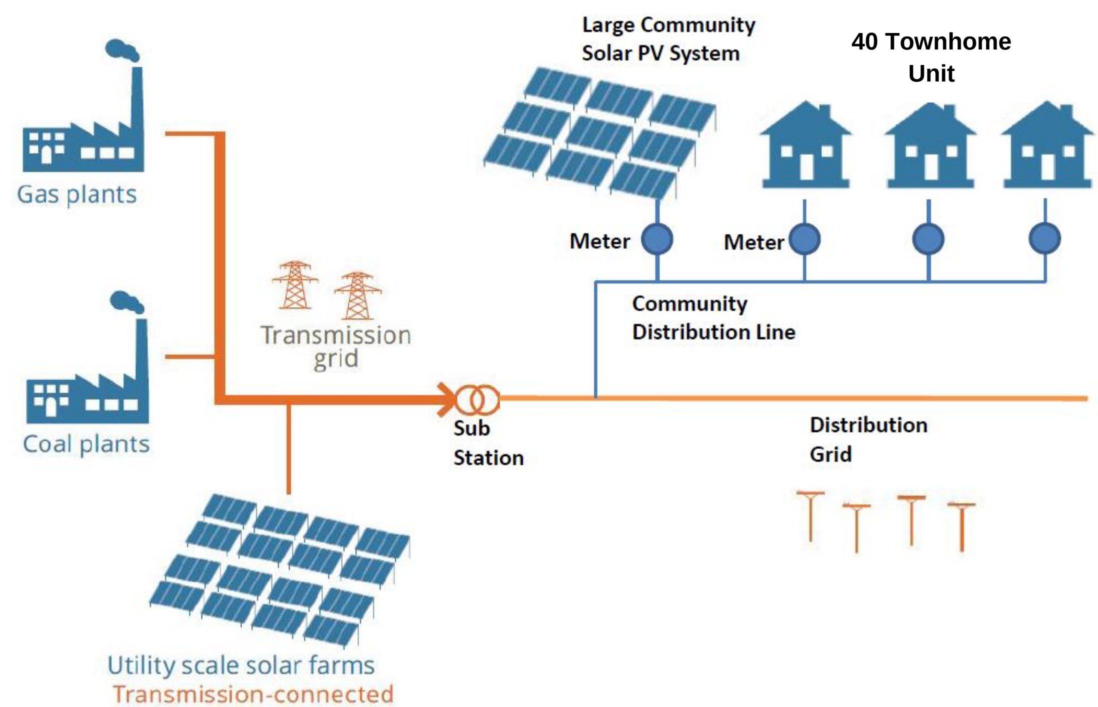

Figure 4.2: Community PV System at Webber Greens

APPENDIX A: ANNUAL SOLAR PV GENERATION CALCULATION

1. Solar PV Systems Installed in Edmonton Area

NREL

NATIONAL RENEWABLE ENERGY LABORATORY

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

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The energy output range is based on analysis of 30 years of historical weather data for nearby , and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

849,695 kWh/Year*

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Value ($)
January	1.63	31,587	N/A
February	2.84	49,234	N/A
March	4.11	74,204	N/A
April	5.65	96,020	N/A
May	6.25	105,882	N/A
June	5.86	95,620	N/A
July	6.40	104,089	N/A
August	5.96	98,302	N/A
September	4.63	76,411	N/A
October	2.95	53,963	N/A
November	2.04	37,067	N/A
December	1.43	27,317	N/A
Annual	**4.15**	**849,696**	**0**

Location and Station Identification

Requested Location	edmonton alberta canada
Weather Data Source	Lat, Lon: 53.53, -113.5 1.2 mi
Latitude	53.53° N
Longitude	113.5° W

PV System Specifications *(Residential)*

DC System Size	714 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	30°
Array Azimuth	180°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2

Economics

Average Retail Electricity Rate	No utility data available

Performance Metrics

Capacity Factor	13.6%

2. Solar PV Systems Installed in Calgary Area

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

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The energy output range is based on analysis of 30 years of historical weather data for nearby , and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

213,309 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	2.27	9,993	N/A
February	3.39	13,306	N/A
March	4.44	18,658	N/A
April	5.73	22,612	N/A
May	5.96	23,496	N/A
June	5.93	22,178	N/A
July	6.93	25,742	N/A
August	6.11	23,063	N/A
September	4.96	18,739	N/A
October	3.58	14,949	N/A
November	2.67	11,330	N/A
December	2.14	9,244	N/A
Annual	**4.51**	**213,310**	**0**

Location and Station Identification

Requested Location	calgary alberta canada
Weather Data Source	Lat, Lon: 51.05, -114.06 0.3 mi
Latitude	51.05° N
Longitude	114.06° W

PV System Specifications *(Residential)*

DC System Size	166 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	30°
Array Azimuth	180°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2

Economics

Average Retail Electricity Rate	No utility data available

Performance Metrics

Capacity Factor	14.7%

3. Solar PV Systems Installed in Red Deer

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

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The energy output range is based on analysis of 30 years of historical weather data for nearby , and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

18,076 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	1.75	704	N/A
February	2.78	983	N/A
March	4.02	1,533	N/A
April	5.43	1,990	N/A
May	6.02	2,163	N/A
June	6.03	2,056	N/A
July	6.40	2,204	N/A
August	6.16	2,128	N/A
September	4.71	1,634	N/A
October	3.27	1,249	N/A
November	2.03	755	N/A
December	1.69	676	N/A
Annual	**4.19**	**18,075**	**0**

Location and Station Identification

Requested Location	Red Deer alberta canada
Weather Data Source	Lat, Lon: 52.25, -113.82 1.4 mi
Latitude	52.25° N
Longitude	113.82° W

PV System Specifications *(Residential)*

DC System Size	15 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	30°
Array Azimuth	180°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2

Economics

Average Retail Electricity Rate	No utility data available

Performance Metrics

Capacity Factor	13.8%