Renewable and Low-emission Energy Technologies

This summary of renewable and low-emissions energy technologies outlines the feasibility, opportunities, and barriers for each type of energy generation technology in Saskatoon. The information can help readers determine if investing in renewable and low-emissions energy projects are suitable for a particular property, individual, or organization by reducing uncertainties. Known areas that can reduce uptake include:

- insufficient knowledge to carry out the project;
- uncertainties about the long-term energy savings and the payback period;
- uncertainties in the (relatively) new technology's long-term performance; and
- uncertainty in selecting the best contractors to install, operate, and maintain the systems as required.

Each section goes through a renewable energy technology and can be used as a stand-alone reference paper as needed. The sections will be updated as technology, research, policy, programs, and other circumstances evolve.

Sections:

Solar Power

Solar electricity generation is the process of converting sunlight to usable electricity using solar photovoltaic (PV) panels. Saskatoon offers an ideal climate for solar power generation with over 2,260 hours of bright sunlight per year.

Rooftop Solar Generation

In the Climate Action Plan Progress Report 2020, Saskatoon reported ~3.4 MW of generating capacity from solar panels on private properties[1]. Environmental Insights Explorer[2] estimates the technical rooftop solar potential for Saskatoon at up to 940 MW.

Technical potential was determined by Environmental Insights Explorer based on Project Sunroof's criteria for installations, using roof size and shape, shaded roof areas through satellite imagery, 3D modeling, and shade calculations from Google, as well as local weather data from the National Renewable Energy Laboratory (NREL):

- Sunlight: Every included panel receives at least 75% of the maximum annual sunlight in the region. This is visualized in Figure 1.
- Installation size: Every included roof has a total potential installation size of at least 2kW and less than 1,000 kW.
- Space & obstacles: Only areas of the roof with enough space to install four adjacent solar panels are included. Only solar arrays on buildings are considered, not other spaces such as parking lots or fields.

The estimated technical potential assumed economics and grid integration were not constraints.

[1] "Climate Action Plan: Progress Report 2020" *City of Saskatoon*, April 2021, www.saskatoon.ca/sites/default/files/documents/climate_action_plan_progress_report_2020-webprint.pdf, pp. 30

[2] "Environmental Insights Explorer – Rooftop solar potential." *Google Environmental Insights Explorer*, insights.sustainability.google/places/ChIJK5ntR7_2BFMRkCZ3lTKeBAU/solar.

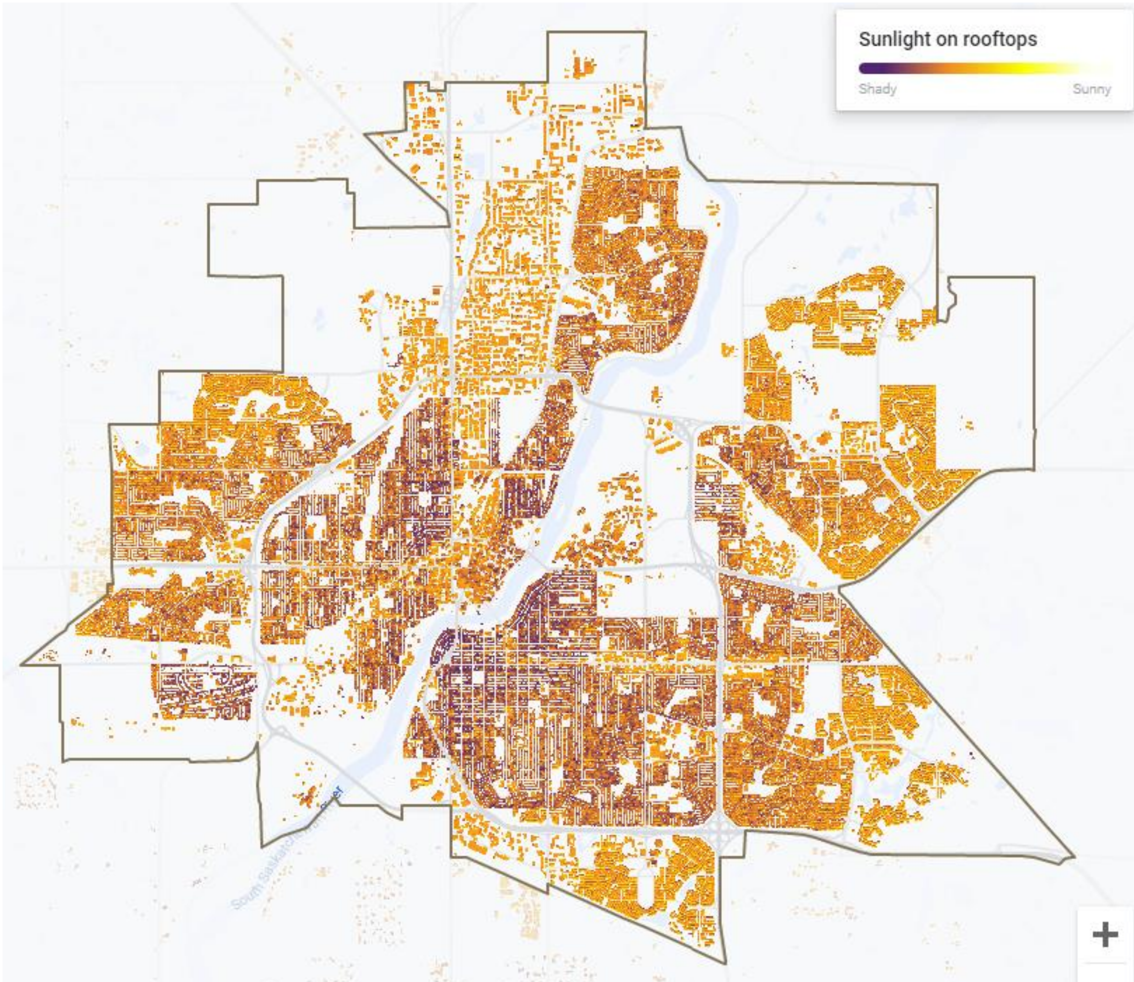

Figure 1: Environmental Insights Explorer Rooftop Solar Potential

The 2017 City Council Report, *Facilitating Solar Energy Opportunities in Saskatoon*, estimated between 122 MW and 1217 MW of solar potential on private rooftops[3]. This larger range could be attributed to the City's estimation including a consideration for local constraints, that may drastically impact capacity.

Typically, large buildings with south facing roofs and minimal shading create optimal conditions for solar electricity. To comply with the National Building Code, rooftop structures with solar panels must be able to accommodate the additional weight of the panels and snow, rain, and wind loads. The age and condition of the rooftop is also considered; if the roof requires replacement during the lifetime of the system, the entire system will need to be removed for the rooftop replacement, and re-installed.

[3] Rajakumar, Bibian. *Facilitating Solar Energy Opportunities in Saskatoon*. November 2017. pub-saskatoon.escribemeetings.com/filestream.ashx?DocumentId=41483, pp.3

Ground-mount Solar Generation

For large, open sites, ground-mount installations may be the best option for solar generation. The cost for installation can be much lower than installing on rooftops and does not require consideration for rooftop replacement within its lifecycle. Ground-mounts are typically larger which can reduce costs with bulk purchasing of solar PV panels. Sites considered for ground-mount solar would require assessments before committing to a long-term solar project. If the site is developed, considerations include surrounding buildings and the potential for further development on the site. If the site is undeveloped, considerations include the nature and timing of future urban development. Agri-voltaics may be suitable as co-location projects before urban growth reaches an area. These projects allow for farming and solar power generation to occur on the same site by combining ground-mounted solar PV panels with tree, shrub, and other plantings beneath or between the rows. Panels are installed with enough height to allow people and equipment to pass underneath and to prevent prohibitive shading from occurring.

Overhead solar is another option well-suited for spaces like parking lots where there can be excellent solar access and parked vehicles may benefit from additional shading and shelter from the panels above. The solar power generated may also be used by electric vehicles (EVs) parked for charging. These systems require additional structures to be built, so they would only be pursued by the City after lower-cost systems have been prioritized.

Solar Benefits

Investing in solar electricity has many benefits and is a critical component within the Low Emissions Community (LEC) Plan and meeting the City’s greenhouse gas (GHG) reduction targets. Local solar power generation is an important way to reduce grid-tied electricity consumption. As well, solar PV systems, when equipped with islanding inverters (i.e., inverters capable of operation without external electricity grid power), can increase community resiliency to power outages and grid interruptions while balancing supply and demand issues, especially when paired with battery storage. Solar power can also result in long term savings through avoided electricity purchases. Actual long-term savings are contingent on the value of energy and available interconnection programs which impose financial risk to generators. Currently in Saskatchewan, high energy prices and sunny conditions can provide a positive return-on-investment over the long term.

Solar electricity is incredibly customizable and versatile – any property with sunlight access can potentially generate solar power, depending on PV panel access and installation requirements. Systems can be installed in spaces that would not typically be used for any other purposes, such as the roof of a building, or an area with contaminated soil that cannot be used for food production or development. The average size of local solar PV systems is typically 7kW for a residential system, and 32kW for a commercial system.

Solar Considerations and Barriers

Generation Capacity

The following factors affect solar panel output:

- Available sunlight: determined by time of year, latitude and angle of the panels, and cloud coverage.
- Temperature: Solar cells inside the panels degrade when they get hot, resulting in less efficient solar panels. Efficiency of panels typically increases as temperatures decrease.
- Shading: Anything blocking the sunlight that's not weather-created, such as nearby buildings, trees, and smog.
- Soiling: snow, dirt, dust, and other grime that accumulates on the surface affects solar panel efficiency. While clearing panels will improve efficiency, the panels are able to generate power provided they are not completely covered.

Peak Generation vs Peak Usage

Renewable electricity sources such as solar and wind are intermittent and may not necessarily align with peak demands. Solar power can be used as it is generated, which is the most efficient and cost-effective way to use solar. However, typical peak usage of electricity for residential homes occurs between 6-9pm when there is little to no sun; also, more electricity is typically consumed during the winter while solar generation is at its lowest.

For self-generation, Saskatoon Light and Power (SL&P) or SaskPower (depending on the location) can help with this as excess power can be fed back onto the power grid, either through a power purchase agreement where the utility buys the power from the customer, or through net metering where the utility credits the customer for the amount generated so they can use it later. Battery storage can also be used to store excess electricity for the generator to use later in an off-grid system.

Solar PV Life Cycle and Degradation

Solar PV panels are subject to a decline in power output over time, which is referred to as the degradation rate. Most manufacturers will include an estimation of the degradation rate in the panel specifications. Typically, solar PV panels are available with performance guarantees of over 25 years, during which manufacturers guarantee that the panels will lose no more than 1% of their total output per year. With a slower return-on-investment, a solar PV system may not pay off within its guaranteed lifetime. However, a study by Jordan and Kurtz on reported degradation rates from nearly 2000 solar PV systems over a 40-year period yielded an average degradation rate of 0.5% per year[4].

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[4] Jordan, Dirk and Kurtz, Sarah. *Photovoltaic Degradation Rates — An Analytical Review.* 2012. www.nrel.gov/docs/fy12osti/51664.pdf, pp. 5

Costs and Utility Rates

According to EnergyHub.org, the up-front cost of an average 7kW residential solar system will typically be over $22,000 (between $2.64/W and $3.22/W)[5]. Estimates for a solar system need to include the panels, grid-connection, mounting structure, inverters, wiring, labour, design, permitting, and financing. Incentive availability can be a large driver for the uptake of solar panels.

Provincial energy rate adjustments are envisioned in the short and medium term which may further reduce the return-on-investment. Specifically, the rates may begin to include higher fixed costs with lower variable rates, resulting in a smaller portion of the electricity costs that can be offset through renewable energy generation.

Urban Development

Solar PV systems rely on direct access to sunlight; this can be challenging to achieve in developed areas of cities where tall buildings, fully developed lots and mature trees can limit solar access.

Before installing solar panels, property owners must consider existing and potential surrounding development, including buildings and trees, that may impact that access. Areas that have large lots, low neighbouring buildings, and few mature trees can be well-suited to solar energy generation.

At a community scale, the benefits of solar access must be balanced with other environmental considerations such as density targets and urban forest targets. The City's Official Community Plan Bylaw No. 9700 (OCP) has policies to ensure the community is compact and efficient and its environmental footprint is minimized. The OCP directs density and growth to defined areas such as major corridors, sets density guidelines for new neighbourhoods, and facilitates infill development. The City's Zoning Bylaw No. 8770, which is used to implement the OCP, permits taller buildings such as two-story homes in many zoning districts throughout the city. These policies result in some of the most substantial cumulative emissions reductions in the LEC Plan and are key to the City achieving its GHG reduction targets.

Urban forests provide significant ecosystem services; they store and sequester carbon dioxide, and filter air pollutants. They also provide shade and wind protection, which can reduce nearby buildings' heating and cooling needs. The OCP has policies that encourage the maintenance and enhancement of the urban forest, and the City's Urban Forestry Management Plan has targets for planting trees and increasing tree canopy cover throughout the city.

Disposal

The manufacturing of solar PV panels requires the mining of certain elements as well as the use of hazardous materials. Many citizens have expressed concerns for the disposal of solar panels once a generating project is complete. Some solar modules

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[5] "Solar Power Saskatchewan (2021 Guide)" *EnergyHub.org*, www.energyhub.org/saskatchewan/

may be reused by selling them second-hand to buyers that are not necessarily looking for the newest technology on their sites and could benefit from a more affordable system. For modules past their usable life, recycling is becoming more accessible; Battery recycling facilities in the United States are preparing to begin accepting solar modules for recycling. Typically, solar modules are made up of 90% recyclable materials (by mass) such as copper, aluminum, glass, and electronic components. Through disassembly or shredding, each component can then be processed through established recycling processes.

In 2021 ERI, the largest electronics asset disposition provider in North America partnered with Redwood Materials, a lithium-ion battery recycler, to create a circular supply chain for solar modules. Redwood will accept disassembled solar modules from ERI for further separation into their raw materials.

Wind

Wind power is produced when wind passes over turbine blades that spin a shaft connected to a generator. In 2022, SaskPower reported 630 MW of wind energy generating capacity at their current wind power facilities[6]. Based on Barrington-Leigh and Ouliaris's spatial analysis of renewable energy in Canada, which considered any operationally feasibly areas without environmental or social concerns with average wind speeds of more than 7 m/s at a height of 80 m, Saskatchewan's potential wind energy generating capacity could reach a maximum capacity at 274,000 MW[7]. Figure 2 shows the map provided by the Government of Canada of the average annual wind speeds across Canada at 80m above ground, for reference[8].

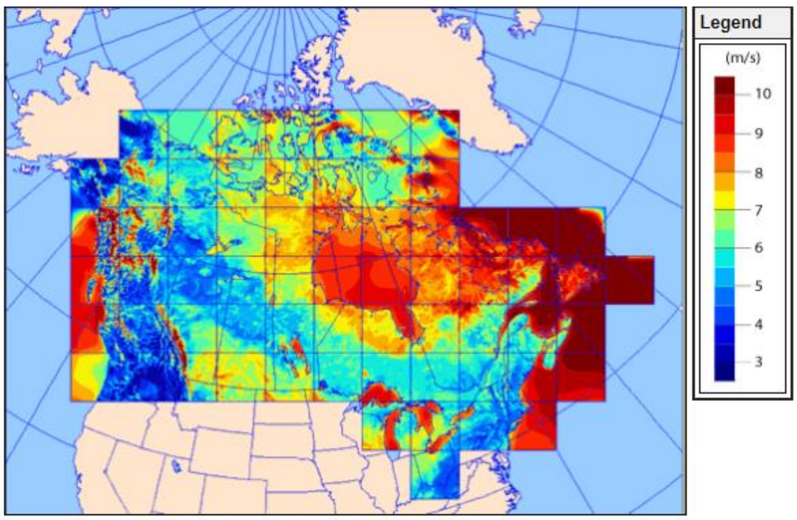

Figure 2: Average annual wind speeds across Canada

Wind Benefits

Wind Energy technology is improving as wind turbines become increasingly reliable, powerful, and cost-effective. Wind facilities only produce GHG emissions during manufacturing, transportation, assembly, and maintenance, but not during energy generation. Nor do they pollute air or water resources. Wind turbines and their access roads use as little as 1% of the total wind farm acreage; this enables more land to be used for farming, ranching, or other uses.

Wind Considerations and Barriers

Wind turbines can cause noise and visual disturbances and it is often preferred to site wind facilities far away from major municipal centers. For example, the above

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[6] "SaskPower Annual Report: 2022-21", *SaskPower*, July 2022, www.saskpower.com/-/media/SaskPower/About-Us/Reports/Report-AnnualReport-2021-22.ashx, pp. 12

[7] Barrington-Leigh, Chris and Ouliaris, Mark. *The renewable energy landscape in Canada: a spatial analysis,* December 2015, wellbeing.ihsp.mcgill.ca/publications/Barrington-Leigh-Ouliaris-IAEE2015.pdf, pp. 11

[8] "Wind Atlas - Overall Map." *Government of Canada.* June 2016. www.windatlas.ca/maps-en.php?field=EU&height=80&season=ANU

generating capacity was calculated assuming that wind turbines would be sited at least 5km from any populated areas. However, more remote locations may require further development of the electrical grid for distribution to customers. Cold climates also have an impact on their construction and maintenance, such as de-icing needs.

Wind is an intermittent and unpredictable energy source, producing energy only while the wind is blowing and therefore requires redundant energy systems or battery storage.

Wind can also pose a potential impact on local and migratory bird and bat species. Technology innovations, including bladeless wind turbines that oscillate to collect the kinetic energy of the wind, are being prototyped and reported on, and will be considered as opportunities arise. These turbines are anticipated to have virtually no negative impact on bird migration patterns, or wildlife, and vibrate at a frequency that produces noise undetectable to humans.

Saskatoon's Wind Status

Saskatoon does not currently have any local wind generation projects and is limited to using wind energy generated or purchased by SaskPower. A wind power project had been investigated at the Saskatoon landfill and was not pursued due to public concerns related to disrupting local birdlife and vistas. Saskatchewan's Ministry of Environment also recommends a 5km setback from important bird areas, ecological reserves, and waterways, including the South Saskatchewan River, when siting wind turbines[9]. For this reason, wind power within Saskatoon is not seen as a viable alternative. However, opportunities outside City limits may be explored for future wind projects, in consultation with the relevant municipality.

[9] Saskatchewan Ministry of Environment, *Wildlife Siting Guidelines for Saskatchewan Wind Energy Projects.* September 2016. www.saskatchewan.ca/-/media/news-release-backgrounders/2016/sept/wind-siting-guide.pdf, pp. 13

Energy Storage

Energy storage systems can be very beneficial when paired with renewable energy that has variable generation productivity, such as wind and solar. They can be as small or large as desired and can be used by the customer or at the transmission and distribution levels. Their storage and usage provide adaptability for when there is a discrepancy between when energy is being produced and when it is needed by the consumer.

Energy storage can also be beneficial to distributors through reduction of a grid's peak capacity requirements, improving grid system operation reliability through back-up, and increasing resiliency during outages.

Battery Storage: Lithium-ion

Key components of a lithium-ion battery are the anode and the cathode, which both store lithium. Batteries can store energy by the cathode releasing lithium ions to the anode, generating a flow of electrons from one side to the other. The energy can later be accessed by the anode releasing lithium ions to the cathode, at about 95% efficiency.

Mechanical Energy Storage: Compressed Air Energy Storage

Compressed Air Energy Storage (CAES), which utilizes the electricity generated from renewable sources to compress and store atmospheric air in purpose-built salt caverns. The compressed air can be controllably released later into an electricity-generating turbine, at about 55% efficiency. This solution allows for longer term storage and is ideal for Saskatoon’s surrounding geological conditions (i.e., the layer of rock salt at 800-1200 m in depth). This system would likely be sited outside of city limits (or at the very least, outside of SL&P’s district) so a partnership would be required with neighbouring jurisdictions and SaskPower.

Energy Storage Considerations

Estimated battery cost is $1,500–2,500 per kW of power installed, depending on power output and energy capacity. There are cost savings if battery storage is simultaneously installed with a new solar PV system, compared to adding the battery storage to existing systems.

Mining the lithium for lithium-ion batteries can be harmful to the environment. This is because removing raw materials, like lithium, can result in soil degradation, water shortages, biodiversity loss, and damage to ecosystem functions.

CAES systems are estimated to produce electricity that costs $72-114/MWh, included the paired wind generating system. For such a system to be viable, the scale of the system would need to be 150-300 MW, which would significantly impact the City’s current electricity partnership with SaskPower.

The benefits of energy-storage are most significant for users with higher electricity rates during peak usage times, as energy can be stored at off-peak times and then used when grid capacity is at its highest – a practice known as peak shaving. Systems with larger and longer storage capacities, such as CAES, could also be used to emulate a steady and necessary base load generation.

Saskatoon's Energy Storage Status

The City of Saskatoon does not currently have any corporate-led projects for energy storage. The Dundonald Ave Solar Farm feasibility study considered the implementation of a 1 MW battery storage system capable of supplying energy for 4 hours. However, it was determined that a battery system was uneconomical as it would have nearly doubled the capital expenditure of the project, and that there was a lack of vendor/product certainty and standardization. As the project becomes operational, and as energy storage systems opportunities arise, SL&P will re-evaluate the option of incorporating battery storage at the site or on future projects.

Energy Storage examples

There have been some smaller-scale residential battery projects installed across the province, as well as some larger projects. For example, Saskatchewan Research Council has partnered with Cowessess First Nation for a wind-battery project that started in 2014. The battery will either charge or discharge in real-time to steady and smooth the output of the wind turbine, which improves the system's predictability[10].

As reported by Wiens the Town of Lumsden has installed a 616 kW solar PV system, with 500 kW battery storage, for their wastewater treatment plant. The solar energy generated is estimated to be enough to power 66% of the wastewater treatment plant's energy needs. The battery would charge at peak production/low usage (midday) and then be used nightly. No electricity from the panels will be exported to the grid[11].

In of March 2021, SaskPower announced their first utility-scale energy storage system to be located in northeast Regina. The system plans to be in operation by the end of 2022 and supply 20 MW of power which is equivalent to powering up to 20,000 homes for one hour[12].

CAES using salt caverns has been around since 1978, providing industry over 70 years of operational experience. There is a 290 MW CAES Plant at Huntorf, Germany, developed in 1978, and a 110 MW CAES Plant at McIntosh, Alabama, developed in 1991.

Hydropower

Hydropower is the largest renewable energy source in Canada; it utilizes the energy created from moving water to activate a turbine connected to a generator. Unlike the intermittent nature of wind and solar energy systems, hydroelectric plants can produce electricity on demand and are capable of supplying energy reliably. Canada Energy

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[10] Saskatchewan Research Council, *Smoothing it Out: Improving Wind Turbine Reliability with Energy Storage,* April 2014, www.src.sk.ca/blog/smoothing-it-out-improving-wind-turbine-reliability-energy-storage

[11] Wiens, Colton, *Lumsden to install solar panel array the size of 2 football fields.* August 2020. regina.ctvnews.ca/lumsden-to-install-solar-panel-array-the-size-of-2-football-fields-1.5077221

[12] "SaskPower's First Battery Energy Storage System Will Support Renewables to Help Balance Grid", *SaskPower,* March 2021, www.saskpower.com/about-us/media-information/news-releases/2021/saskpowers-first-battery-energy-storage-system-will-support-renewables-help-to-balance-grid

Regulator reported an installed capacity of 81,400 MW for hydroelectricity energy generation in Canada, as of 2019[13].

Hydropower plants vary in size and type in consideration for local topography, climate, and conditions. The amount of energy produced will vary in proportion to the water volume and speed.

Reservoir hydropower

Reservoir hydropower uses a dam to capture river water, which is then stored in a reservoir for release when needed; this allows for the system to respond to base loads and peak demands as required and can provide resiliency against unpredictable water flows. This type of hydropower is best suited for sites that construct a dam with large volume capacity.

Run-of-river hydropower

Run-of-river hydro is built on an existing stream or river. Facilities are usually located where water naturally falls. However, improvements to turbine technology have made it possible to build and operate run-of-river projects in sites with low flow and no height differences. The installed capacity of run-of-river facilities in Canada varies from less than 1 MW to over 1,900 MW at Beauharnois Generating Station[14].

Hydropower Benefits

Hydropower, especially large hydropower, is financially competitive with other electricity sources. Advantages include no fuel cost, low operating costs, and a very long and reliable service life. Hydropower is also 90% efficient at converting available energy into electricity.

Hydropower Considerations and Barriers

Hydropower projects can involve long construction periods and large upfront capital costs. Returns on investment may also vary greatly from year to year, depending on precipitation.

Reservoir hydropower dams can interfere with fish migration, deplete oxygen in reservoirs, mobilize contaminants, and trap sediment that is important for maintaining downstream habitats (including protecting deltas from erosion), which can result in the creation of new GHG emissions.

Run-of-river facilities, which do not use dams, can cause fewer disturbances to fish and natural water flow when installed and operated according to specified limits.

Bodies of water that are disrupted for the purpose of hydropower electricity generation can also impact traditional and/or Indigenous land use.

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[13] "Canada's Energy Futures 2021 Fact Sheet: Electricity" *Canada Energy Regulator*¸ May 2022. www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2021electricity/

[14] "Beauharnois Generating Station." *Hydro Quebec.* www.hydroquebec.com/projects/beauharnois-les-cedres/installations.html#hq-menu. Accessed October 2022

Saskatoon's Hydropower Status

Saskatoon does not have any local hydropower projects – but the City, together with the Saskatoon Tribal Council, has considered the construction of a run-of-river hydropower station to capture the energy falling over the weir. In March 2010, a pre-feasibility study was presented to City Council outlining the possibility of a 5 MW to 7 MW system. This study, provided by Knight Piesold Consulting, indicated numerous cost and environmental barriers. Project capital cost requirements were estimated at $61.5 to $65.2 million and included raising the weir by an additional 2 meters, a fish bypass channel, and a pedestrian bridge over the infrastructure. The project capital also includes a retrofit of adjacent land to include a recreational whitewater park for multi-purpose use. The project was predicted to eventually recover costs and produce a positive return on investment if purchased at approximately $0.135 per kWh or greater[15].

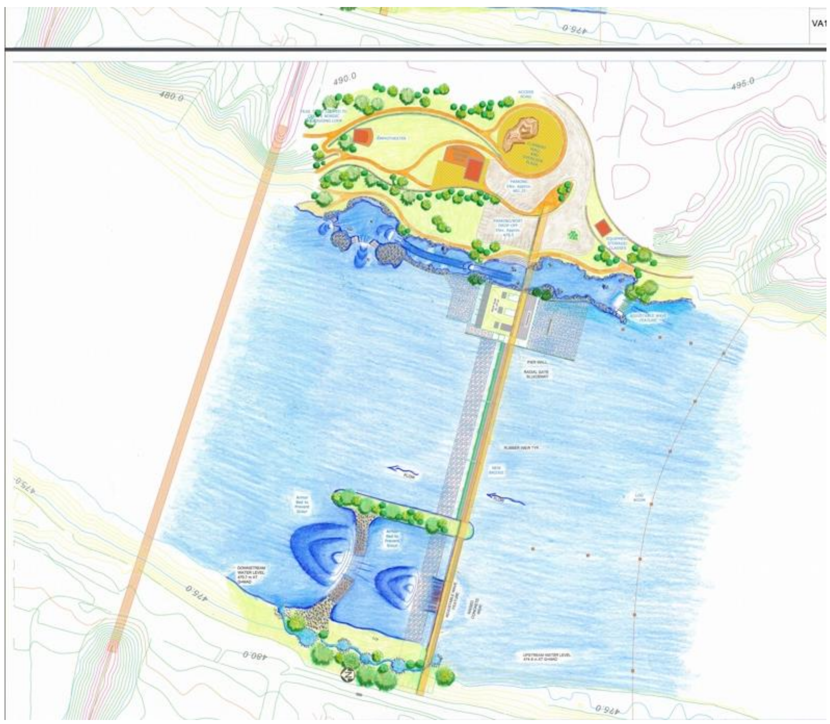


Figure 3: Concept drawing for run-of-river hydroelectricity stations at the Saskatoon weir

In 2018, the First Nations Power Authority, in partnership with Saskatoon Tribal Council, submitted an Unsolicited Power Proposal to SaskPower with the intent to proceed with project implementation. The proposal was rejected by SaskPower because the cost for power generation, double SaskPower's current bulk purchasing rates, was viewed as not competitive with other renewable energy options available.

To pursue the project further, a full feasibility study is needed. This feasibility study would include both a geotechnical and environmental impact assessment to better

[15] Knight Piesold Ltd. *Saskatoon Light & Power, Hydropower and Whitewater Park Development Studies*. February 2010. https://www.saskatoon.ca/sites/default/files/documents/transportation-utilities/saskatoon-light-power/Hydropower/hydropower_environmental_baseline_study.pdf. Pp.24

understand any adverse outcomes to the weir and its surrounding features. Without external funding sources to support the study and eventual capital costs, the project is considered a high-risk investment to the City.

In 2022, SaskPower reported owning seven hydroelectric stations with a total energy capacity of 997 MW[16]. Four of these stations are run-of-the-river type. Based on Barrington-Leigh and Ouliaris's spatial analysis of renewable energy in Canada, which estimates the technical hydroelectric potential across the country, based on water flows, elevation, geography, etc., Saskatchewan's hydroelectricity generating capacity potential is estimated to be 5,000 MW[17].

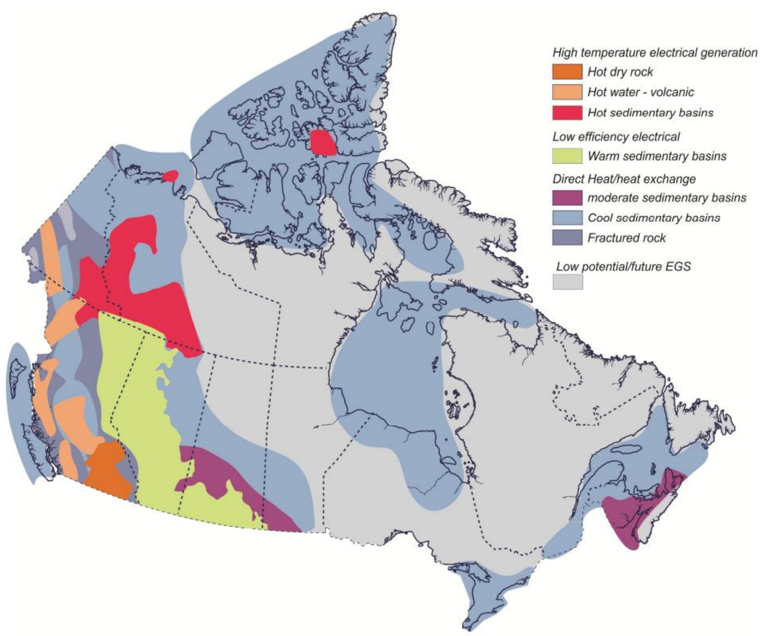
[16] "SaskPower Annual Report: 2022-21", *SaskPower*, July 2022, www.saskpower.com/-/media/SaskPower/About-Us/Reports/Report-AnnualReport-2021-22.ashx, pp. 12

[17] Barrington-Leigh, Chris and Ouliaris, Mark. *The renewable energy landscape in Canada: a spatial analysis,* December 2015, wellbeing.ihsp.mcgill.ca/publications/Barrington-Leigh-Ouliaris-IAEE2015.pdf, pp. 16

Geothermal Energy

Geothermal Energy is heat that is harnessed from the sub-surfaces of the earth and used for direct application such as heating and cooling buildings. High temperature geofluid from hydrothermal reservoirs can also be utilized to drive a turbine and generate electricity.

Geothermal energy efficiency and performance varies depending on location, temperature differential & fluctuation as well as equipment use. Locally, Saskatoon's moderate sedimentary basins' geothermal potential is best suited for direct heat geothermal applications, and not power generation. Figure 4 provides a map of geothermal potential across Canada, as reported by Grasby et al[18].



- Figure 2. Map showing distribution of geothermal potential in Canada based on end use.

Figure 4: Map showing distribution of geothermal potential in Canada based on end use

Direct-application geothermal

As described by Natural Resources Canada[19], ground-source heat pumps use open or closed loop geothermal systems to extract or release heat from ground.

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[18] S.E. Grasby, D.M. Allen, S. Bell, Z. Chen, G. Ferguson, A. Jessop, M. Kelman, M. Ko, J. Majorowicz, M. Moore, J. Raymond, R. Therrien. *Geothermal Energy Resource Potential of Canada.* 2012. publications.gc.ca/collections/collection_2013/rncan-nrcan/M183-2-6914-eng.pdf. pp 13

[19] "Heating and Cooling with a Heat Pump" *Natural Resources Canada,* August 2022. nrcan.gc.ca/energy-efficiency/energy-star-canada/about/energy-star-announcements/publications/heating-and-cooling-heat-pump/6817#a

Closed Loop Systems

Closed-loop systems draw heat through a continuous piping system that is filled with water or a water/refrigerant mix. The fluid absorbs ground heat as it travels through the pipes and is pumped back up to the surface for heating and electricity generation.

Open Loop Systems

Open-loop systems draw hot water (geofluid) from underground hydrothermal reservoirs and feed the fluid through a series of heat exchangers. The heat exchangers then collect thermal energy captured from the geofluid before the geofluid is sent back down to the reservoir at a colder temperature to be reheated and reused.

Just like any geothermal system, ground-source heat pumps are not impacted by fluctuating temperature changes, guaranteeing constant heating in the winter and cooling in the summer. Heat pumps are also very efficient; Natural Resources Canada states that for every kilowatt of power used, 2-4 kilowatts of thermal energy are produced. Once installed, they are a good replacement for conventional space heating equipment such as furnaces and boilers.

Geothermal Energy for Power Generation

High temperature geofluid from hydrothermal reservoirs can be utilized to drive a turbine and generate electricity. Geothermal power facilities can also supply excess heat to neighbouring facilities. These facilities require hydrothermal temperatures above 120℃ to function, which limits available locations for installation.

Geothermal Energy Benefits

Temperatures below the frostline remain constant year-round and are not impacted by fluctuating weather patterns. Geothermal energy can provide constant heating in the winter, constant cooling in the summer and a steady baseload for generating electricity with one of the highest capacity factors amongst other renewable energy sources. Also, most of the system is below ground and does not occupy substantial amounts of above-ground land.

Geothermal Energy Considerations and Barriers

Initial capital for geothermal is significant, with installation work requiring drilling vertically below the frostline meaning installation can be costly and disruptive. According to Alley, Blumsack, and Bice from Pennsylvania State University, Hydraulic fracturing is also known to induce earthquakes, which are often imperceptible, but can be larger if drilling near pre-existing faults[20]. However, once operational, the systems are inexpensive to operate and maintain, and little to no emissions are generated.

Saskatoon's Geothermal Status

Saskatoon’s geothermal potential is best suited for heating, and not electricity generation. The City could pursue the purchase of geothermal electricity but it would need to be in partnership with the jurisdiction and utility where the facility is sited.

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[20] Alley, Richard, Blumsack, Seth, and Bice, David, Pennsylvania State University. *Barriers to Adoption of Geothermal Power Generation.* www.e-education.psu.edu/earth104/node/1303. Accessed October 2022

The LEC plan has the following actions related to geothermal heating:

- LEC Action 5: Retrofit municipal heating and cooling systems with ground-source or air-source heat pumps.
- LEC Action 14: Retrofit home heating and cooling systems with ground-source or air-source heat pumps.
- LEC Action 15: Retrofit ICI heating and cooling systems with ground-source or air-source heat pumps.

Because these actions are related to heating, and not electricity, they were not included in renewable and low-emissions energy implementation plan.

Geothermal Examples

Saskatchewan is embarking on Canada's first ~35 MW commercial geothermal power generation system to be located near Estevan in Southeastern Saskatchewan. The project is led by a Saskatchewan-based private entity known as DEEP Corp and is partially funded through Natural Resources Canada's Emerging Renewable Power Program. According to the project website, this first facility is planned for full commissioning by early 2025. A staged build aims to increase the project to produce approximately 140 MW of renewable power generation[21].

[21] "About Deep", *Deep Earth Energy Production.* deepcorp.ca. Accessed October 2022

District Energy Systems

District energy systems use a network of underground pipes to pump steam, hot water, and/or chilled water from a central plant to multiple buildings in a localized area. Providing heating and cooling from a central plant replaces the need and additional fuel required for individual heating and cooling and hot water systems in each building. It is not a renewable energy technology but is important for the reduction of GHGs by maximizing efficiency of energy use.

Electric power plants conventionally lose over half of their energy content as heat; the thermal energy for district heating is often cogenerated by Combined Heat and Power (CHP) plants; or through "waste heat" from industrial processes, such as boilers and renewable energy generation. This increased efficiency and use of otherwise lost heat for a localized purpose can help reduce operation costs and GHG emissions from fuel consumption. District cooling can also help reduce electrical demand and strain on the grid that typically occurs in the late afternoons of summer months.

District Energy Benefits

One of the primary benefits of a district energy system is that the fuel source can be changed at a future date (e.g., to renewable biogas). This switch can also be made en masse (i.e., the entire district) in comparison to individual heating systems for each building in a development.

According to the guidelines created by Carou for the City of Toronto[22], buildings in a new development can easily be designed to be district energy ready. This can be as simple as providing space in each building for future equipment and thermal piping and designing the building mechanical systems to be compatible with a future district energy service. In the case of a multi-building development, a district energy system could be established by designing a single, slightly larger mechanical room in one building and connecting the other buildings through a thermal energy distribution network. The mechanical room would include the equipment necessary to serve other buildings being constructed on the site, and connected buildings would be designed to be district energy ready.

Once operational, the systems are inexpensive and simple to operate and maintain, which allows for a forecasted internal rate of return for district energy system ranges from 10% to 14%.

District Energy Considerations and Barriers

The construction of a new district energy system is a major infrastructure project that requires high upfront costs. These systems require underground pipe installations to connect the buildings to the plant, and often require connecting CHP systems to the power grid. Because of these considerations, the most important factor in developing a viable business case for a district energy system is securing long term contracts

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[22] Carou, Fernando. *Design Guidelines for District Energy-Ready Buildings.* October 2016. www.toronto.ca/wp-content/uploads/2018/01/96ab-District-Energy-Ready-Guideline_October-2016.pdf pp. 2

(e.g., 20 years) with an energy-dense customer base, as the financial return from a district energy system increases as the heating density and heating load increases.

Saskatoon's District Energy Status

In 2010, the City of Saskatoon began work with consultants to supply buildings with heat from a District Energy System (DES), in anticipation of developing its North Downtown. The planned natural gas cogeneration concept was to capture the waste heat from the natural gas fired reciprocating engines used to produce electricity. The capital cost estimated for this project was between $54,000,000-$59,000,000 and has not been further pursued since the design work was completed in 2015.

The feasibility study found that the proposed North Downtown redevelopment was well-suited to a district energy application. A district energy system was modeled based on the land absorption or growth rate anticipated for the development. The total cost over all phases is $39.6 million. The electrical power output of the proposed CHP plant is 7 MW, which could provide enough power for 4,200 homes.

The City has installed CHP systems at two recreational facilities – Lakewood Civic Centre and Shaw Centre, which each cost $600,000-$700,000. These systems can reduce the facilities' heating and electrical demand by 50-68% and provide annual operational savings of over $30,000 each.

Municipal Examples

City of Richmond, BC Geoexchange systems

The City of Richmond completed its first district energy system in 2012, the Alexandra District Energy Utility (ADEU). This system uses ground source heat pumps for heating, cooling and hot water and supplies this energy to 1700 residential homes. Heat is extracted using multiple boreholes at 250 feet in depth and disturbed through a network of buildings with pipes. The ADEU won the Global District Energy Climate Award in 2021 under the Emerging District Heating and Cooling Market category[23].

Rural Municipality of Ritchot, MB - Geoexchange system

Richot also has a district energy system which uses ground source heat pumps. The district energy system provides heating and cooling to a community center, an arena, and a fire hall in the small community. This system has achieved energy savings of 60% compared to a standard fossil fueled system and received funding from FCM to complete the project[24].

City of Yellowknife's Biomass District Energy System

Yellowknife installed a district energy system for City facilities, providing heating for the multiplex arena, a soccer field house, the fire hall, and a couple of City garages. Combined, they previously used over 360,000 liters of heating oil every year and

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[23] "Alexandra District Energy Utility – Richmond, Canada" *Global District Energy Climate Award.* www.districtenergyaward.org/wp content/uploads/2019/09/0cb8cc684e864c57bf8d1863b58e24dftmp1.pdf. Accessed October 2022

[24] "Case study: Energy-efficient community centre uses geothermal heat" *Green Municipal Fund, a program of FCM.* fcm.ca/en/resources/gmf/case-study-energy-efficient-community-centre-uses-geothermal-heat. Accessed October 2022

produced over 1000 tonnes of CO_2 GHG emissions. The heat is now provided by a 970kW biomass boiler. The biomass district energy system reduces operating costs and GHG emissions, and in 2018 was the winner of FCM's Sustainable Communities Awards in the energy category[25].

City of Markham, ON – Gas combined heat and power system

As featured in the International District Energy Association's District Energy Magazine in 2013, the City of Markham owns a district energy utility that manages two district energy systems. These systems use combined heat and power and a gas-fired boiler and serve a regional hospital, higher schools, a community center, and other community members. These systems reduce GHG emissions by 50% compared to a business-as-usual heating system[26].

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[25] "Case study: Switch to biomass cuts costs and GHG emissions in Yellowknife" *Green Municipal Fund, a program of FCM.* greenmunicipalfund.ca/case-studies/case-study-switch-biomass-cuts-costs-and-ghg-emissions-yellowknife. Accessed October 2022

[26] Ander, Bruce. "Cornell Centre, Ontario: Markham's continuing commitment to district energy, CHP and city building" *District Energy,* Third Quarter 2013. www.markhamdistrictenergy.com/wp-content/uploads/2014/03/IDEA-3Q13-Cover-Story-1.pdf

Waste to Energy

A waste to energy (WTE) facility uses municipal or industrial waste in an energy recovery process. Common waste byproducts like landfill gas and biogas can be used for energy. Direct waste products, such as wood waste, can also be used to create energy through combustion.

Landfill Gas

As organic waste decomposes at the landfill, it produces landfill gas that contains almost equal parts methane and carbon dioxide. The collection process of this gas involves covering or "capping" a section of the landfill with clay, drilling vertical wells into the waste, and connecting them with underground piping. Vacuum compressors then capture the gas and pipe it to a blower/flare station where it is either piped to the power generation facility or combusted in a flare. During the flaring process, the methane is converted to carbon dioxide, a less harmful gas (methane gas is about 25 times more harmful to the atmosphere than carbon dioxide). While effective at reducing methane gas emissions, ending the process at this point makes no use of the heat energy that is produced during the conversion. Alternatively, after the gas is collected, it can be piped to a power generation facility and combusted in two engine-generator sets to generate electricity.

Saskatoon's Landfill Gas Capture Status

The landfill gas collection and power generation system has been operating since 2014. The system includes a collection facility and a power generation facility. The collection facility includes vertical wells drilled into the waste in the landfill and underground piping connected to a vacuum compressor that collect the gas that is produced and pipe it to the power generation facility. Gas is then combusted in engine-generators to generate electricity.

As reported in the Climate Action Plan Progress Report, in 2020 the landfill gas system extracted a total of 200,000,000 standard cubic feet of landfill gas. 95% of this was used to generate 10,600 MWh of electricity and the other 5% was destroyed within the facility's enclosed flare[27]. Ideally, all gas captured by the system would be utilized for electricity generation. However, factors including poor gas quality, generator maintenance, and grid connection limits resulted in gas being flared. The City will need to identify opportunities to utilize more of the gas given these limitations to avoid flaring.

Biogas

Biogas is a by-product created during the digestion of solids removed in the wastewater treatment process. Digestion of the solids occur in three digesters. These biogases are composed of approximately 65 percent methane, 35 percent carbon dioxide and trace amounts of hydrogen sulphide. This gas can be used as a fuel for boiler heating.

Saskatoon's Biogas Production Status

At the Saskatoon Wastewater Treatment Plant (WWTP), produced biogas is captured and used as a fuel for the boilers that heat the many buildings and digesters on site. By

[27] "Climate Action Plan: Progress Report 2020" *City of Saskatoon*, April 2021, www.saskatoon.ca/sites/default/files/documents/climate_action_plan_progress_report_2020-webprint.pdf, pp. 35

using the energy from biogas, the WWTP saves money in heating costs and reduces GHG gas emissions.

In 2022, the City announced the facility's completion of its Digester and Heating Upgrades project, which included a new biogas scrubbing system[28]. This upgrade increased the system's generating capacity to 5.88MW and enables >90% of the biogas to be re-used as energy, instead of being flared[29].

Biomass Energy

As described in the Canadian Encyclopedia, biomass energy is the conversion of combusted biomass to electricity, through various thermodynamic technologies. The biomass material used can range from forestry and agricultural byproducts, to industrial and household mixed solid waste, depending on the technology. The material is often considered renewable given the shorter turn-around for its production in comparison to fossil fuels (i.e., less than 10 years compared to 1000s of years). The material can be processed as a solid, liquid, or gas, such as wood chips, vegetable oils, or landfill gas, respectively[30].

Current technology often proposes using waste wood from forestry sector, grains and agricultural waste including grain dust from granaries, and municipal solid waste (MSW) as their fuel source. Including MSW allows for the use of a broader range of materials but does lose some conversion efficiency and requires source-separation of any undesirable waste feedstock.

Biomass source: Forestry

Current forestry practices result in residual biomass, such as undesirable trees for the industry, as well as branches, bark, trunks, and stumps. If too much material is left in one area, it risks becoming a fire hazard, a medium for the spread of pests and disease, or an impermeable layer on the forest floor that reduces plant production. If surplus material cannot be left in the forest without negative impacts, removal and hauling the additional volume to biomass energy facilities to be used as fuel would be preferred. However, productivity losses have been observed in forests where intensive removal of biomass is practiced. According to Natural Resources Canada, the ideal removal of biomass will depend on many factors, including the forest's health, soil, and climate[31].

Also mentioned in the Canadian Encyclopedia, in areas without a forestry industry, such as the Prairies, there is an opportunity to convert marginal and sub-marginal agricultural land, as well as non-agricultural land, into forest farms that can be harvested every 10 years.

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[28] "Digester & Heating Upgrades" *City of Saskatoon.* www.saskatoon.ca/services-residents/power-water-sewer/wastewater/wastewater-treatment-plant/digester-heating-upgrades. Accessed October 2022

[29] Sadowski, Mike (Wastewater Treatment Plant Manager). Personal interview. 7 July 2020

[30] Cruickshank, W., Robert, J., Silversides, C. "Biomass Energy". *The Canadian Encyclopedia.* September 2014. www.thecanadianencyclopedia.ca/en/article/biomass-energy

[31] "Forest Bioenergy" *Natural Resources Canada*. www.nrcan.gc.ca/our-natural-resources/forests-forestry/forest-industry-trade/forest-bioeconomy-bioenergy-biop/forest-bioenergy/13325. Accessed October 2022

However, if current native ecosystems are disrupted for high-yield forest farming, there will be a loss of biodiversity and natural regulating services to the region. Carbon storage may also be disturbed – the average soil organic carbon stored in wetlands is 175.1 tonnes per ha, and for grasslands, the average soil organic carbon stored is 135 tonnes per ha[32]. In comparison, the average annual carbon sequestration for forests/shrubs is 10.17 tonnes C/ha/year[33], although any carbon sequestered by the farms will ultimately be re-emitted once harvested and processing for energy.

Biomass source: Agriculture

Most biomass technology can include agricultural straws, processor plant by-product, and almost any combustible agricultural waste. Agriculture residuals often have alternative purposes available onsite for their management, such as animal fodder, or soil amendment. The seasonality of agricultural residue makes it less reliable year-round for harvesting than forestry residuals or mixed solid waste.

Biomass source: Solid Waste

Possible usable solid waste inputs for feedstock include demolition wood products, rail ties, paper, cardboard, plastics, tree/yard waste, carpet, tires, shingles, food waste, etc. If the City were to supply its MSW to a Biomass energy facility, the arrangement would need to be in alignment with the City's waste reduction and diversion goals. While energy recovery (e.g., biomass technology) is prioritized before disposal in the hierarchy of waste management options, it should only be considered if the waste cannot be reduced, reused, repaired, or recycled first.

Paper, cardboard, tires, food waste and tree/yard waste have established and sustainable recycling options available and would not be prioritized for WTE. Composite materials, or materials that contain chemicals, such as some plastics, construction waste, and rail ties, however, may be currently better suited as energy recovery feedstock. As the City strives for waste reduction at the source, less and less feedstock input should be available for energy production though waste combustion. Further consideration for waste feedstock would be whether the material contains high concentrations of metal or minerals that may require additional considerations for disposal of the residual ash.

GHGs

Biomass combustion when using forest farms is generally considered "carbon neutral", since the trees will typically emit a comparable amount of CO_2 when combusted that

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[32] . Badiou, P. et.al, "Greenhouse gas emissions and carbon sequestration potential in restored wetlands of the Canadian prairie pothole region" *Wetlands Ecology and Management*. March 2011. Doi: 10.1007/s11273-011-9214-6.

[33] Pasher, J., McGovern, M., Khoury, M. and Duffe, J., "Assessing carbon storage and sequestration by Canada's urban forests using high resolution earth observation data" *Urban Forestry & Urban Greening*, 2014., Doi: 10.1016/j.ufug.2014.05.001. pp.484-494

they sequestered while growing [34,35,36]. The emissions will vary depending on the efficiency of the technology and the fuel type. However, intensive forest farming can be in direct opposition to current carbon sequestering practices such as protecting forests and wetlands and diversifying and rotating crops.

Emissions produced from transporting feedstock to a generating facility would also need to be included in emissions calculations if feedstock other than Saskatoon's MSW is used. The GHG Protocol tool for mobile combustion estimates that for every 100,000 tonnes of material hauled 1 km, 20.4 tonnes of CO_2e are emitted[37].

Examples

In some cases, biomass facilities can be an effective carbon-neutral solution for energy production. For example, through the First Nations Power Authority, Meadow Lake Tribal Council has completed the construction of a Biomass facility plant that processes the wood waste from the nearby NorSask Sawmill. Since the material is just wood waste, the technology can be simple combustion with an ORC generator. The system is expected to produce 6,600kW (net) of carbon neutral baseload electricity to power approximately 5,000 homes. According to the project's website, the project is expected to decrease greenhouse gas emissions by more than one million tonnes over 25 years[38].

This solution is appropriate for the area; the energy produces is sold to SaskPower and fed into the grid, which improves the province's overall emissions and bolsters the local job market. The fuel source is also readily available with minimal transportation, and without a competing alternative use, as their one available composting program does not accept woody products larger than branches[39]. The generating capacity of the facility is also within an acceptable range for grid interconnection with SaskPower without major payload considerations.

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[34] Danish, Zhaohua Wang. "Does biomass energy consumption help to control environmental pollution? Evidence from BRICS countries" *Science of the Total Environment*. Volume 670 June 2019. Doi: 10.1016/j.scitotenv.2019.03.268. pp. 1075-1083

[35] Sarkodie, S, Strezov, V., Weldekidan, H., Asamoah, E., Owusu, P., Doyi, I., "Environmental sustainability assessment using dynamic Autoregressive-Distributed Lag simulations d nexus between greenhouse gas emissions, biomass energy , food and economic growth" . *Science of the Total Environment*. Volume 668 June 201 . Doi: 10.1016/j.scitotenv.2019.02.432, pp. 318-332

[36] Balezentis, T., Streimikiene, D., Zhang, T., Liobikiene, G., "The role of bioenergy in greenhouse gas emission reduction in EU countries: an Environmental Kuznets Curve modelling" *Resources. Conservation, and Recycling*. Volume 142 March 2019. Doi: 10.1016/j.resconrec.2018.12.019 pp. 225-231

[37] "GHG Emissions from Transport or Mobile Sources" *Greenhouse Gas Protocol*. May 2015. ghgprotocol.org/calculation-tools

[38] "About The Project" *Meadow Lake Tribal Council BioEnergy Centre.* mltcbioenergy.ca/about/. Accessed October 2022

[39]"Resident Services: Garbage and Recycling" *City of Meadow Lake*. meadowlake.ca/p/garbage-and-recycling*.* Accessed October 2022

Municipality of Saint-Ubalde, QC – Biomass district energy system

The municipality of Saint-Ubalde previously relied on oil to heat a variety of buildings including community buildings, a church, its town hall, schools, and the municipal library. In 2014, the municipality developed a district energy system that uses biomass waste from a sawmill nearby. The system produces 110KW total and is connected by a network of boilers and underground pipes which circulate waste and glycol for heating. The biomass system has saved $15,000-$20,000 in energy costs just from the church building[40].

Saskatoon's Biomass Energy Status

While Administration has not been actively pursuing biomass technology, SL&P has received multiple unsolicited informal proposals from potential service providers, some of whom claim 150MW+ of generating capacity. This amount would significantly disrupt the relationship between SL&P and SaskPower since SaskPower currently provides SL&P with about 200 MW of electricity. If the City were to pursue purchasing Biomass energy, an agreement would be required between SL&P and SaskPower to purchase this power.

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[40]"Réseau de chauffage collectif et usine de séchage de copeaux de bois pour la municipalité de Saint-Ubalde" *FCM.* August 2016. data.fcm.ca/documents/reports/gmf/2017/GMF_12057_CREP_FR_2017.pdf

Nuclear Energy

Nuclear energy is generated through the reaction of milled, refined, and converted uranium. This process is known as nuclear fission and does not produce GHG emissions. However, uranium is a finite resource. According to the Pembina institute, at current levels of consumption, Canadian reserves of the metal are estimated to be sufficient for 40 years[41].

While commercial power reactors can be quite large (around 1000MW), small modular reactors (SMRs) are being designed for better sizing to meet the energy needs of less populated regions. SMRs are small in both power output (up to 300MW) and physical size, and they are factory constructed, portable and scalable.

SMRs could be used to replace end-of-life coal plants with non-emitting base-load plants of similar size. They could also be used for on- and off-grid combined heat and power for heavy industry. Also, small SMRs could provide off-grid power, district heating, and desalination in remote communities.

Nuclear Considerations

Nuclear power generating facilities can be expensive and require long construction times. The handling, storing, and managing of waste fuel and other radioactive wastes is another cost consideration particularly important to nuclear energy. Managing waste and decommissioning reactors can be a substantial portion of the project's entire budget. Nuclear waste sites have also been identified by the Pembina Institute as potentially severe targets of attack with particularly severe consequences of releasing radioactive material into the environment (Winfield et al, 88).

As described by Coxworth for the Saskatchewan Environmental Society, SMRs would have most of the same environmental disadvantages as large reactors. They would generate the same kinds of waste, but in smaller quantities and decentralized across the region. Small reactors are expected to require either enriched uranium or plutonium as fuel, which has a higher concentration of radioactivity per kilogram than the wastes from CANDU reactors that use natural uranium[42].

Saskatoon's Nuclear Status

Saskatoon does not currently have any Nuclear Energy generation projects, and conventional nuclear plants are too large for Saskatchewan's entire power grid.

However, the Government of Saskatchewan signed a Memorandum of understanding with the governments of New Brunswick and Ontario to collaborate in supporting the development and deployment of nuclear power from small modular reactors. In June 2022, SaskPower selected GE Hitachi Nuclear Energy's BWRX-300 SMR for potential

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[41] Winfield, Mark, Jamison, Alison, Wong, Rich, and Czajkowski, Paulina. “Nuclear Power in Canada: An Examination of Risks, Impacts, and Sustainability”. *Pembina Institute.* www.pembina.org/reports/Nuclear_web.pdf. pp. 88-91

[42] Coxworth, Ann. “Small Modular Nuclear Reactors” *Saskatchewan Environmental Society.* August 2020. environmentalsociety.ca/wp-content/uploads/2020/11/Small-Modular-Nuclear-Reactors.pdf

deployment in the province in the mid-2030s after an assessment process in which it looked at several SMR technologies.

SaskPower has also selected two potential sites for SMR deployment – Elbow and Estevan. Work will now begin on environmental and impact assessments and the Regional Evaluation Process (REP), which includes stakeholder engagement.

The Government of Canada has also created a Small Modular Reactor (SMR) Action Plan[43] to lay out the next steps to develop and deploy this technology. These steps will be in collaboration with utilities, provinces and territories, Indigenous Peoples and communities, industry, innovators, laboratories, academia, and civil society.

[43]"About the Action Plan" *Canada's Small Modular Reactor: SMR Action Plan*. smractionplan.ca/. Accessed October 2022.