Solar Energy for Public Buildings in Alberta

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Executive Summary

As part of the Government of Alberta's 2016 Climate Leadership Plan, renewable energy generation is being considered as a method to reduce greenhouse gas (GHG) emissions. Recent studies indicate substantial health and climate benefits for implementing renewable energy technologies to displace GHG emissions. Moreover, increasing renewable energy has the potential to create jobs in design, manufacturing, sales, purchasing, transporting, installing and servicing. Solar energy in particular has been garnering considerable interest as a source of renewable energy, as Alberta has among the highest amount of annual sunlight in Canada. There are four main methodologies for harvesting solar energy: solar photovoltaic (PV), building integrated photovoltaic, solar thermal collectors, and passive solar heating (see pages 5 and 12 for more details). This paper focuses on the use of solar PV technology.

Solar PV modules are safe, reliable fixed panels that can be used to convert sunlight to electricity. The panels can be mounted in a variety of configurations, but are most commonly located on rooftops. With proper operation and maintenance, life spans for solar PV installations are expected to be 25 years or more. These installations are most often connected to the utility grid and allow for various metering arrangements. For implementing PV technology in buildings, site factors such as sloping, vegetation (tall trees), microclimate, wind, precipitation, orientation to the sun's path, etc., must be considered. Such factors and considerations are important whether or not solar PV is added as a supplement to the overall facility design.

Implementing solar PV technology is not without constraining factors. Though PV technology reduces ongoing GHG emissions, the manufacturing and transportation of its necessary components results in negative environmental impacts. However, these impacts can be alleviated by sourcing PV panels from local manufacturers and fabricators, and by re-cycling PV modules at the end of their useful life. Moreover, PV technology by nature contains variability and uncertainty, including daily and seasonal fluctuations in available sunlight, fluctuating amounts of production, grid stability and energy storage. Finally, a lack of statutory protection of solar rights or any sort of regulatory framework could lead to challenges related to solar access, views and development on adjacent properties.

Solar PV technology is applicable to all building typologies whether a school, hospital, government office building, courthouse or cultural facility. However, it is important to make the facility as efficient as possible prior to the consideration of adding active efficiencies through renewable sources. A practical consideration for prioritizing which buildings merit early implementation of solar PV configurations are ones that are LEED certified and net-zero ready, or have at the very least been recently modernized with building envelope efficiency upgrades. In this respect, construction of new buildings is an ideal place to implement solar PV technology, followed by recently upgraded existing buildings.

In the Edmonton region, the estimated cost of a typical solar PV configuration is approximately $160,000 (based on an average project size of 200 modules). A project of that size could potentially generate 49,800 kWh per year, that could in turn save about $8,400 a year in power costs today. It would take up to 19 years to achieve a return on investment. For each

building that can be designed or retrofitted to incorporate 200 modules of solar PV, it is equivalent to taking 1.4 cars off the road each year. In addition to the environmental benefits of solar PV technology, the measurement, verification and reporting of energy usage of these systems can provide benefits beyond determining the difference in energy usage after the installation of the equipment. Measurement, verification and reporting can: detect building anomalies or problems that might have gone unnoticed, find opportunities for greater efficiencies and verify the commissioning process. Moreover, solar PV panel arrays used for measurement and reporting provide a convenient and tangible display of how the solar PV systems work, how they are connected to the grid, and how the environment benefits.

The use of solar PV technology on buildings can provide considerable long-term cost savings and GHG reductions. Solar PV technologies are best implemented on new building projects since the components are easier to integrate during the design stage and can provide the best return on investment. The use of solar PV technology will respond to the Government of Alberta's 2016 Climate Leadership Plan in three ways: reducing greenhouse gas emissions, creating jobs and growing the renewable energy industry, and increasing public education and awareness of responsible energy consumption.

1. Introduction

1.1 Context

Earlier this year, the Government of Alberta introduced a Climate Leadership Plan with a strategy that includes two initiatives: major reductions in methane emissions (GHG emission reduction), and ending pollution from coal-fired electricity generation (GoA, 2016). As part of the implementation of these two initiatives, renewable energy generation will be looked to as one source for an energy replacement alternative. Renewable sources of energy include such natural phenomena as the sun, wind and tides. This paper will focus primarily on the merits that harvesting the sun can bring and in particular, solar photovoltaics (PV). It will explore benefits of solar PV technology, study current technical information from a growing field, and examine applications of the technology for use on public buildings and what constraining or enabling factors need to be considered.

1.2 Demand for Renewable Sources of Energy

There is considerable interest from Alberta communities in moving forward with such an initiative. PV technology is seen as an area of growth with the ability to provide clean, sustainable energy while also providing jobs. School Boards are inquiring whether or not their school can be the first to benefit from solar energy. Groups like the Pembina Institute and Calgary Economic Development have held workshops to draw stakeholders together and discuss how to move forward with renewables (McKitrick, 2016). Post-secondary institutions such as the University of Calgary (UofC, 2016) and University of Alberta (UofA, 2016) are leaders in researching solar PV and implementing pilot projects that demonstrate the benefits of deployment. The town of Banff is taking a proactive approach and providing solar leadership. It has implemented a feed-in solar tariff system that pays businesses and residents a rebate if they are able to send surplus power to the grid from their solar installations. This allows the payback for the installations to be reduced to 7 years. The rebates come from an environmental reserve that is also used to “pay for LED street lights, hybrid buses and solar systems on public buildings” (Dodge & Kinney, 2015). Overall, the concept of moving forward with widespread implementation of solar PV technology appears ready for launching.

1.3 Solar Technology Types

There are four main methodologies for harvesting solar energy: solar photovoltaic (PV), building integrated photovoltaic (BIPV), solar thermal collectors, and passive solar heating. PV modules are safe, reliable fixed panels that can be used to convert sunlight to electricity. The panels can be mounted in a variety of configurations but are most commonly located on rooftops. The BIPV option is a variation of PV. The main difference is that BIPV are integrated into other building materials rather than used as stand-alone features. Solar thermal involves circulating fluid through collector piping by means of a low-energy pump. The circulated fluid delivers heat to a centrally located hot water tank. When users need heat, the solar-heated water feeds the primary water heating system. Finally, passive solar heating is a methodology that can be used to harvest the sun’s energy. There are no moving parts to this method. It mainly involves orienting the building and configuring the windows to collect the natural heat/energy of the sun in an optimal way. While this research paper is focusing on solar PV, a brief description of the technology needed for each type along with the explanation of the benefits and disadvantages of each is warranted. Refer to section 3.0 of this report for these descriptions.

2. Planning and Technical Considerations

2.1 Geography of Alberta (for PV Potential)

Alberta is located between 49 and 60 degrees latitude and is mostly in climate zone 7, a zone that is described as very cold. On average there are about 5000C heating degree days (HDD) per year while only about 33C cooling degree days (CDD). Note that the number of HDD (for one day) is the number of degrees that the day's average temperature is below 18ºC (below which buildings need to be heated); CDD are average temperatures above 18ºC. Summer days are warm and long, with hours of daylight reaching 18 hours per day on June 21st. Summer temperatures average about 18C although a handful of days can reach 30C or higher. Winter can also be sunny although daylight hours are reduced to about 8 hours per day on December 21st. Winter temperatures average -11C in January though temperatures can go as low as -30C.

Alberta's climate puts it in the enviable position of having among the highest amount of annual sunlight available in Canada. The available sunlight translates into a solar potential that makes PV technology very viable. Figure 1 shows that an optimally orientated PV array can yield 1100-1400 kWh/kW (of installed capacity) per year, a comparatively high potential. In contrast, cities like Berlin or Tokyo have significantly less solar potential, though they are leading the world in implementation of PV technology. Refer to Table 1 for comparisons to Tokyo, Berlin and other Canadian cites.

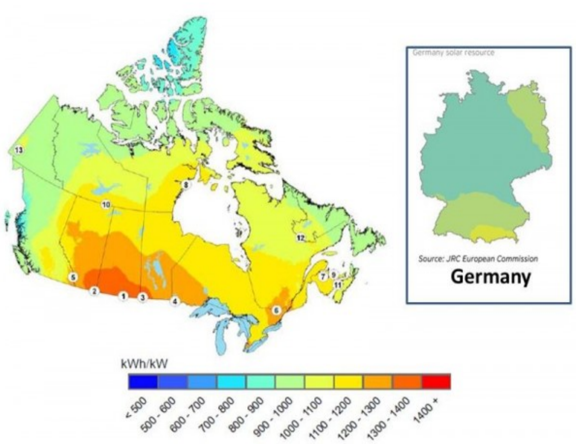

Figure 1 – Map of PV potential – Natural Resources Canada

Municipality	**PV potential** (KWh/kW)
Regina, Canada	1361
Calgary, Canada	1292
Rome, Italy	1283
Winnipeg, Canada	1277
Edmonton, Canada	1245
Montreal, Canada	1185
Toronto, Canada	1161
Vancouver, Canada	1009
St. John's, Canada	933
Tokyo, Japan	885
Berlin, Germany	848

Table 1 – Municipal PV potential – Natural Resources Canada

2.2 Siting of Buildings

For implementing green technology in buildings, the first step is to become familiar with the site. Per Leadership in Energy and Environmental Design (LEED) principles, greenfield sites should be avoided along with development on steep slopes and low lying (potentially wetland) areas. Factors other than typography and hydrology include vegetation, microclimate, design temperatures, wind, precipitation and views (Wilson, 1998). Some of these factors also affect insolation (solar radiation) and solar access. Tall trees or a sharp rise can diminish solar access or the available sunshine that is part of the normally available solar potential.

Orientation of the building to the sun's path is also an important consideration. The sun's path varies throughout the year. In summer, it rises in the north-east and sets in the north-west while rising to a high position in the south sky at mid-day. In winter the path is quite different with a low sun angle at mid-day. Refer to Figure 2. Passive solar principles recommend placing most of the glass toward the south with large overhangs to shield from the high summer sun. East and west glazing can be problematic due to the low early morning or later afternoon sun angles. Most designers will compensate by providing different glazing configurations for different orientations. Low-e coatings are also used to make adjustments for thermal transmittance (U-factor) and solar transmittance (solar heat gain coefficient).

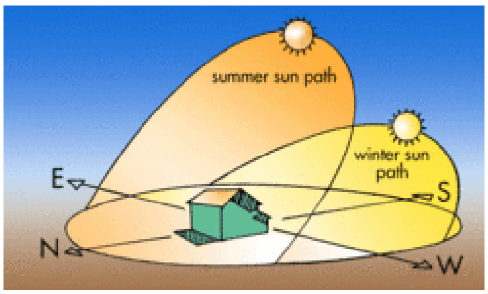

Figure 2 – Illustration of Sun's Path – Building Green

Such factors and considerations are important whether or not solar PV is added as a supplement to the overall facility design. It is important to use good passive design principles, and make the facility as efficient as possible prior to the consideration of adding active efficiencies through renewable sources.

2.3 Structural/Wind Capacity

Wind characteristics for the site and the additional weight of solar PV equipment to be mounted on a building must be taken into consideration as structural variances. Prevailing winds in Alberta are primarily from the west or north-west. However, there are times of the year when consistent winds are from different directions. Location of hills, valleys, other buildings or plantings can all affect the direction and intensity of wind. Data is available from a variety of sources including weather stations, airports or Environment Canada (http://climate.weather.gc.ca/). It is often useful to examine the wind rose of a particular community before confirming the relevant data to be used.

For safety, the involvement of a structural engineer registered in Alberta is also an important aspect of determining the implications of adding solar PV equipment. Per Part 4 of the latest edition of the Alberta Building Code (NRC, 2014), an engineer can determine wind factors and extra load factors to be used. As part of the consideration, many public buildings in Alberta will either belong to the high or post-disaster level of the building's importance category. Per Table 4.1.6.2 of ABC-2014, these categories will significantly increase the allowances needed for load factors. For roof-top applications, consideration of fastening methodologies to the roof while limiting roof membrane penetrations is important for sustaining the design life of the roof.

2.4 Maintenance and Operations

The solar PV industry is expected to keep growing and maturing. With proper operation and maintenance, current life spans of PV installations are expected to be 25 years or more. Some fundamental considerations for operation and maintenance (O&M) include the following:

- It is important that only qualified personnel work on PV installations, since as PV systems evolve there are ever increasing voltages of systems being used.
- Safety is of primary concern when servicing installations. Qualified personnel should work in teams of at least two people when working on live equipment at heights to satisfy OH&S requirements.
- Signage for systems needs to appropriately warn of any proximity risks.
- System uptime and availability is a key objective. Low production impacts return on investment (ROI) so operations and maintenance (O&M) personnel need effective strategies for bringing systems back online quickly (Haney, et al., 2013, p. 4).
- Consideration for snow removal, and cleaning of glass panels and debris.

2.5 Grid Fed Systems

Solar PV systems are most often connected to the utility grid. There are two types of metering arrangements that can be used. The first type is net metering as depicted in Figure 3. When the solar panels are producing more than is consumed locally, the surplus is exported to the grid and the utility meter runs backward. At present, if there is a large net surplus of exported electricity for the year, the utility company does not pay for the surplus, and once a year the accounts are reset to zero.

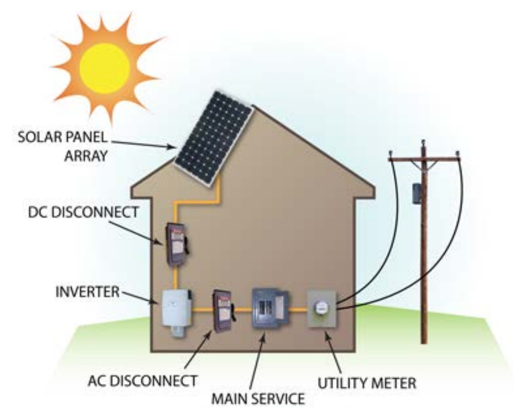

Figure 3 – PV Modules Net Metered Arrangement - Photo credit – Google Images

The second type of metering arrangement is similar to net metering except that two utility meters are used. There is one meter for electricity that is generated and another meter for electricity that is used. The utility company pays for generated electricity at a different rate (often higher) than for consumed electricity that is taken from the grid. These type of contracts, known as “feed-in tariffs, are used to accelerate the adoption of renewable energy technologies” (CMHC, 2016). The Ontario provincial government, for example, began offering such an incentive beginning in 2009.

2.6 Islandable Systems (Energy Storage)

For campus style facilities and particularly ones where at least one building is declared to be at a post-disaster level in the building's importance category, solar powered district micro-grids should be considered. Green researcher Alex Wilson indicates that, "with more intense storms, wildfires, terrorist actions, and other events causing widespread power outages, there is a growing demand for creating islandable microgrids" (Wilson, Dec., 2013). Microgrids are small to medium sized power grids that have the ability to isolate themselves from the regional power grid in the event of a power outage. Universities and larger hospital complexes are natural candidates for such systems. Figures 4 and 5 show a schematic for a district microgrid and an associated modular battery bank.

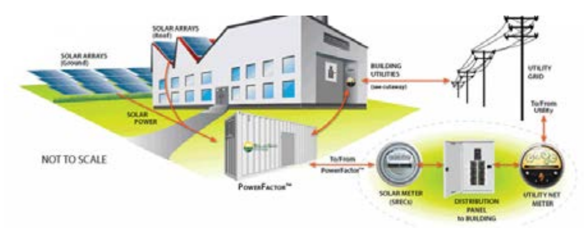

Figure 4 - Islandable microgrid – Photo credit – Solar Grid

Figure 5 – Modular battery bank – Photo credit – Solar Grid

Figure 6 – Inverter panel – Photo credit – Sunny Island

More advanced battery banks now use lithium-ion batteries to avoid the use of heavy metals such as lead and cadmium (Wilson, Dec., 2013). For smaller facilities, an economical inverter like the one pictured in Figure 6 is available that can provide some basic power for day-time use (cell phones and laptop re-charging) when the grid is down. Such a device can avoid the higher costs of developing a standalone off-grid system or an islandable micro-grid. Small remote projects where a traditional electrical service is impractical may use a PV system with modular battery backup (e.g. Tesla Powerwall – https://www.tesla.com/en_CA/powerwall).

2.7 Life Cycle Impacts

PV is not without impacts when the environment is considered. As of 2012, 60% of PV modules manufactured globally originate from China where carbon-intensive fuels are used to generate electricity (Rosenbloom & Meadowcroft, 2014, p. 493). Additionally, the long distance shipping also contributes negatively to the lifecycle GHG emissions. Overall, it makes sense to implement solar PV technology in Alberta where much of the current energy comes from burning coal for electricity, particularly if more local manufacturers and fabricators of arrays for the PV panels can be sourced. An option that can alleviate some of the end of life cycle carbon footprint cost is to require manufacturers to take back the PV modules for re-cycling at the end of their useful life. Refer to 5.2 below for quantification of GHG emissions for solar PV compared to other low carbon options.

2.8 Other constraining and enabling factors

A number of other factors need to be considered. PV technology by nature contains variability and uncertainty. There are daily and seasonal fluctuations in available sunlight. Storage of the energy is of concern because without it, large amounts of energy generated during the day or in summer are of little use at night or in winter. For grid connected systems, fluctuating amounts of production and the stability of the grid are a concern. Fortunately, solar PV generation often correlates well with peak load demand of energy grids (in late afternoon). Electricity rates can be a concern, however. Researchers at Carlton University (Rosenbloom and Meadowcroft, 2014) found that “PV has begun to emerge as a politically contentious topic in relation to its perceived impact on electricity rates” (p. 493). On the positive side, PV does benefit from high levels of social acceptance. Not to be overlooked, a final consideration may include architectural guidelines (form, materiality and fenestration) that must be satisfied for each municipal setting.

2.9 Legal Issues

A University of Calgary study (Krivitsky, 2010) found that “statutory protection of solar rights in Alberta is non-existent”. It is important, therefore, to consider implications of solar rights and “access to direct sunlight in particular” (p. 13). For some properties, it may be appropriate to purchase and establish an easement or a restrictive covenant on an adjacent property, if there are concerns of loss of solar access or views. Krivitsky concludes her study by stressing that, “if the goal of greening the energy mix by increasing the share of renewable energy is to be achieved, a meaningful commitment to such sources must be made and reflected in the regulatory framework” (p. 23).

3. Current Technologies

3.1 Photovoltaics (PV)

Solar photovoltaic (PV) systems are safe, reliable and low maintenance systems that are designed to convert sunlight into electricity. The most basic unit of a PV system is the module which is formed by connecting many individual solar cells. Modules are then attached side-by-side to form an array. For low profile applications, the arrays are often one row high but can be higher depending on the space and configuration (shape) of supporting surface available. Refer to Figure 7.

Each module is capable of producing about 200W of power when the sun is shining. The solar array is connected to an inverter that converts direct current (DC) to alternating current (AC). The AC can be used directly by the facility or exported through the utility meter to the power grid.

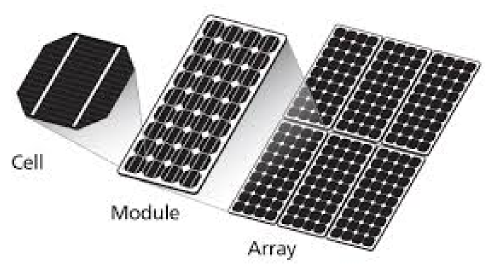

Figure 7 – PV Modules – Photo credit – Google Images

3.2 Building Integrated Photovoltaics (BIPV)

Figure 8 – Integrated PV – UofA Isotope Centre - Photo credit – V. Solbak

Building integrated photovoltaics (BIPV) is an emerging technology that shows promise to generate energy while providing shelter. An Alberta example is the curtainwall glazing at the University of Alberta Isotope Centre. Refer to Figure 8. Photovoltaic vision glass integrates a thin-film translucent panel directly between the layers of glass as part of regular glazing. The BIPV can also be incorporated onto the opaque portions (or the spandrel panels) of curtainwall glazing.

There are a few advantages of this technology compared to PV. The first is the improved aesthetics compared to placing PV panels in rows on the roof of a building. A second advantage is the dual purpose for materials where BIPV can be integrated; it can be a supplanted part of the building envelope while producing energy. A third advantage is the widespread array of materials that can incorporate the BIPV technology; use can be for windows, claddings, canopies, façades and roofing materials (SolarServer, 2016).

3.3 Solar Thermal

Solar thermal involves using a piping system arranged in an array to collect the energy from the sun. As the liquid in the piping is heated, it is circulated through the system to heat hot water. For decades it was assumed that the greenest way to heat hot water was using this method. As PV equipment became cheaper and heat-pump water heaters became widely available (Holladay, March, 2013), solar thermal began to decline as an efficient harvesting method. On a summer day, one can heat a lot of hot water on a day when it isn't needed. Since the heat from the water cannot be stored for future use, the energy may be wasted. In winter, the system may not produce enough hot water unless supplemented by other systems. Compared to a solar PV system, the solar thermal system has several disadvantages as follows:

- Most solar thermal systems have moving parts (pumps and solenoid valves) that require frequent maintenance
- Solar thermal systems are less adaptable than BIPV for integrating into window configurations or roofing materials (refer to Figure 9 – integrated panels at U of A)

Figure 9 – Integrated solar panels – PAW Building, University of Alberta

- In freezing climates, solar thermal systems require antifreeze additives (glycol) to prevent freezing
- Frequent maintenance is needed including antifreeze replacement, and
- Solar thermal systems have lower life expectancies than PV (Holladay, March, 2013).

3.4 Passive Solar Heating

Passive solar heating strategies have a number of efficiencies, particularly when they can be incorporated into the design of a building. Some related practical measures that can be incorporated include a solar wall (exterior) and a Trombe wall (interior). The exterior solar wall uses a dark cladding material on south facing elevations in front of an air space. As the air space heats up the warm air rises in the cavity and is harvested to the interior of the building. Refer to Figure 10. The Trombe wall is located on the interior side of south facing glass. The wall heats up during the day and radiates the heat back into the interior of the building at night. Refer to Figure 11. A disadvantage of this methodology is a time lag of up to 12 hours before the heating is effective. In practice these have been mostly suited to residential and small scale applications where the resident actively controls the systems.

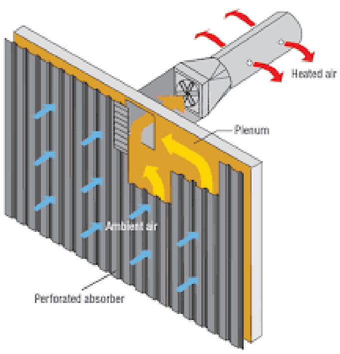

Figure 10 – Solar wall schematic – Photo credit – Google

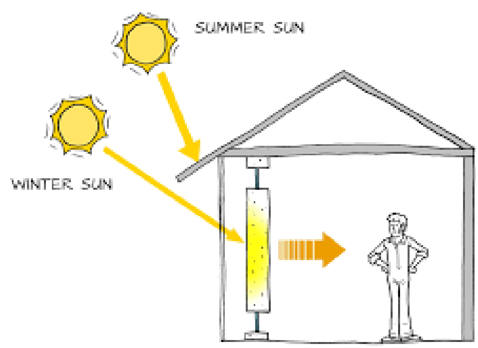

Figure 11 – Trombe wall schematic – Photo credit - Google

4. Feasibility and Applications

4.1 New Construction

While there are a number of planning considerations to grapple with, construction of new buildings is an ideal place to implement solar PV technology. Many new public buildings have a near flat roof for mounting PV arrays. Other applications of the technology can include integrated panels in window configurations or as practical sunshades on the building such as the Child Development Centre at the University of Calgary. Refer Figure 12.

Figure 12 – Child Development Centre – University of Calgary

Along with currently mandated measures (LEED – Silver) and legislated standards (NECB-2011), it seems a logical goal to pursue net-zero GHG emissions for applications where solar PV technology is incorporated. The technology is applicable to all building types.

4.2 Existing Buildings

Solar PV technology is applicable to all building typologies whether a school, hospital, government office building, courthouse or cultural facility. Existing buildings represent a daunting challenge because they are responsible for a high proportion of existing GHG emissions in Alberta (as high as 40% in some studies). In this context, consideration of existing levels of efficiencies should be a beginning step. Upgrading and retrofitting of existing buildings will ideally include a modernization of the building envelope to reduce air leakages and increase insulation efficiencies. Before proceeding it is best to know the measureable benchmarks and ongoing operational parameters for a proper understanding of the building's weaknesses. Once implemented, the measure can then allow a down-sizing of any contemplated solar PV system compared to an equivalent sized efficient building.

4.3 Supported and Senior's Housing

Supported and senior's housing lends itself to a more domestic scale and building typology. Many of the principles outlined above for passive solar principles will be more easily applied to this building type. There may be other innovations needed to incorporate solar PV if the buildings incorporate pitched roofs. One possibility is to blend integrated PV cells into the roofing materials. Another innovative idea is to use PV arrays for covered parking. This will have the double benefit of providing superior access for barrier free stalls (protection from rain and snow) while producing energy for the project. Refer to Figure 13.

Figure 13 – Covered parking with Solar PV array

4.4 Prioritizing Applications

In moving forward, the current GoA's LEED mandate along with the newly adopted National Energy Code of Canada for Buildings (NECB-2011) (NRC, 2011) will greatly assist in ensuring that future buildings meet a higher level of efficiency. A practical consideration for prioritizing which buildings merit early implementation of solar PV configurations is as follows:

- LEED certified buildings that are net-zero ready (includes PV rough-ins to the roof)
- All other LEED certified buildings
- Recently modernized buildings that include building envelope efficiency upgrades

5. Cost Considerations

5.1 First Costs

First costs for PV have steadily been coming down over the last few decades. According to researchers, each solar PV module each produces about 200 watts of power. A typical commercial PV configuration now costs under $1.00 per watt (Rosenbloom & Meadowcroft, 2014, p. 489). For this study, $3.00 per watt is used to allow for supply and soft costs such as installation and permitting. Assuming that a typical configuration could involve as many as 200 modules in an array, the net cost of such an installation is [200Wx$3.00/Wx200=] $120,000. For a total construction cost, add 18.5% for a general requirements allowance, 10% for design allowance and 7% for construction allowance. Total construction cost (first cost) is [$120,00x1.355]= $ 162,600 per project (based on an average project size of 200 modules).

In the Edmonton region, the solar potential is 1245 kWh/kW [per Table 1]. The proposed configuration could generate [1245 kWh/kW x 40.0kW=] 49,800 kWh per year. This renewable energy generation would save about [49,800 kWh/year x $0.17/kWh =] $ 8,466/year in power costs alone at today's costs. These savings do not factor in the advantages of improved health and a cleaner environment, where society can expect to significantly benefit from widespread implementation of PV.

5.2 Life Cycle Costs

Rosenbloom & Meadowcroft indicate that depending on sourcing, PV may "suffer from higher lifecycle impacts than other low-carbon sources" (p. 493). Refer to Table 2. The researchers clarify this by explaining, "while PV systems produce marginal GHG emissions during operation (some emissions stem from maintenance and inverter replacement, for instance), silicon purification and cell production are energy intensive processes that can have substantial carbon footprints depending on the local energy mix". In summary, although PV is slightly more GHG intensive than other low-carbon options, it is a superior option compared to carbon intensive technologies.

Energy Source	**Grams of CO2 Equivalent Per kWh** (range)
PV	
PV: (Study 1)	1 - 218
PV: (Study 2)	5 - 217
Selected low-carbon technologies	
Hydroelectricity	0 - 43
Geothermal	6 - 79
Tidal	2 - 23
Wind	2 -81
Nuclear	1 - 220
Natural gas (w. carbon capture & storage)	65 - 245
Coal (w. carbon capture & storage)	98 - 396
Selected carbon intensive technologies	
Natural gas	290 - 930
Coal	675 - 1689

Table 2 – Estimates of Lifecycle GHG emissions for selected energy sources – (Rosenbloom et al., 2014).

5.3 Return on Investment (ROI)

Using the estimates from First Costs above for the given scenario, a per project savings of $ 8,466/year can be realized with an investment of $ 162,600. The payback and Return on Investment (ROI) calculations results as follows:

Payback = Investment / Savings per year = $ 162,600 / $ 8,466 per year = **19.0 years**.

ROI (in percentage) = $\frac{\text{[Gain from investment – Cost of investment] x 100\%}}{\text{Cost of investment}}$

Or equal to $\frac{\text{[Savings over the life of the change – Capital cost of the change] x 100\%}}{\text{Capital cost of the change.}}$

Note: It is assumed that the PV modules have an expected trouble-free design life of 25 years.

Therefore, ROI = $\frac{\text{[25 years x \$8,466/year] – [\$ 162,600] x 100}}{\text{\$ 162,600}}$ = 30.2% (a positive return)

Return on investment for the provided scenario = 30.2% (considering financials only).

6. Outcomes

6.2 GHG Reduction

A Natural Resources Canada study (Pelland & Poissant, 2006) reveals that buildings account for over 50% of electricity end use and over 30% of total energy end use. Since solar PV systems generate no emissions during operation and little overall during their complete life cycle, there is a huge potential to reduce GHG emissions by adopting this technology on a wider scale. The study looked at “what fraction of electricity demand it can supply, and what greenhouse gas emissions it can avoid” (p. 1). It was discovered that for commercial and institutional buildings, the total PV electricity generation potential is about 15-17% of electricity use. Since Alberta has a higher solar potential than most other Canadian provinces, it can be implied that Alberta’s potential will be at least this high. At the per building scale, the potential corresponds to about 82 kW per building. “For greenhouse gases, this installed capacity would lead to reductions of about 6.5 Megatonnes per year, or about 16 tons per building” (p.5). An Environmental Protection Agency (EPA) greenhouse gas equivalency calculator estimates this is equivalent to a passenger car driving 24,762 less km per year. Each building that can be designed or retrofitted to incorporate 200 modules of solar PV is equivalent to taking 1.4 cars off the road each year.

6.3 Measurement and Reporting

An important consideration for the implementation of solar PV is to measure the energy use changes. Measurement and verification (M&V) of energy usage can bring many benefits to a building project or retrofit of an existing building. Historically, M&V focused on measuring the differences in energy usage when new energy efficient equipment replaced old equipment. The green design community, however, is learning that there are many other benefits. M&V can find anomalies in systems, problems that might have gone unnoticed, and can even find opportunities for greater efficiencies when systems are operating as intended (Boehland, 2006). Knowing that M&V is being incorporated into a building also helps designers focus on how the building will be operated (Boehland, 2006). After commissioning the modelled design, M&V verifies the commissioning process and continuously looks for design improvements. It is essentially a tool that gives feedback and allows for proper and responsible management of a facility. An obvious benefit of M&V is a reduction in utility consumption. An indirect benefit is that it extends the life of equipment and building systems by early detection of problems, allowing timely repairs.

M&V brings transparency allowing the owner to quantify and publicize the emission reductions that result from measures related to renewable energy and building efficiencies. “Laws mandating energy use disclosure are gaining steam in the U.S. as more cities and states seek to leverage these transparency requirements to drive energy savings and job creation” (Malin & Roberts, 2012). In Canada, the municipalities of Toronto and Vancouver are becoming leaders in introducing energy reporting legislation. In this regard, energy reporting (benchmarking) can pick up where codes that mandate energy efficiencies leave off. It is hoped that disclosing energy performance of existing buildings will lead to voluntary changes in behavior, particularly if that disclosure is made available when buildings are sold or leased.

Figure 14 – Example of interactive dashboard – Photo credit – Delta School District

Another feature that can affect behavior is energy dashboards. A growing number of products are becoming available that can display energy usage on a dashboard in a public lobby. Dashboards that are interactive and user friendly can be informative and educational. For example, a dashboard can be related to a known scope of comparable size, like “site lighting”, demonstrating gains or losses against that demand. Refer to Figure 14.

6.4 Teaching Opportunities

The incorporation of solar PV technology into public buildings provides teaching opportunities at several levels. In schools, the PV panel arrays provide a convenient tangible display of science in action. For the past several years, the Canada Green Building Council has sponsored the “Greenest School in Canada” competition (CaGBC, 2016). The program is designed to encourage the design of better schools for children that feature fresh air, natural light, sustainable low toxic materials, improved acoustics and programs that encourage environmental literacy. Some characteristics of a green school that can be enhanced by solar PV include:

- Conserves energy and natural resources

- Saves taxpayer money
- Employs sustainable purchasing
- Improves environmental literacy in teachers, students and their communities.

The science of how the solar PV systems work, how they are connected to the grid, and how the environment benefits, can all be taught using easily accessible physical examples of the systems. If dashboards are incorporated, there is data available that can be used for teachable moments or can be linked with curriculum.

6.5 Economic Diversification

Increasing renewable energy has the potential to create many direct jobs in designing systems, manufacturing, sales, purchasing, transporting, installing and servicing. There is also the ripple effect where industries in the supply chain will indirectly benefit. Local unrelated businesses will also benefit from increased household and related business income.

A consultant's study done for CanmetENERGY in Ontario (Navigant, 2012) revealed that for the level of activity taking place in Ontario in 2011, 5143 full time equivalent jobs were provided. These can be grouped into skill sets such as manufacturing trades, manufacturing engineers, management and overhead, construction trades, civil engineers, electrical engineers, permitting consultants and sales. The study found that the largest needs are for manufacturing trades and construction trades. In both of these groups there is an upfront need for specialized training.

6.6 Improved Health

A new Harvard study (Buonocore, et al., 2016) found that there are substantial health and climate benefits for implementing energy efficiency/renewable energy (EE/RE) technologies to displace emissions of greenhouse gases. The study found that there are health benefits worth millions of dollars in the Mid-Atlantic and Lower Great Lakes region of the United States for each project that displaces a coal-fired electrical generation plant.

Figure 15 – Renewable Energy – Photo credit – iStock

The researchers "developed an assessment tool that calculated the public health and climate benefits of renewable or energy efficient installations. . . Depending on the project type and location, the benefits ranged from $5.7 to $210 million per year" (p. 101). For example, they found that a wind installation near Cincinnati was twice as beneficial as one in Virginia, based primarily on Cincinnati's larger downwind population and greater reduction in coal-fired electricity. Refer to Figure 15. The study is significant in that it finds a positive correlation between public health and EE/RE implementation. It may also be important for making policy decisions about where projects can have the greatest impact.

7. Conclusion

Alberta is in the position of having a climate that has among the highest amount of annual sunlight available in Canada. The available sunlight ensures a large untapped solar potential that makes PV technology very viable. Unlike some provinces that have a high availability of hydroelectricity, Alberta currently relies heavily on coal-fired plants for generating power. The concern with these plants is the resulting high GHG emissions. Some benefits of providing a portion of power needs by means of solar PV include increased resiliency, improved efficiency of public buildings with resulting lower operating costs, teaching opportunities, lowered GHG emissions, economic diversification and improved health.

The research conducted for this study finds that the benefit of incorporating solar photovoltaic (PV) technology into public buildings as a source of renewable energy far outweighs the concerns. As the Government of Alberta looks to implement its Climate Leadership Plan, the strategy of considering PV as one measure for a replacement energy alternative, has great potential and can be considered validated. While there are other low carbon options, PV is one measure that can be implemented easily on a project by project basis, at relatively low costs with low risk and no direct GHG emissions.

8. References

Boehland, J. (June, 2006). Measurement and verification: Monitoring building systems for optimal performance. *Environmental Building News / Building Green, Volume 15 (6).* Retrieved from: https://www2.buildinggreen.com/article/measurement-and-verification-monitoring-building-systems-optimal-performance

Buonocore, J.J., Luckow, P., Norris, G., Spengler, J.D., Biewald, B., Fisher, J., & Levy, J.I. (January, 2016). Health and climate benefits of different energy-efficiency and renewable energy choices. *Nature Climate Change. doi:10.1038/nclimate2771.* Retrieved from: http://www.nature.com/nclimate/journal/v6/n1/full/nclimate2771.html

CaGBC. (2016). What is a green school? *Canada Green Building Council.* Retrieved from: http://www.cagbc.org/CAGBC/Programs/CanCoalitGrSchls/What_is_a_Green_School_/CAGBC/Programs/CanCoalitGrSchls/What_is_a__green__school_.aspx?hkey=09193dba-1842-4b5c-b4c2-0bb849892e73

CMHC. (2016). Photovoltaic (PV) systems. *Canadian Mortgage and Housing Corporation.* Retrieved from: http://www.cmhc-schl.gc.ca/en/co/grho/grho_009.cfm

Dodge, D., & Kinney, D. (November, 2015). Canada's first municipal solar tariff. *Green Business Canada, (11)*. Retrieved from: http://businessofgreen.ca/023-canadas-first-municipal-solar-tariff/

GoA. (2016). Ending coal pollution. *Alberta Government*. Retrieved from: http://www.alberta.ca/climate-coal-electricity.cfm

Haney, J., & Burstein, A. (August, 2016). PV system operations and maintenance fundamentals. *Solar America Board for Codes and Standards Report.* Retrieved from: http://www.solarabcs.org/about/publications/reports/operations-maintenance/pdfs/SolarABCs-35-2013.pdf

Holladay, M. (March, 2012). Solar thermal is dead: It is now cheaper to use photovoltaic system to heat hot water. *Green Building Advisor.* Retrieved from: http://www.greenbuildingadvisor.com/blogs/dept/musings/solar-thermal-dead

Krivitsky, J. (July, 2010). Solar rights and renewable energy in Alberta. *University of Calgary / Canadian Institute of Resources Law.* Retrieved from: http://prism.ucalgary.ca/bitstream/1880/47976/1/SolarOP31w.pdf

Malin, N., & Roberts, T. (August, 2012). Energy reporting: It's the law. *Environmental Building News / Building Green, Volume 21 (8).* Retrieved from: https://www2.buildinggreen.com/article/energy-reporting-its-law

McKitrick, A.(February, 2016). Promote solar energy strategies. *Sherwood Park News, February 18, 2016.* Retrieved from: http://www.sherwoodparknews.com/2016/02/18/promote-solar-energy-strategies

Navigant. (March, 2012). Sector profile for solar photovoltaics in Canada. *CanmetENERGY / Varennes Research Centre.* Retrieved from: http://www.cansia.ca/uploads/7/2/5/1/72513707/sectorprofile_solarphotovoltaicscanada.pdf

NRC, (2011). National Energy Code of Canada for Buildings - 2011 (*1st edition*). *National Research Council*. Ottawa, Ontario.

NRC. (2014). Alberta Building Code - 2014 (*9th edition*). *National Research Council, Volume 2*. Ottawa, Ontario.

Pelland, P., & Poissant, Y. (August, 2006). An evaluation of the potential of building integrated Photovoltaics in Canada. *Natural Resources Canada.* Retrieved from: http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/2006-047_OP-J_411-SOLRES_BIPV_new.pdf

Rosenbloom, D., & Meadowcroft, J. (August, 2014). Harnessing the sun: Reviewing the potential of solar photovoltaics. *Elsevier / Renewable and Sustainable Energy Reviews, 40*. Retrieved from: http://www.sciencedirect.com.libezproxy.nait.ca/science/article/pii/S1364032114005875

SolarServer. (2016). Building integrated photovoltaics: An emerging market. *SolarServer / Global Solar Industry Website.* Retrieved from: http://www.solarserver.com/solar-magazine/solar-report/solar-report/building-integrated-photovoltaics-an-emerging-market.html

UofA. (2016). Renewable energy. *Campus Sustainability Initiative / University of Alberta.* Retrieved from: http://www.sustainability.ualberta.ca/en/CampusInitiatives/Energy/RenewableEnergy.aspx

UofC. (2016). Centre for advanced solar materials. *University of Calgary.* Retrieved from: http://www.solar.ucalgary.ca/research

Wilson, A. (March, 1998). Getting to know a place: Site evaluation as a starting point for green design. *Building Green, Volume 7,* (3). Retrieved from: https://www2.buildinggreen.com/article/getting-know-place-site-evaluation-starting-point-green-design

Wilson, A. (December, 2013). Solar-powered microgrids could protect us from power outages: Energy Solutions. *Building Green*. Retrieved from: https://www2.buildinggreen.com/blogs/solar-powered-microgrids-could-protect-us-power-outages