Renewable Energy Strategies for Communities in Alberta

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Photo credit – Environmental Design + Construction / April, 2014

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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. Several forms of renewable energy generation could play an important role in Alberta, and include wind power implemented in the context of a wind farm, solar PV at the scale of a solar farm, and geothermal in combination with heat pumps. This paper focuses primarily on the use and merits of these three forms of renewable energy in the context of Alberta communities.

Alberta has experienced an upsurge in wind power use over the last two decades and now ranks third in Canada for overall use. Wind farms have excellent potential for expansion in the Alberta market, particularly in the southern prairies and foothills regions. Careful wind turbine siting is essential to installing a successful wind farm and must account for the direction of prevailing winds, the height of nearby obstacles (including trees), and access to a distribution network and major roadways. Solar farms also have excellent potential, given Alberta's higher solar potential compared to other regions in Canada, but have been slow to take off. Finding appropriate land for community based solar farms may be the biggest challenge of a successful development – but does present an opportunity to utilize marginal land and consequently pursue biodiversity enhancements on the site (e.g. planting of appropriate native species). A geothermal heat pump (GHP) operates by using electricity to drive a compressor that moves thermal energy between the earth and the conditioned space. For geothermal potential, Alberta compares favourably with countries that have a high implementation level of the technology (e.g. Japan, Iceland, and Norway). However, geothermal heat pumps require electricity to operate, which can negate these systems' overall environmental benefits if the electricity isn't supplied from a renewable source.

While strategies for various renewable energy systems can be easily incorporated into new construction, they may be optimally suited for planned new communities and new campus style applications (e.g. Edmonton's Blatchford Community). Geothermal in particular has synergies with district energy systems and can be used in shared applications for whole districts. Pooling resources between projects or creating community solar farms has the potential to make it more widely accessible by allowing customers with site limitations to purchase a portion of the photovoltaic array or directly purchase the green power. In this way, an existing community can supply its energy requirements from renewable sources. At more remote locations, industrial, forestry and agricultural applications are possible where the technologies can take advantage of economies of scale. Applications could include wind or solar farms in combination with the Alberta oil sands projects, other oil and gas sites, pulp and paper mills, or large farms.

Definitive costs for renewable energy systems are difficult to determine because there are so many variables within each system. However, using initial capital costs, payback and return *on investments can be estimated. For example, an investment in a single 2.0MW turbine wind farm at $4.5M could provide a payback in 4.7 years. An investment in a 10MW solar farm at $3.54M/MW in the Edmonton region could provide a payback in 18.3 years and a return on investment of 136%. There are too many site-specific variables to quote capital costs for commercial GHP systems. However, for comparison purposes, the first costs for a typical home are in the order of $20K to $30K with a payback between 4 to 20 years.*

The environmental benefits of wind farms, solar farms and geothermal heat pump systems include emissions-free electricity production, no air contaminants or toxic pollutants, and significant GHG emissions reduction. These renewable energy sources could also contribute to several economic benefits including industry and employment growth in these sectors, the utilization of repurposed land, and existing provincial industry expertise (particularly for wind farms). However, these energy sources are not without their drawbacks and challenges. Wind farms, solar farms and GHP systems have high first costs, limited design life, and may not create many direct long-term jobs. Moreover, there are challenges related to financing, negotiations and cooperation with utility companies, legal implications and insurance. Wind and solar farms require balancing power grids to deal with fluctuations in intermittent energy production, require large land spaces, and can potentially impact wildlife (though impacts to wildlife are limited, especially compared to more energy intensive activities such as manufacturing, mining and forestry).

The use of renewable energy sources such as wind, solar and geothermal can provide long-term cost savings, reduce GHG emissions, and contribute to diversifying Alberta's energy markets. Though harnessing the energy generation power of the sun, wind and the earth is not without its challenges and drawbacks, careful planning within Alberta communities can contribute to positive overall results. Incentivizing renewable energy generation industries will respond to the Government of Alberta's 2016 Climate Leadership Plan by reducing greenhouse gas emissions, creating jobs and growing the renewable energy industry, and increasing public awareness of renewable energy technologies.

1. Introduction

1.1 Context

In June 2016, the Government of Alberta introduced a Climate Leadership Plan with a strategy that includes two initiatives: major reductions in greenhouse gas emissions (GHG reduction), and ending pollution from coal-fired electricity generation (GoA, 2016). As part of the implementation of these two initiatives, the use of renewable energy in a variety of forms becomes an important consideration and strategy for supplementing energy needs within communities. The first form of renewable energy that could play an important role in Alberta is wind power and particularly when implemented in the context of a wind farm. “Wind power has become the world’s fastest growing energy resource, partly because of advances in technology and its reputation as a cost effective energy resource” (Benitez et al., 2008). A second form of renewable energy that shows promise for the future is solar PV at the scale of a solar farm. Solar PV for individual buildings is commonly used and recognized, but solar farms (or community solar) remains largely an unknown commodity with an unrealized exergetic (or higher quality energy) capacity. A third form of renewable energy is geothermal in combination with heat pumps. While “high and medium temperature thermal resources are often deep within the earth” (Self et al., 2013) and more costly to extract, heat pumps can allow low temperature thermal energy to be easily captured and practically used. This paper will focus primarily on the use and merits of these three forms of renewable energy in the context of Alberta communities. The study will examine applications of the technologies for expanded use in the public realm, what advantages can be gained and what constraining or enabling factors need to be considered.

1.2 Energy Planning at the Community Level

An emerging trend in Canada is for communities to become more involved in energy plans for their regions. “A desire to reduce greenhouse gas emissions and to become more energy self-sufficient is driving this change” (St. Denis et al., 2009, p.2088). In the past, many decisions and options were left to the individual customer and planning was done by regional utility companies. The focus is now shifting towards three ways to more effectively use and “manage energy systems: energy efficiency, energy conservation and the switching of energy sources to renewables” (Jagoda, et al., 2011). Energy efficiency can simply be defined as “the useful energy output divided by the total energy input” (St. Denis et al., 2009, p.2089). The goal is to reduce as much waste as possible on the input side of the input/output equation. Energy conservation is defined as “any measure made to reduce the amount of (high expenditure) energy that is demanded to provide goods or services” p.2089). In one sense, conservation is related to renewable energy because the switching of sources to local renewables helps to ensure less impact on the environment. This paper will concentrate on exploring and analyzing the benefits that can be realized by adopting wider use of renewable energy. While energy efficiency and conservation is recognized as less expensive and easier to deploy than developing new energy supplies, a more holistic approach is to explore the full spectrum of strategies that can be used to move communities towards energy self-sufficiency. By doing so, the triple bottom line of economic, environmental and social benefits can be realized with the least possible harm to the environment.

1.3 Historical Context in Alberta

Alberta has experienced an upsurge in wind power use over the last two decades. “Wind energy is an established and growing player in the electricity market . . . generating over four percent of Alberta’s electricity” (Canwea, 2016). The first commercial wind farm was installed at Cowley Ridge in southern Alberta in 1993. In the last 23 years, wind energy has grown significantly to the point where the province ranks third in Canada with an installed capacity of 1,500MW (refer to Figure 1). “Excellent wind resources are found along the western border of southern Alberta, in the foothills of the Rocky Mountains, with good resources (also) available across the rolling hills and prairies of southern Alberta” (Ferguson-Martin et al., 2011, p. 1648).

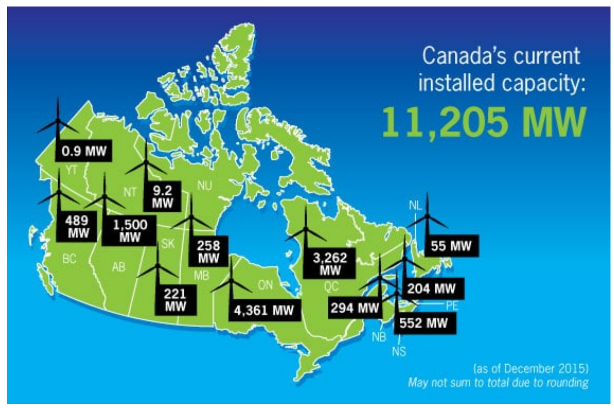


Figure 1 – Canada’s 2015 Installed Wind farm capacity-Photo credit – Google.

By contrast, “community based solar farms have long had the potential to make PV more accessible, but the practice has been slow to take off” (Ehrlich, 2014). In Alberta, there are only a handful of examples of community solar to date (refer to Figure 2). For many people, even if they are motivated to install solar, there are barriers to installation that include lack of roof space or available land, the right site, and/or the right orientation. Other challenges include regulations, budgets, financing, and navigating the regulations or demands of utility companies. To help counter some of these hindrances there is an incentive program administered by the Alberta Government, called “Growing Forward 2” that is designed to “increase industry competitiveness, improve environmental stewardship, and improve energy management” (Growing Forward 2, 2016). The program is geared specifically to improving energy efficiency on agricultural farms.

Figure 2 – Southern Alberta solar farm at Brant Hutterite Colony - Photo credit –Google

A final consideration of renewable energy in Alberta is geothermal. Direct use of geothermal energy is one of the oldest forms of utilizing geothermal energy. An example of geothermal in action using a high temperature resource includes the mineral hot springs at Banff, however, the high and medium temperature resources in Alberta are primarily limited to deep depths in geologically active areas. The best potential for these are in the western half of the province, particularly around the Edson and Grande Prairie regions. Nevertheless, a growing awareness of ground-source heat pumps has made it practical to utilize lower temperature ground water at much shallower depths. The viability of growing this application for wider use in Alberta hinges on making higher quality (clean) electricity available since the ground-source heat pumps do require a significant electricity draw. “In general, ground source heat pumps provide the largest emissions reductions relative to conventional heating devices. . . when the electricity used by the heating pumps is derived from environmentally benign power plants” (Self et al., 2013, p. 348).

2. Planning and Technical Considerations

2.1 Alberta’s Climate and Geography

Alberta is located between 49 and 60 degrees latitude and is mostly in climate zone 7, a zone that is described as very cold. Overall, the requirement for cooling in Alberta is much less than for heating. However, natural day-time heat build-up in the summer and shoulder seasons does make it necessary to provide cooling in public buildings. Wind farms have excellent potential for expansion in the Alberta market, particularly in the southern prairies and foothills regions. Solar farms also have excellent potential, given Alberta’s higher solar potential compared to other regions in Canada. For geothermal potential, Alberta compares favourably with northern European countries, along with Iceland and Japan, countries that have a high implementation level of the technology. One drawback for operating geothermal heat pumps is the lack of hydro power for economical, clean power. Geothermal can become more and more viable as other renewable sources of energy are developed.

2.2 Siting / Planning of Wind Farms

Careful wind turbine siting is essential to installing a successful wind farm. “A wind turbine must be mounted in a good wind site, well above ground clutter, in the strongest, smoothest winds” (Chiras, 2012). The direction of prevailing winds must be determined so that the turbines can be faced optimally perpendicular to the wind’s most predominant direction. It is helpful to obtain a wind rose for a particular region in order to understand the percentage of wind from each direction in a graphical manner. In an open site, the entire rotor should be located a minimum of 10m above the highest obstacle within a 150m radius. If trees are present, the mature height of the trees needs to be allowed for. Good designs for wind towers will exceed the minimum height requirements and be rewarded with improved performance (refer to Figure 3). In the past decade, most installed wind power has been with increasingly larger turbines, with some reaching 90-125m heights where the winds are significantly greater. Another advantage to the larger turbines is that blade speeds are slower. “Bird fatalities from today’s MW-scale wind turbines are very low” (Buildinggreen, 2016). Distances between turbine towers are variable and depend on the height of the tower and complexity of the landscape. Towers can be as close to each other as 500m or as far apart as 1 km.

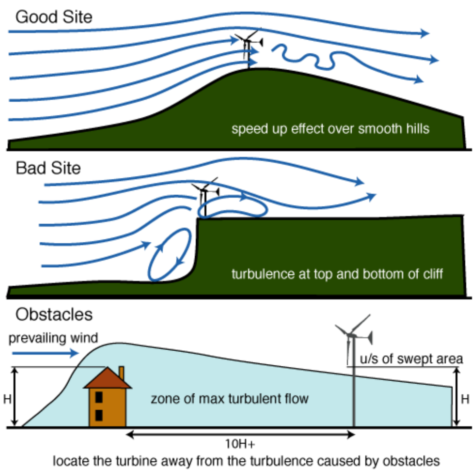


Figure 3 – Wind Farm Siting - Photo credit – Google

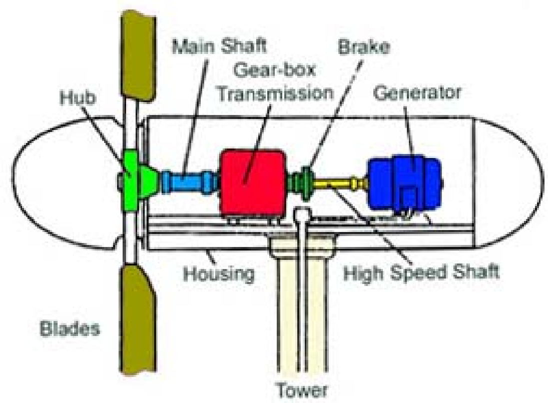


Figure 4 – Wind Turbine - Photo credit – Google

Wind power converts the kinetic energy of the wind to generate electric power. As the wind passes the turbine, the force of the wind turns a large propeller that usually has three blades. The hub of the propeller is connected mechanically via a gear-box to a generator. The generator uses the turning motion of the shaft to drive a rotor that along with oppositely charged magnets and copper wire loops, creates DC electricity (GoldPower, 2016) (refer to Figure 4).

To be able to distribute electricity from wind, there needs to be a distribution network. Ideally, the wind farm is located close to a transformer sub-station that ties into a grid. This is not always convenient, as wind farms are often located in remote areas away from major development. The overall cost of the project escalates as the distance between the wind farm and the nearest sub-station increases. Access to major roadways is an important consideration because of the size of the equipment that is transported to the site. The impact of service roads to each tower also needs to be factored into overall costs (refer to Figures 5 and 6).

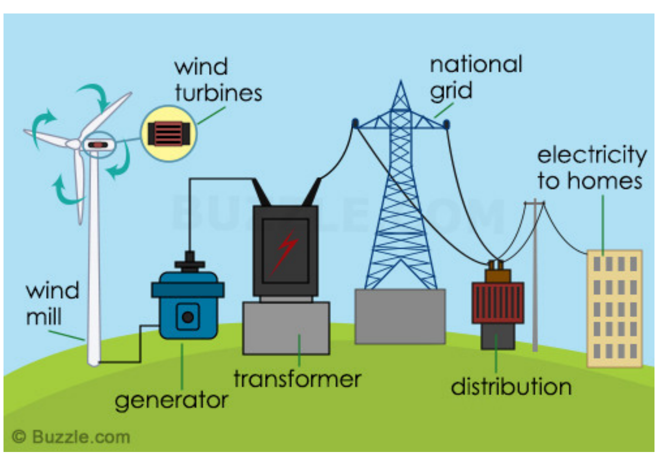


Figure 5 – Wind Farm Distribution Network - Photo credit – Google

Figure 6 – Wind Farm in Central Alberta - Photo credit – Google

2.3 Siting / Planning of Solar Farms

Pooling resources between projects or creating community solar farms has the potential to expand the benefits of photovoltaic (PV) by making it more widely accessible. It allows customers with site limitations to purchase a portion of the PV array or simply to directly purchase the green power. Challenges can include complying with provincial or local regulations, financing, insuring systems, navigating the demands of co-operating utility companies, and managing customer billing (Ehrlich, 2014).

Finding appropriate land for community based solar farms may be the biggest challenge of a successful development. Renewable energy (RE) systems of this nature are land intensive. “An integrated approach to land-use and energy planning, or land-energy planning, can help to ensure that RE technologies can be intensively implemented while minimizing negative impacts” (Calvert & Mabee, 2015, p. 209). Ontario has several examples of successful solar farms and identifies appropriate parcels of land as “mutual land”. “Mutual land is located using GIS-based land-suitability modeling and map overlay techniques” (p. 209). Parcels designated as mutual land generally try to avoid using prime agricultural land (classes 1-3) that is more suitable for food production, as well as forested land. Rather, marginally productive land (classes 4-6) is sought that can be reverted back to its original purpose if a farm is eventually decommissioned. Benefits of using marginal land include the following: diversification from traditional farming practices is welcomed by owners of low quality land, significantly higher energy densities can be achieved compared to alternative energy uses (particularly if comparing to energy crops), and there are lower installation costs relative to rooftop solar PVs (Calvert & Mabee, 2015).

Figure 7 – Solar Farm and Biodiversity - Photo credit – Parker & McQueen.

A synergy that can occur with a solar farm and nature is to combine the benefits of the renewable energy produced from the panels with pursuing biodiversity at the site. A study in the UK found that if the land was planted with a wild flower mix prior to installing the PV panels, that significant benefits can be realized (Parker & McQueen, 2013) (refer to Figure 7).The results can be maximized through careful planning and managing. Although wild-flower meadows are just one component of several potential habitats that can be enhanced or created on a solar farm, the benefits include the following:

- Suitable conditions are provided for grassland herbs, bumblebees and butterflies and a wide range of natural species including birds, mammals and invertebrates.
- Compatible secondary uses could include bee keeping or low density sheep farming.

- The meadows can remain relatively undisturbed after the initial planting. Lengthy periods of time (without disturbances) can allow land management practices to become well established.

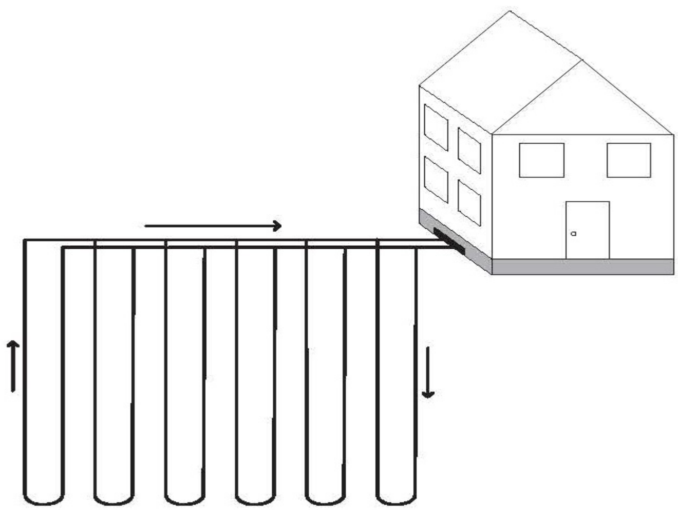
- The planting of appropriate native species will reduce the risk of weed colonization, particularly if bare areas are re-sown without delay once identified.

- Sites with biodiversity enhancements result in improved overall aesthetics of the solar farms.

2.4 Geothermal Heat Pumps and Considerations

Geothermal heat pump (GHP) systems are considered to be a renewable energy source because they can "provide heat efficiently and economically with low emissions" (Self et al., 2013). Low temperature geothermal resources are widespread and can be extracted and used in most locations around the world. "GHP systems utilize the earth or bodies of water as both a source of and a sink for the energy needed to heat and cool buildings and to heat water (Huttrer, 1996). Polythene pipes are placed in continuous loops in vertical boreholes, horizontal trenches or at the bottom of surface water bodies. Fluid in the piping, often a non-freezing type of refrigerant, is circulated throughout the loops and past fan coils or radiating tubes to give off heating or cooling. The fluid is then discharged back to the geothermal source to regenerate (refer to Figure 8).

Figure 8 – Vertical closed loop heat exchanger for a geothermal heat pump - Photo credit – Self et al., 2013.



On a daily basis, shallow ground temperatures fluctuate because of "factors such as incoming solar radiation, snow cover, air temperature, precipitation or thermal properties of the ground" (Self et al., p. 343). In Canada, constant annual temperatures can be found at depths below 10m. The main advantage of heat pumps is their ability to utilize low ground or water temperatures of between 5 and 30º C. GHP systems are highly efficient and are free of direct and associated CO_2 emissions, provided electricity sources to operate the pumps are clean sources. One drawback is that there is a higher capital cost than other conventional heating and cooling systems (p. 346).

2.5 Life Cycle Impacts

A Life Cycle Analysis (LCA) study considers the environmental burden associated with the entire lifetime of an activity. For renewable energy sources, the LCA can be divided into five phases: sourcing of the raw materials and manufacturing of components, on-site assembly, transportation, operation phase, and dismantling at the end of the system's life. Some studies simplify this further into upstream processes, operation process and downstream processes. "LCA can help determine environmental burdens from 'cradle to grave' and facilitate fair comparisons of energy technologies" (NREL, 2016). By comparing various renewable energy sources with each other and with non-renewable energy sources, it is evident that for renewables, the main environmental burden (expenditure) is in the upstream processes including raw materials extraction, materials production, module manufacture, transport and installation. This intensive phase could result in 60-70% of the GHG emissions during the lifetime of the energy system. For a coal-fired power plant, by contrast, about 98% of the GHG emissions are in the operations phase. However, the overall emission of CO_2 per kWh of power produced is extremely low with renewables compared to the coal option (see Figure 9 for comparisons).

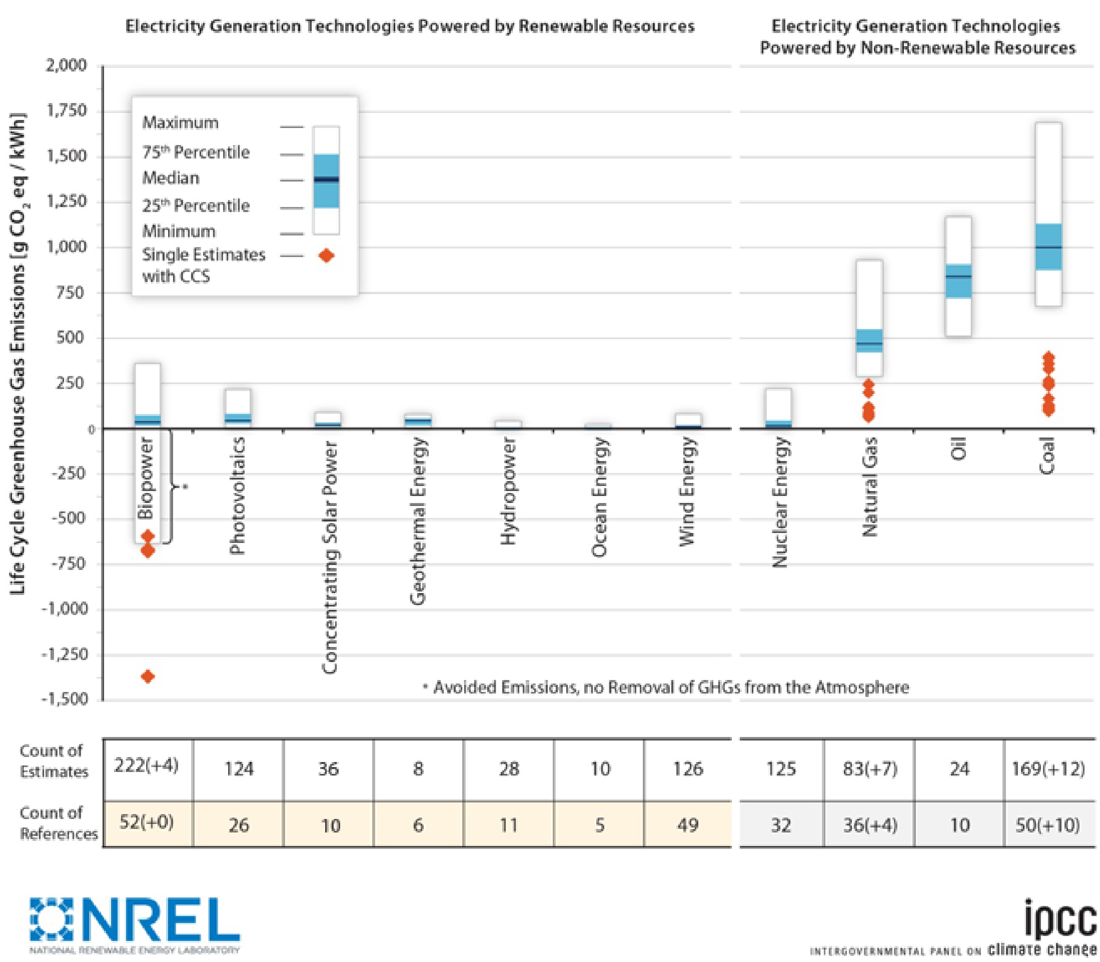


Figure 9 – Comparison of GHG emissions for renewables/non-renewables - Graph credit – NREL, 2016.

The three renewable energy strategies considered in this study (solar farms, wind farms and geothermal energy) are all represented in Figure 9 on previous page. Solar farms (or utility scale photovoltaics) are represented by the generic term “Concentrating Solar Power” (or CSP). One can see from the graph that CSP, geothermal energy and wind energy are all similar to each other and much lower than fossil fuel in total life cycle GHG emissions.

2.6 Other Constraining or Enabling Factors

While most will agree that we need to promote and develop broader implementation of non-polluting energy sources, there are many challenges ahead. Some people will object on aesthetic grounds for both wind farms and solar farms. Other challenges include selecting and acquiring suitable mutual land for community energy projects. There are challenges for the individual projects that include complex legal agreements with land-owners, investors, contractors and customers. The sharing of costs, financing, insurance and the introduction of incentives (or lack of incentives) can be similarly challenging. Finally, all forms of renewable energy systems involve negotiations and cooperation with utility companies. A characteristic of both solar and wind energy is that the energy produced is intermittent. This necessitates a diversified energy strategy to deal with the balancing of power grids when there are fluctuating amounts of energy available at any given time.

3. Current Technologies

3.1 Wind Turbines

Large commercial wind turbines have three main parts: the rotor shaft (with 3 blades), the nacelle (a centre hub that contains gearbox and generator) and the tower. The turbines now most commonly used in Alberta are like the one shown in Figure 10 but optional configurations include vertical shaft designs as in Figure 11. Smaller turbines at the scale that can be used on individual buildings come in all shapes and sizes. They are often mounted in rows on the parapet to catch winds coming over the roof edge. They can be located to be as hidden as possible or be a feature of the building as in Figure 12.

Figure 10 – Common tall commercial turbine in Alberta - Photo credit – Google.

Figure 11 – Turbine option with vertical shaft - Photo credit – Google.

Figure 12 – Featured turbines on a building - Photo credit – Google.

Two main factors that affect the energy output are the local wind speed and the diameter of the turbine's rotor blades. Energy output increases by the square of the rotor's diameter (D^2) and by the cube of the wind speed (S^3). For this reason, it is better to allocate resources for finding a better site or higher tower (and optimize wind exposure) than on a turbine with larger rotor diameter (Weis et al., 2010).

3.2 Solar Farms and PV Technologies

Solar farms require a large land area and as a result are most often located in rural or remote areas. However, brownfield sites or locations such as an abandoned airport may also be a prime option for a solar farm. About 25 acres of land is required for every 5MW of potential production. Each 5MW of installed capacity can power about 1515 houses (AZoCleantech, 2013). There is no upper limit to the farm size provided that appropriate land is available (refer to Figure 13).

Figure 13 – Solar farm example on marginal land - Photo credit – Buildinggreen.

Solar farms are assembled by ground-mounting standard PV panels into large arrays. Over the last several decades, prices of PV panels have dropped dramatically while efficiencies continue to improve. Pure silicon panels are now produced commercially that are able to convert 15% of sunlight striking them into electricity. More than 90% of today's solar market involves using silicon solar cells, although they are still relatively expensive to make. Recent lab tests at Massachusetts Institute of Technology (MIT) have improved cell efficiencies up to 22.1% using cadmium telluride technology (Martin, 2016). As gaps close between what is possible and what is available, PV panels will become more and more viable for everyday use. This will in turn make utility-scale solar farms a more attractive option as a low emission replacement power source.

3.3 How a Geothermal Heat Pump Works

A geothermal heat pump (GHP) operates by using electricity to drive a compressor that provides the necessary work for the transportation of thermal energy (Self et al., 2013). The working fluid within the pump is a type of refrigerant. The GHP moves thermal energy between the earth and the conditioned space by controlling temperature and pressure using compression and expansion. Five major components of the pump are: compressor, expansion valve, reversing valve and two heat exchangers (refer to Figure 14). Cooling can be accomplished by reversing the system and sending heat into the ground. The merit of such a system is usually evaluated by determining the energy efficiency by percentage. However, since heat pumps deliver more product heat (energy) than is needed for input energy, the efficiency is greater than 100%. To avoid expressing efficiencies of greater than 100%, the term “coefficient of performance” (COP) is used and is “defined as the ratio of product thermal energy to input driving energy” (Self et al., 2013, p. 342). It is common for heat pumps to have a COP in the range of 3-6 meaning that they are 300-600% efficient. Along with being a highly efficient technology, geothermal heat pumps can be part of a strategy to reduce C02 emissions and avoid fossil fuel usage. Geothermal also has synergies with district energy systems and can be used in shared applications for whole districts.

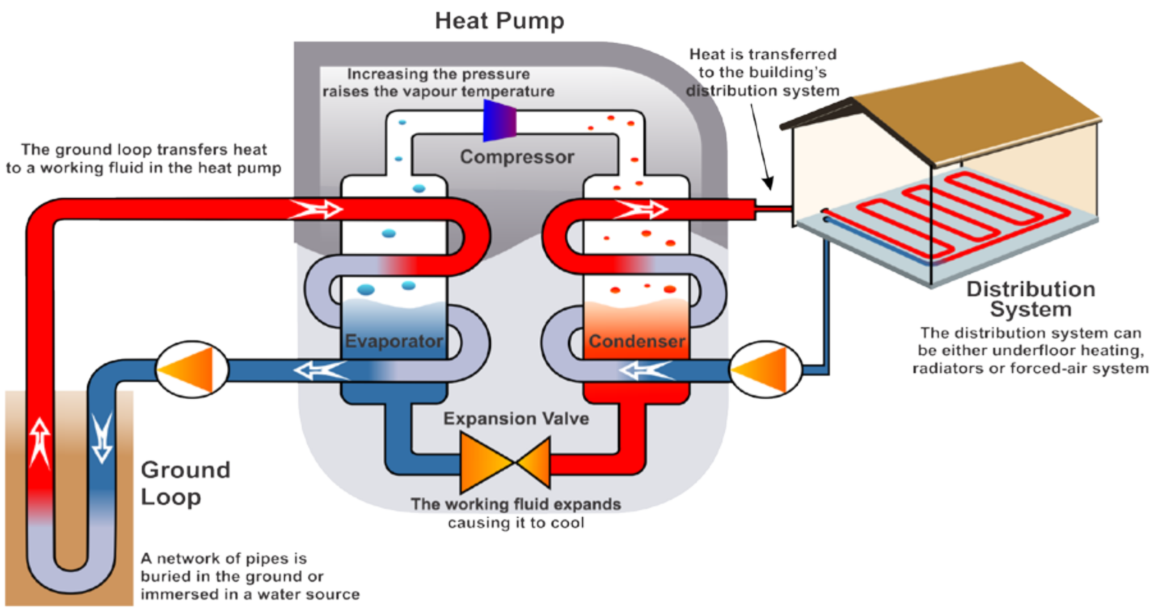


Figure 14 – Schematic of a Geothermal Heat Pump - Photo credit – Google.

4. Feasibility and Applications

4.1 Applications in Planned Communities

While strategies for various renewable energy systems can be easily incorporated into new construction, they may be optimally suited for planned new communities and new campus style applications. New infill districts such as Edmonton’s Blatchford Community (refer figures 15 and 16) are a prime example of where the methodologies can be easily incorporated in the heart of a city. Blatchford plans to have a “geo-exchange” system and then distribute the harvested heat via district piping to residential and commercial buildings.

At more remote locations, industrial, forestry and agricultural applications are possible where the technologies can take advantage of economies of scale. Applications could include wind or solar farms in combination with the Alberta oil sands projects, other oil and gas sites, pulp and paper mills, or large farms.

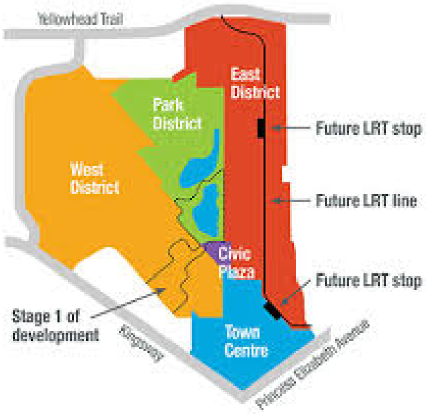


Figure 15 – Edmonton Blatchford Community Schematic - Photo credit – Google.

Figure 16 – Edmonton Blatchford Community Proposed Image - Photo credit – Google.

4.2 Enhancements to Existing Communities

At any time, the benefits of renewable energy strategies can enhance the life of an existing community. As renewable energy systems are developed, the outputs can plug into and be used as inputs for a community's energy requirements. One example is Calgary's C-train system. In 2001, Calgary City Council voted to purchase 21 MWh of wind power a year for 10 years, enough to power the C-train system (Dodge & Kinney, 2015). Although the trains do not run directly off the wind power, the investment made was enough that 12 new wind turbines needed to be built. In 2012, Calgary City council went further and began purchasing renewables for all their City operations. This meant that two new wind farms were added, totaling 144 MWh of installed wind capacity (refer to Figure 17). The agreement was not exclusively limited to wind power but also included other renewables such as hydro, biomass and solar power. Combined, "Calgary's LRT and city operations are running 100 percent on renewable energy, making the city a leader in Canada . . . (and is) something that is reducing congestion, bringing down emissions and building the clean energy economy of the future" (Dodge & Kinney, 2015).

Figure 17 – Southern Alberta Wind Farm - Photo credit – David Dodge, Green Energy Futures.ca.

4.3 Campus Environments

Campus environments lend themselves well to the adoption of renewable energy technologies because of economies of scale and shared resources/facilities. A campus environment can include a university campus, a hospital complex, an airport, a manufacturing facility, a condo development, or a shopping mall. There are many creative solutions that can be used to combine renewable energy strategies with campus buildings while maintaining safety and aesthetics. A local example of an innovative strategy is the new terminal expansion at the Edmonton International Airport that uses solar panels on the roof to offset some hot water heating requirements. However, there are many other creative examples around the world in various campus settings where renewable energy strategies have been used. Refer to collage of examples below at Figure 18.

Figure 18 – Top right and clockwise; Edmonton International Airport expansion terminal with roof-mounted solar panels; In 2014, Ikea purchased a 46MW wind farm at Pincher Creek in Alberta that will produce enough electricity to power 60% of Ikea stores in North America; University of Buffalo in 2010 commissioned a solar farm that is designed as "land art" and contains 5,000 PV panels; University of North Texas stadium includes wind turbines as part of the stadium design; the Campus for Research Excellence and Technological Enterpriese (CREATE) in Singapore wins design award by R&D magazine, design incorporates solar panels and wind turbines; condo building in Florida uses roof top turbines; and, research park in Singapore uses solar panels on building roof and over the parking – photo credits – Google.

5. Cost Considerations

5.1 First Costs

Definitive costs for renewable energy systems are difficult to determine with pinpoint accuracy because there are so many variables within each system. With both wind and solar power there are also associated costs with intermittency issues when other power sources are needed to make up the gap. However, some generalizations can be made as follows.

Wind Power. A Pembina Institute study (Weis et al, 2010) found that costs in Alberta for large turbines typically varied from $2M to $2.5M per MW, and variances depend primarily on the wind profiles of each turbine. Smaller turbines such as under 10kW in size cost more per kW than larger ones, and may typically cost $35K to $50K each. Alberta utility companies and private developers have been able to develop a history (and expertise) with their activity in wind power. Without any government incentives, green market programs (example, Greenmax by Enmax) have successfully gained traction by marketing green power at a premium of two cents per kWh above market rates (Ferguson-Martin et al., 2011). By contrast, Ontario began offering a feed-in tariff program in 2006 that paid 11 cents/kWh for wind power. This was raised to 13.5 cents in 2009 with a resulting upsurge in applications for projects.

Solar Power. First costs for PV have steadily been coming down over the last few decades. According to researchers, each solar PV module produces about 200 watts of power. A typical commercial PV configuration now costs under $1.00 per watt for supply only (Rosenbloom & Meadowcroft, 2014, p. 489). A conservative approach might be to allow $3.00 per watt, a figure that will make allowances for installation plus various soft costs such as design and permitting. Although there are economies of scale with solar farms, there can be other unknown associated costs such as land acquisition, grid tie-ins, and legal agreements. Cost of tie-ins can vary by a distance factor from the site to the nearest electrical sub-station. Conservative estimates indicate that a 1.0MW farm needs 5 acres of land and overall project costs are about $3.54M (adding construction and design allowances of 18.5% to above figures).

Geothermal Heat Pump Systems. There are too many site-specific variables to quote capital costs for commercial GHP systems. For comparison purposes, however, the first costs for a typical home (including ground loops and heat pump) are in the order of $20K to $30K (Canadian GeoExchange Coalition, 2016). This compares to a conventional natural gas furnace system that is in the range of $8K to $12K, putting the GHP system about 2.5X higher. On the operations side, a study by University of Ontario (Self et al., 2013, p. 347) found that annual heating costs in Alberta for the GHP system is $ 601 compared to $1109 for the natural gas option for a typical home (Self et al., 2013, p. 347). Both GHP and natural gas systems have an assumed trouble free design life of about 20 years.

5.2 Life Cycle Costs

As described earlier in section 2.5, Life Cycle Assessment (LCA) is “a way to account for the environmental burden of a given product or service across its whole lifetime, from material extraction to manufacture to use to disposal or from ‘cradle to grave’ “(Kelly et al., 2014). This definition provides a generic outline of the phases involved in the life cycle of renewable energy systems. For extraction, because of the variable nature of the composition and complexity of systems, it is difficult to make assumptions for the sourcing of the major equipment that makes up certain systems. Similarly, it is difficult to determine the amount of emissions expended during manufacturing. Studying a manufacturer’s website will give clues about their process emissions and how they measure up in their corporate social responsibility. Generally, sourcing products from closer to home and/or using lower carbon transportation such as rail or ship will lower the overall carbon footprint and resource use.

For design life, researchers (Benitez et al., 2018, p. 1980) use an expected life of 25 years for a wind power technology. Similarly, the expected optimum life for solar panels is 25 years. Although the panels can be expected to still produce power for 30 years or more, there is often a drop-off that can be as much as 20% after 25 years (Energy Informative, 2016). For a solar farm, options after 25 years include: continue to use the panels (at 80% output), renew the panels with current technology, or decommission the system if there are better uses for the land after that time. Finally, for GHP systems, an assumed design life is 20 years. Although the ground loops can be used indefinitely, the system pump cannot be expected to be trouble free after this time. These life spans are used as a basis for calculating return on investment in the next section. At the decommissioning and disposal stage, renewable energy systems are favorable because most materials (including many valuable metals) can be salvaged for re-cycling.

5.3 Return on Investment (ROI)

Using the estimates from First Costs above for several renewable options, per project savings and return on investments can be determined. The results for the given examples are as follows (assuming expected trouble-free design life of 25 years for wind and solar farms and 20 years for geothermal systems):

Wind farm systems -

Payback = Investment / Savings per year = $ 4. 5M / (2.0MW produced x 8760h per year x 0.35 x $155/MWh) = $4.5M / $950.46K/year = **4.7 years**.

(Where investment is a single 2.0MW turbine at $4.5M, savings = output in MW x 8760hrs per year, price of electricity is $170/MWh less $15/MWh for operations and maintenance, and net capacity factor is 35% for the southern Alberta area. This assumes a stable market price of electricity of $0.17/KWh for the calculation period).

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

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

Therefore, ROI = [25 years x $950.46K/year] – [$ 4.5.0M] x 100 = 428% (a positive return)
$ 4.5M

Return on investment for the provided scenario = **428%**.

Solar farm systems -

Payback = Investment / Savings per year = $ 35.4M / (10MW produced x 8760h per year x 0.1421 x $155/MWh) = $35.4M / $1.929,434M/year = **18.3 years**.

(Where investment is a 10MW farm at $3.54M/MW, savings = output in MW x 8760hrs per year, price of electricity is $170/MWh less $15/MWh for operations and maintenance, and net capacity factor is 1245KWh/KW (or a capacity factor of 0.1421) for the Edmonton area. This assumes a stable market price of electricity of $0.17/KWh for the calculation period).

ROI (in percentage) = [Gain from investment – Cost of investment] x 100%
Cost of investment

Or equal to [Savings over the life of the change – Capital cost of the change] x 100%
Capital cost of the change.

Therefore, ROI = [25 years x $1.929,434M/year] – [$ 35.4M] x 100 = 87.4% (a positive return)
$ 35.4M

Return on investment for the provided scenario = **136%**.

Geothermal systems –

For payback, it is difficult to generalize because GHP systems are so many variables from one application to another. A study at the University of Ontario Institute of Technology found that GHP systems generally have high capital costs for the installations, though this is somewhat offset by the high efficiencies of the systems in their operations. Their findings are as follows:

Payback = Investment / Savings per year = **4 - 20 years** (Self et al., 2013).

ROI - not addressed.

A caution: Benefits to emission reduction can be lost unless the "electricity used by the heat pumps is derived from environmentally benign power plants" (p. 348).

6. Outcomes

6.1 Environmental Benefits

Several environmental benefits of wind farms, solar farms and GHP systems that are noted in this report, along with contextual benefits are summarized below (refer Table 1).

Environmental Benefits of Wind Farms	
Produce emissions-free electricity.	Although some emissions result from the manufacturing and construction phases of a wind turbine's life cycle, once operating, emissions are negligible.
No air contaminants.	A wind farm emits no air contaminants from the generation of electricity.
No toxic pollutants.	Wind turbines do not emit toxic pollutants, whereas mercury continues to be a concern with respect to electricity produced from coal combustion.
Significant GHG reduction.	Life cycle studies indicate that GHG emissions from coal combustion are well over 10 times higher than life cycle emissions from wind (Weis et al., 2010).
Environmental Benefits of Solar Farms	
Reduced pollution and GHG emissions, similar to wind farms (above).	Like wind farms, the bulk of emissions are in the manufacturing and construction phases. Once operating, solar farms are a safe, emission-free, renewable source of energy.
Opportunity for rehabilitation of marginal land.	Land can be used that is marginal (for agriculture) and may be a brownfield site or next door to a load centre, as they are minimally disruptive to the local environment. With the introduction of biodiversity, the solar farms can often enhance the site compared to former uses. Line efficiencies can be realized if site is in close proximity to an electrical sub-station.
No moving parts and no sound.	Operations costs are very low as there are no moving parts to wear out. Similarly, sites are minimally disruptive to local environments as there are no sounds generated.
Environmental Benefits of Geothermal heat pump systems	
Reduced pollution and GHG emissions, similar to wind farms (above).	Like wind farms, the bulk of emissions and disruptions are in the manufacturing and construction phases. Once operating, GHP systems can displace GHG emissions from other energy sources.
Small land requirements.	Low land requirements compared to other energy sources.
Low freshwater use.	Low lifecycle water consumption relative to other energy sources.
Low consumption and production patterns.	Waste heat can be cascaded or recaptured for improved efficiencies. (Shortall et al., 2015).

Table 1 – Environmental Benefits of Renewable Energy Strategies – (Weis et al., 2010; Shortall et al., 2015)

6.2 Economic Benefits

Several environmental benefits of wind farms, solar farms and GHP systems that are noted in this report, along with contextual benefits are summarized below (refer Table 2).

Economic Benefits of Wind Farms	
Payback is short.	The payback is quick and the ROI is attractive, even with operating costs factored into the calculations.
Employment and other indirect benefits.	Construction of wind farms will provide many new jobs during construction, along with some permanent operating jobs and indirect benefits to vendors, suppliers and businesses in the community.
Existing experience and skill increases financial viability.	Alberta's utilities have a history of activity in wind energy development and many private developers have invested in wind projects, that together result in an existing expertise in the wind industry. Financial viability grows as unknown factors become more certain (Ferguson-Martin & Hill, 2011).
Economies of scale.	As more wind farms are added to a particular region, cost per unit decreases because of reduced distances for tie-ins to existing grid infrastructure.
There is a market demand.	The industry has been built up despite consumers having to pay a premium for green energy.

Viable land.	With lease options, win-win scenarios can be established involving higher revenues for the land owner while sacrificing only a small footprint of available land. Possible increase in property value through mixed use.
Economic Benefits of Solar Farms	
Employment and other indirect benefits.	Construction of solar farms will provide many new jobs during construction, along with some permanent operating jobs and indirect benefits to vendors, suppliers and businesses in the community.
Opportunity for synergies with other industries	Solar farms can co-exist with other industries such as animal grazing or bee-keeping.
Viable land.	Land that might otherwise be considered marginal, has a new purpose. With lease options, win-win scenarios can be established involving higher revenues for the land owner. Possible increase in property value through mixed use. Possible gain of habitat.
Economies of scale.	Many PV panels in close proximity and the ground-mounting option makes installation easier, quicker and safer than corresponding installations at heights (if roof mounted).
Economic Benefits of Geothermal heat pump systems	
Increased energy security	Applies to all renewable energy strategies.
High capacity factor.	Once installed, the efficiency of operation is considerably better than other heating sources using fossil fuel options.
Employment and other indirect benefits.	Construction of GHP systems will provide many new jobs during construction, along with some permanent operating jobs and indirect benefits to vendors, suppliers and businesses in the community (Shortall et al., 2015).

Table 2 – Economic Benefits of Renewable Energy Strategies – (Ferguson-Martin & Hill, 2011; Shortall et al., 2015)

6.3 Drawbacks and Challenges

Several drawbacks and challenges of wind farms, solar farms and GHP systems that are noted in this report, along with additional cautions are summarized below (refer Table 3).

Drawbacks and Challenges	
High first cost	The initial capital cost of building any of the three renewable energy options is high, with wind energy having the shortest payback.
Land disruption	Building access roads, burying distribution lines and geothermal energy tubing disturbs land and may necessitate costly ecological restoration.
May diminish the incentive to conserve energy	Inexpensive thermal energy can reduce the motivation to build highly energy-conserving buildings. (In fact, with such buildings, it may be harder to justify renewable energy strategies).
Few direct long-term jobs.	With solar farms and geothermal strategies, there are few direct long-term jobs.
GHP systems use electricity to operate the heat pumps	Electricity used in operating needs to be from environmentally benign power plants in order for the gains made (benefits of efficiency and lack of emissions in operating) to not be squandered.
Large land requirements	Wind farms and solar farms can both occupy large land spaces.
Limited design life	The 25 year design life is the highest life noted with any of these strategies. After that time the site or the system needs de-commissioning or rehabilitating (for wind and solar farms) and pump replacement for geothermal systems.
Wildlife impacts	Birds and bats may be killed through collision with wind towers and turbines, although there are greatly reduced incidents with the more recent larger/higher/slower turbines. Wildlife impacts from renewable energy activities are undoubtedly less than from other more energy intensive activities such as manufacturing, mining and forestry (WWF, 2016)
Education	Education (of the public, policy makers, and industry) regarding the benefits of renewables will be an ongoing challenge.

Table 3 – Drawbacks and Challenges of Renewable Energy Strategies – (Wilson, 2007; Weis et al., 2010; Shortall et al., 2015; Ferguson-Martin & Hill, 2011).

7. Conclusion

Alberta is in the enviable position of having a variety of natural resources available to meet its energy needs, including feasible options for renewable energy strategies. As the Government of Alberta looks to implement its Climate Leadership Plan, the use of wind farms and solar farms for generation of electricity, and geothermal heat pump systems for heating/cooling, are viable alternatives for assisting with future energy needs. These innovative systems can increase resiliency, improve efficiencies, conserve energy, decrease operating costs, and encourage economic diversification, all while lowering GHG emissions.

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