Renewable Energy Options

For Government of Yukon Buildings

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Green Infrastructure Program

Preface

This document is contains information on renewable energies that Energy Management Unit, Department of Highways and Public Works has conducted preliminary internal research and analysis on.

The renewable energy industry is growing rapidly; this list is intended for use as initial considerations to provide some guidance to projects exploring renewable energy options to be implemented in Yukon government buildings. The technologies listed in this document require further investigation, additional resources, or potential collaboration with external parties for implementation. Project managers and consultants are expected to conduct further assessments based on current market and site conditions in order to verify assumptions and determine suitable renewable energy options for each project.

This list is not exhaustive, it represents options that we are consistently evaluating for renewable energy projects. We also encourage innovative renewable energy sources not captured in this document, provided they are relevant and practical in application**.** This document will be periodically updated as new information from ongoing research and analysis becomes available.

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Renewable Power Options

Photovoltaic Solar Installations (PV)

A photovoltaic (PV) system is composed of one or more solar panels that convert UV rays from the sun into electricity. Sunlight cause electrons to move between multiple conductive layers of different material. This movement of electrons generate direct current (DC), and needs to be converted to alternating current (AC) in order for it to be integrated into the building's existing electrical grid. PV systems require minimal maintenance as they do not contain any moving parts.

Photo by American Public Power Association on Unsplash

➤ Efficiency:

- Current solar panel efficiency is typically around 15-20%, though this is expected to increase as solar industry continues to evolve.
- Sunlight drastically drops during the winter season in the North. PV systems are not expected to produce any electricity during January and December.
- Productivity of solar panels decrease over time due to material degradation from the continuous flow of electrons and from the elements.

➤ Maintenance:

- PV systems are stationary; the absence of moving parts minimizes maintenance.
- New panels are expected to last up to 30 years and inverter components have an expected lifespan of 10 years. However, PV technology may be considered outdated 10 years after implementation since the technology may be exponentially more efficient, making the full asset lifespan irrelevant for asset lifecycle costing.

➤ Flexibility and Practicality:

- PV panel installations are flexible; they can be connected to a larger grid or as stand-alone systems, depending on the owner's preference or building requirements.
- PV systems require a large uncovered area in order for maximum efficiency. Nearby trees can impact its generation potential.
- Battery systems can be used to increase the practicality of PV systems, especially for off-grid buildings. Though costs for battery systems are dropping, they remain fairly high and have short lifespans of approximately 7-10 years. Research is underway to find innovative ways to increase battery life and system efficiency such as pairing PV with Electric Thermal Storage (ETS).

➤Financial Feasibility:

- PV system sizes can be flexibly scaled according to available budget.
- On-site renewable electrical generation can mitigate risks associated to rising energy costs. Yukon government pays increased electrical rates to subsidize Yukoners.
- Reasonable payback of approximately 8-10 years, despite high initial investment costs.
- Eligible for many federal funding programs that are aimed to reduce GHG emissions, reduce Northern reliance on diesel, and to improve energy independence in the North.

➤PV Risk Assessment

Risk type	Risk	Mitigation
Implementation	Amount of sunlight is limited in the north and low efficiency.	South-facing two tier panel inclination systems can maximize generation potential for northern summers and winters. Panel orientation and efficiency analysis are required prior to installation.
Implementation	Older buildings with flat roofs may not be able to support the additional weight of the racking system	Systems should be prioritized on buildings with sloped roofs. Buildings with flat roofs will need to assess its structural integrity and weight limit prior to installation.
Environmental	PV panels contain toxic materials that may harm the environment if leached.	Proper disposal and recycling of panels is recommended when the system reaches end of life.
Environmental	Upstream environmental impacts of PV system's production, such as the use of hazardous materials, resource extraction, and material processing, are a common criticism of photovoltaic systems.	This criticism is well known and may be addressed by the industry in the near future, with more environmentally conscious production methods. YG can continue to monitor new technologies to ensure we are purchasing products compliant with industry standards.

Micro Hydroelectricity

Micro-hydro systems are small hydropower turbines that use the flow of a nearby water source, such as a small river or creek, to generate electricity of less than 100 kilowatts (kW). Many micro-hydropower systems operate "run of river," which means that no large dams or water storage reservoirs are built and no land is flooded. The majority of these systems only use a fraction of the available stream flow to generate power, and this has little environmental impact. Micro hydroelectric systems should only be considered when a known water source is nearby.

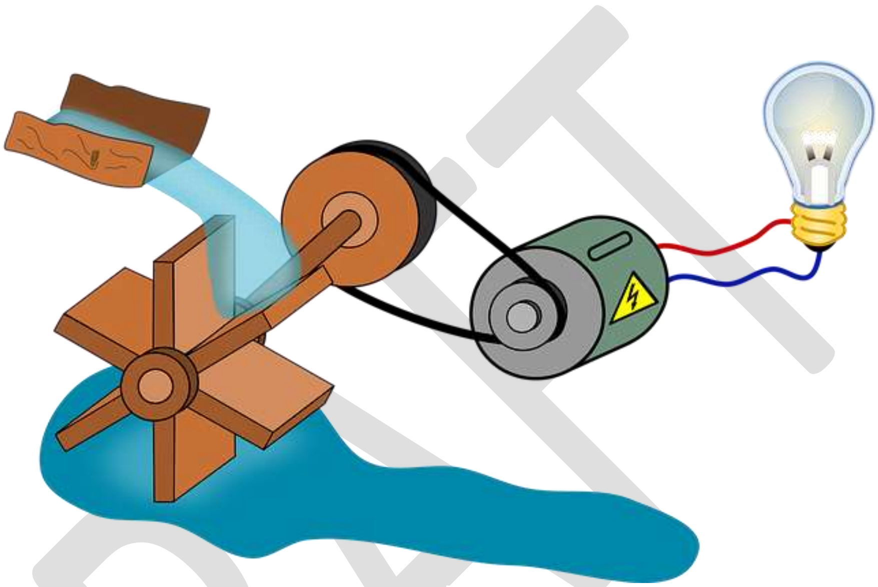


Image by [Jan Helebrant](#) from [Pixabay](#)

Fraser river micro hydro generator shed. Image by [Priyank Thatte](#)

➤Efficiency:

- Micro-hydropower output efficiency is the most predictable of all the renewable energy (RE) electrical systems as it has consistent power generation potential throughout the year. Many other systems, such as PV panels, have seasonal generation capacity.
- The micro-hydro potential of any given site relies on the anticipated electrical demand for the site and the size of the existing resource. The main factors limiting power generation are head and flow rate. The head consists of the vertical drop between the intake and turbine, while flow rate describes the amount of water that passes in a given time period.

➤Maintenance:

- Newer models have reduced moving parts, lowering maintenance costs.
- Micro-hydropower systems have an estimated life span of up to 30 years.
- Maintenance requires specialized expertise, which can be a challenge for remote areas.
- Additional maintenance considerations are required for small water sources with high risks of icing up.
- Hydro electric systems should consider debris mitigation for projects in fast moving creeks and rivers.

➤Flexibility and Practicality:

- Like PV systems, micro-hydropower can be either connected to a larger grid or a stand-alone system.
- There is a wide range of Micro-hydropower equipment and system configurations available to match the conditions of the site and of the body of flowing water.
- Micro-hydro systems have less versatility and flexibility than other types of renewable electrical generation systems dues to the constrictions of geographical requirements.

➤Financial Feasibility:

- Micro-hydropower can produce many times more power and energy than other renewable electrical technologies for the same capital investment.
- The costs of a micro-hydro system increases drastically when water needs to be diverted long distances.
- The initial development costs are very high, resulting in long payback periods despite its high generation capacity.

➤Micro Hydroelectricity Risk Assessment

Risk Type	Risk	Mitigation
Implementation	Micro-hydro water resources can change over time and are not always in convenient locations. The effective utilization of the resource is key to successful implementation.	Micro-hydro systems should only be considered for buildings near a running water source. Conduct a feasibility assessment by a certified hydrologists in conjunction with mechanical contractors to ensure minimal impact.
Maintenance	Remote sites may not have access to the necessary expertise to operate and service a micro-hydro system.	Identify available resources for servicing the equipment as part of the feasibility study.
Environmental	Construction can damage fish, aquatic, and other types of habitat.	Authorized contractor should conduct appropriate environmental assessments prior to construction and acquire necessary permits.
Legislation	Constructions that impact a body of water will require YESAA assessment. Water licenses with Yukon Water Board may also be required.	Additional time and budget of 6-8 months should be allocated for a YESAA assessment and conformity with any additional regulations

Wind Energy/Power

Wind power describes the process by which wind is used to generate electricity. Wind turbines are generators which can convert the kinetic energy in the wind into electricity. Wind power can also be used for specific tasks such as pumping water. Almost all modern wind turbines consist of a three blade assembly mounted upwind of the turbine tower. The blades are mounted to a horizontal drive shaft which is onnected either directly to the generator (direct drive) or indirectly to the generator via a gearbox. Wind power can become more reliable when used in a hybrid hydro-wind system that pumps water up to a reservoir when excess wind power is generated to be used in a micro hydro system that provides power when there's no wind.

Photo by Ferdinand Stöhr on Unsplash

➤ Efficiency:

- Three key factors affect the amount of energy a turbine can harness from the wind: wind speed, air density, and size of the blades (swept area). Picking the appropriate wind turbine (power curve) and tower size will help maximize electrical production.
- A wind turbine is typically 30-45% efficient – rising to 50% efficient at times of peak wind. Wind turbines can never reach 100% efficiency as this would mean the wind would come to a complete stop and not flow through the blades.

➤ Maintenance:

- With proper installation and maintenance, a small wind electric system should last up to 25 years.
- Blades and bearings may need to be replaced throughout the systems life based on wear and tear.
- Wind power in northern climates pose additional maintenance challenges including: accumulation of ice on wind turbine blades reduces power output and increases rotor loads. Cold weather can also require shutdowns to avoid equipment failures and limit or reduce access for maintenance activities.

➤ Flexibility and Practicality:

- The development of wind power projects are limited to areas with proven wind activity and favorable terrain. Significant line loss can occur if there are long distances between the turbines and the building they are powering.
- Wind turbines can be grid connected or used as a stand alone system. If used as a stand alone system off-grid, a hybrid set up with wind, solar or micro-hydro can increase the system reliability.

➤ Financial Feasibility:

- Asset lifecycle costs relies heavily on the wind available at the proposed location.
- Large initial investments are needed for the procurement and installation of wind systems.
- Large down times and unanticipated changes in operational efficiency can have a large impact on payback periods and the financial feasibility on wind systems

➤ Wind Energy Risk Assessment

Risk Type	Risk	Mitigation
Implementation	Sites may lack sufficient wind activity for power generation.	A feasibility study should be conducted and include a detailed resource report used to determined the site potential wind power generation.
Maintenance	Wind turbines require relatively frequent maintenance that demands unique expertise.	Identify available resources for servicing as part of the feasibility study.
Maintenance / Implementation	Northern climates increase operating efficiency challenges such as ice build up, increased down time, and mechanical system failures.	Select turbine manufacturers offer “cold weather packages” which allow for lower operating temperature. Various types of rotor blade de-icing and anti-icing mechanisms, such as heating and water-resistant coatings as well as operational strategies to limit ice accumulation should be considered.
Health and Safety	Severe storms and high winds can cause damage to the blades of the wind turbines. The malfunctioned blade can be a safety hazard to people working on or near the wind system.	Routine monitoring and inspection processes should be established to ensure effective operations and reduce the risk of injury from system malfunction.

Renewable Heating Options

Solid Biomass

The term biomass is used to describe any biological material that originated in living organisms. In terms of energy, GY is exploring the use of wood chips and densely compacted wood pellets as potential heating fuel sources to offset fossil fuel consumption and reduce GHG emissions. However, while biomass has the potential to reduce greenhouse gas emissions when compared to fossil fuel use, its associated lifecycle emissions remains unclear. Yukon government is currently working to quantify the true carbon impacts of biomass so it can be incorporated into future plans for biomass systems.

The use of biomass supports the 2016 Biomass Energy Strategy by upholding the key action area of using biomass energy in government infrastructure. The local biomass industry is in its infancy and the use of biomass fuel is expected to incur increased financial and operational risk for GY.

Image by Hans Braxmeier from Pixabay

➤Efficiency:

- Modern wood pellet and chip heating systems offer automated fuel feeds, advanced emission controls, and controlled combustion which increases the efficiency and effectiveness of new biomass systems.
- Biomass systems are most efficient when running near capacity and therefore needs to be designed based on anticipated heat load. Use of multiple boilers may provide better optimization opportunities, though a single feeding system may reduce operational risk.
- Efficiency of biomass systems are heavily dependent on the quality of wood chips. Key factors such as moisture content, particle size, and ash content have direct implications to its heat output, systemic wear and tear, and maintenance required to sustain operations. This is one of the main challenges of wood chip systems, especially since the local industry has yet to prove they can produce fuel of this necessary quality. The risk of subpar wood pellets is considered to be lower due to the rigorous process required for production.

- The inclusion of a fuel dryer, a heating element added into the fuel feeding system, may improve combustion efficiency and reduce operational risk.

➤Maintenance:

- Biomass burners can last up to 25 years minimizing the frequency of replacement.
- Biomass systems have more moving parts then conventional heating systems due to the mechanical feeding mechanisms of solid fuels. This paired with frequent ash removal causes high maintenance costs.
- The amount of maintenance required for a biomass system is heavily dependent on the quality of fuel provided. Poor quality fuel increases ash disposal frequency and operational challenges such as breakdowns and increased wear and tear.

➤Flexibility and Practicality:

- The implementation of biomass systems in Government of Yukon buildings creates economic development within the territory by supporting the growth of a local biomass industry.
- Wood fuel is relatively safer to handle, transport, and store than fossil fuels.
- Some biomass systems are capable of co-generation and can provide both heat and electricity.

➤Financial Feasibility

- Long-term projections show rising fossil fuel prices and instability whereas biomass fuel projections show stable long term prices.
- Less economically viable for small buildings due to large installation costs.
- Biomass systems require a large initial investment and have high ongoing maintenance costs.

➤Biomass Risk Assessment

Risk Type	Risk	Mitigation
Implementation	The quality and reliability of biomass fuel is essential to the effective implementation of a biomass system. It is undetermined whether the local biomass industry will be able to consistently supply the amount or quality of fuel demanded. It is also important that our suppliers be able to maintain operations for the entirety of the contract period.	Engaging with Forest Management Branch and Wildland Fire will encourage adequate timber supply is available in every region to meet out anticipated demand. This will remove barriers for our local biomass industry allowing them to access the raw materials needed to create biomass fuel. Engaging with the industry about upcoming projects and creating policies showing our commitment to biomass will help the industry be proactive in creating a reliable supply of biomass fuel.
Maintenance	Low fuel quality, particularly for wood chips, may increase	The inclusion of a fuel dryer in the feeding system can lower moisture content prior to combustion.

	frequency of breakdowns and accelerate wear and tear.	Fuel supply contracts can include specifications for fuel quality and fuel quality reporting/management.
Maintenance	Some regions may not have access to the necessary expertise to operate and service a biomass system.	Identify available resources for servicing the equipment as part of the feasibility study.
Environmental	Biomass combustion creates air pollution and may fosters unsustainable forestry practices.	Ensure the location, stove selection, installation, and maintenance practices adhere to air pollution standards. Ensure the supply of biomass fuel purchased are harvested and managed sustainably according to the Forest Resources Act.

Electric Thermal Storage (ETS)

Electric thermal storage (ETS) is a proven and established technology that allows for heat generated from electricity to be generated at a time that differs from when that heat is needed using a storage medium. While the storage medium can be a variety of materials, solid materials like ceramic or magnetite bricks are most common. ETS systems are highly scalable but are typically used as a distributed energy resource, installed within the buildings they're heating. A pilot project is underway that is studying whether the benefits of ETS that have been proven elsewhere – including across the United States including Alaska and the Canadian maritime provinces – can be replicated here in Yukon.

➤Efficiency:

- ETS systems typically use resistive heating to produce heat, which is 100% efficient.
- Some ETS furnaces and space heaters minimize standby losses by using bricks contained within an insulated steel box. However, any standby losses that do occur do not significantly impact system efficiency as the "losses" are lost to the heated space that the system is heating nonetheless.
- Passive ETS-style "ECOMBI" baseboards are also available, though controlling heat released from a passive heater is inherently less refined than from an active system.

➤Maintenance:

- ETS systems – particularly passive ETS technologies – are low maintenance heating systems. Systems typically last 20+ years, with moving parts like fans the most likely to need replacement within that timespan.
- Annual inspections are recommended, particularly for systems with moving parts.
- Maintenance requires additional expertise that local resources (electricians, HVAC technicians) are expected to have, with additional support from manufacturers and distributors.

➤Flexibility and Practicality:

- ETS systems come in a variety of shapes and sizes, from the smallest baseboard-style ECOMBI ETS unit to institutional hydronic units.
- ETS systems can use a variety of storage mediums, including ceramic or magnetite bricks, phase change materials, building foundations, and more. This variety allows for site-specific storage medium selection.
- ETS systems can be used in conjunction with heat pumps, including air-source heat pumps and central hydronic heating. This integration can reduce fossil fuel consumption and reduce GHG emissions.
- ETS systems require additional space and electrical capacity for implementation, which may be challenging for some buildings.

➤Financial Feasibility:

- ETS systems require significant electrical draw from the system. If not properly managed, an ETS system could increase peak demand resulting in prolonged electrical costs for the following 12 months. Measures need to be put in place to ensure ETS systems are only charged when the building's electrical draw is low, to avoid increasing its monthly peak demand.

➤ ETS Risk Assessment

Risk Type	Risk	Mitigation
Implementation	ETS systems may increase the maximum demand of individual institutional buildings, significantly increasing heating costs.	Work is underway to study the likelihood of this risk and mitigation strategies. Such strategies will likely include specific charging schemes to minimize demand charges.
Implementation	ETS systems' maximum draw may exceed the local distribution infrastructure's design capacity.	Development of a study to determine which areas of the Yukon Integrated System's distribution system are most likely to pose this risk and mitigation strategies to address this risk is underway.
Implementation	The selected control strategy may fail, such as in the case of an internet outage for units controlled through an online dashboard.	ETS systems typically continue to operate based on the latest control signal in the case of a communication failure, ensuring the building continues to be sufficiently heated.
Maintenance	With most ETS manufacturers based in the US and Europe, lead time on replacement parts may be problematic.	Spare parts should be ordered in advance of any issues and kept on hand to quickly address any issues that arise.
Financial	If not properly implemented, ETS could increase the building's peak demand and incur significant charges for the following year.	Measures need to be put in place to ensure ETS systems do not exceed the building's monthly peak demand. This can be done through strategic scheduling or through the Building Automation System.
Financial	ETS purchase and shipping costs are vulnerable to international risks, including USD/CAD exchange rate and international shipping costs.	As the demand for ETS units in Canada increases, so too does the likelihood of additional Canadian ETS manufacturers and distributions joining the market.

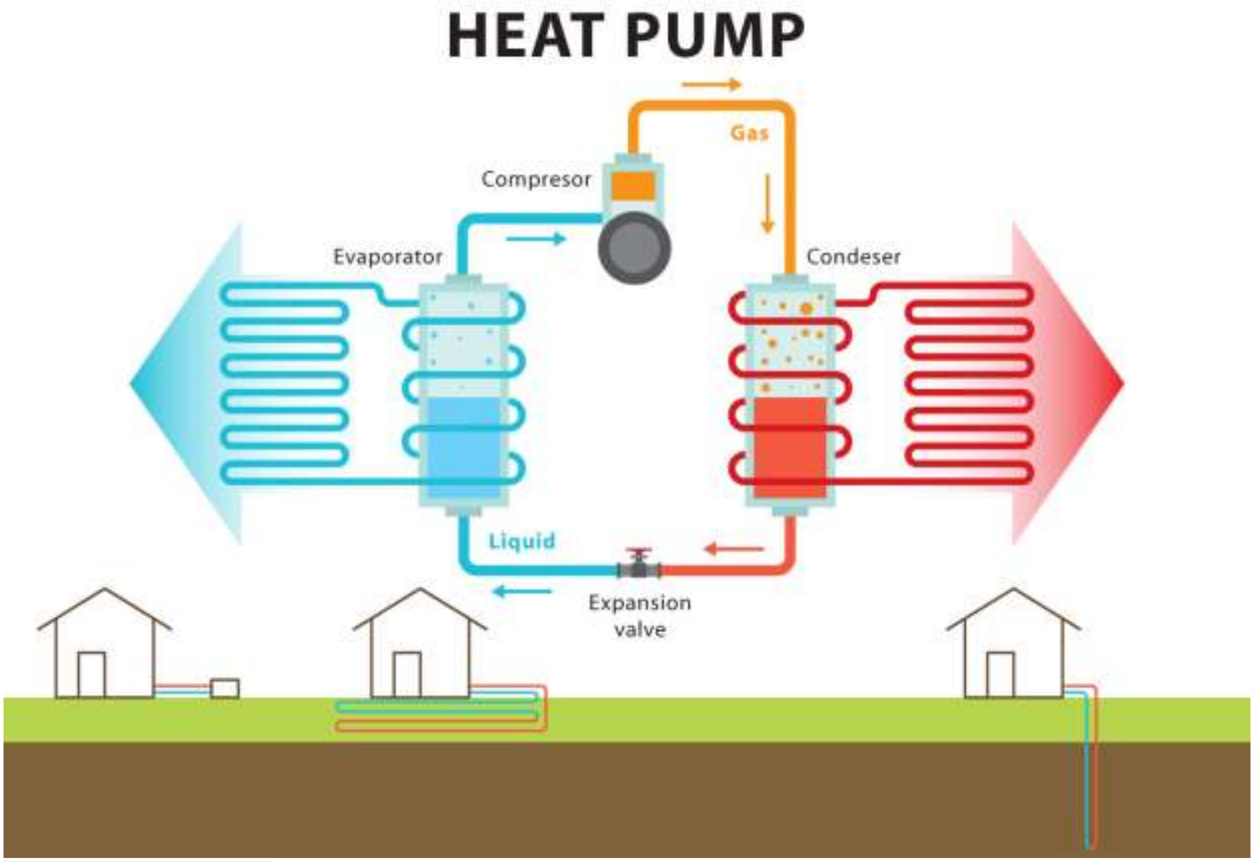
Heat Pumps

Heat pump systems are used to move heat from one location to another location. This technology is used to heat and cool buildings by using refrigerants to capture and reject heat where desired.

Heat pumps can be used to balance heat load within a building, transferring heat from a warmer zone to a cooler zone of the building. Under this configuration, heat pumps can simultaneously heat and cool the building with minimal energy use by simply transferring heat from one area of the building to another. This is most effective in buildings with different thermal needs and during shoulder seasons

Variations of heat pump applications are also used to add or extract heat from an external energy source, such as outdoor air (air source) or the ground (ground source).

Since heat pumps need electrical power to operate, these systems can further optimize efficiency and emission reductions when paired with renewable power systems such as solar panels.



[Heat Vectors by Vecteezy]

➤Efficiency:

- Heat pumps are inadequate when thermal demands exceed available heat within the building, such as during cold weather. A boiler can be added as a primary heating source to provide the additional heat required.

- These systems can regulate the temperature in specific rooms by transferring heat from the warmer typically south facing rooms to colder areas of the building. This satisfies both heating and cooling needs without generating increasing heating or cooling loads.

➤Maintenance:

- Heat pumps have a service life of 20+ years reducing the frequency and cost of replacements

➤Flexibility and Practicality:

- Advanced systems can incorporate hot water heating functionalities.
- Can act as thermal regulators that can heat or cool a building depending on the needs.

➤Financial Feasibility:

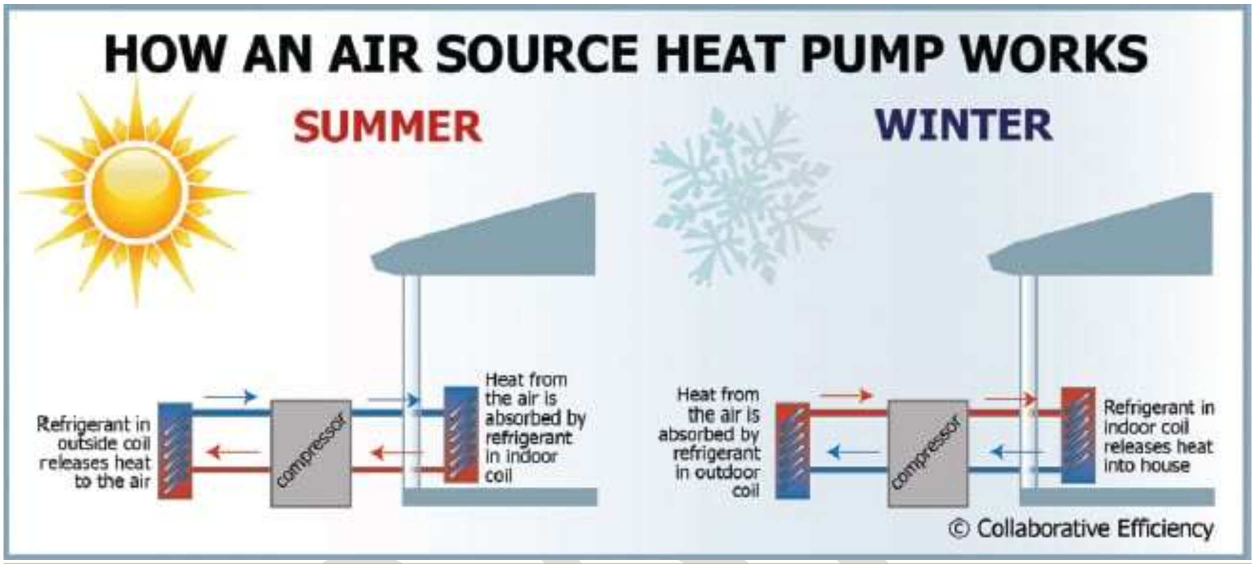
- Heat pumps have high initial cost which may be a barrier for widespread implementation.
- Cost savings are obtained by offsetting the use of conventional heating fuels.
- Additional savings by pairing with solar as both systems have increased efficiencies in shoulder seasons.

➤Heat Pump Risk Assessment

Risk Type	Risk	Mitigation
Implementation	The use on additional compressors and system related equipment may increase maximum capacity and cause increases in electrical costs.	Compressor systems can ramp up slowly minimizing capacity spikes or heat pump systems can be paired with a solar PV system since both are most effective in shoulder seasons.
Environmental	Heat transfer and refrigerant fluids are toxic and can pose an environmental risk if leaked or not disposed properly.	Proper disposal and recycling of system fluids is recommended when the system reaches end of life.

Air-Source Heat Pumps

Air source heat pumps can cool or heat buildings by releasing or extracting heat from outdoor air. These systems rely on a refrigerant cycle to maximize heat transfers, and can perform best in shoulder seasons when ambient air temperatures are within desirable temperature ranges.



Example of air source heat pump technology

➤Efficiency:

- Air source heat pumps work best in shoulder seasons and can reach coefficients of performance (COP) of 3.3 at 10 C and a COP of 2.3 at -8.3 C. This means a 10 degree weather a heat pump requires 1 unit of electrical energy to extract 3.3 units of thermal energy from outside air.
- Air source heat pumps' efficiency reduces during cold temperatures. This is being addressed by advances in refrigerants with lower boiling temperatures (-40C). A low boiling point increases efficiency in cold climates since the refrigerants can be vaporized in colder weather.

➤Maintenance:

- Air source heat pumps require more maintenance than other systems due to frost accumulation on heat pump evaporators in cold weather.

➤ Flexibility and Practicality:

- Air source heat pump systems require a primary heating source as it cannot provide building heating requirements when outdoor air temperatures are above acceptable thresholds for cooling or below acceptable thresholds for heating.

➤Financial Feasibility:

- Cost savings can be achieved through offsetting conventional heating fuel usage. Additional savings by pairing with solar as both systems have increased efficiencies in shoulder seasons and the one powers the other.

➤Heat Pump Risk Assessment

Risk Type	Risk	Mitigation
Implementation	Operational risk associated to high maintenance requirements of the system and decreased efficiency due to frost accumulation on heat pump evaporator (Air Source).	Plan seasonal system shut downs when the coefficient of performance begins to drop and frost builds on evaporator. Some ASHP systems can reverse cycle to defrost the evaporator in cold climates.
Implementation	The use on additional compressors and system related equipment may increase maximum capacity and cause increases in electrical costs.	Compressor systems can ramp up slowly minimizing capacity spikes or heat pump systems can be paired with a solar PV system since both are most effective in shoulder seasons.
Environmental	Heat transfer and refrigerant fluids are toxic and can pose an environmental risk if leaked or not disposed properly.	Proper disposal and recycling of system fluids is recommended when the system reaches end of life.

Ground-source Heat Pump (Geo-Exchange)

Ground-source heat pump, or geo-exchange systems, utilizes the energy from constant ground temperatures by using horizontal or vertical loops to capture low grade heat. These systems rely on a refrigeration cycle to move heat between the building and the ground, heating and cooling buildings through a series of coils and fans. Geo-exchange systems require specific ducting and underground infrastructure which makes implementation more practical in new constructions.

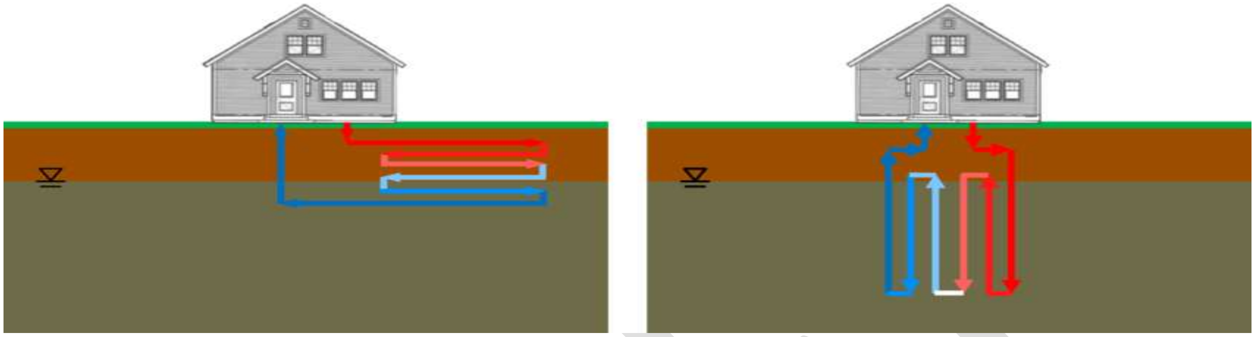


Image by Cory A. Kramer from https://www.researchgate.net/

➤Efficiency

- Advances in refrigerant technology now offers refrigerants with low boiling temperatures (-40C), which increases efficiency in cold climates since the refrigerants can be vaporized at colder temperatures.
- Geo-exchange systems can have a coefficient of performance (COP) of up to five. These systems can generate an energy output 5 times larger than its input.
- Geo-exchange systems in Yukon may not perform as efficiently and may have shorter lifespans due to the imbalance of cooling and heating demands during the summer and winter. When a buildings' demand for heat exceeds the amount of energy stored in the ground, it results in a depleted field that can on longer support the system. Further modeling and investigation is strongly recommended to prove long-term viability of proposed geo-exchange systems.
- Ground source heat pumps perform better when extracting low-grade heat. It may be more challenging to integrate these systems into a high temperature building heating loop.

➤Maintenance:

- Ground loops (piping) can last up to 50 years and interior components (compressors and heat coils) can last up to 25. These relatively long asset lifecycles reduces replacement costs.
- Geo-exchange systems are entirely sheltered, protecting them from weather degradation.
- Lower safety related cost compared to conventional heating.
- Multiple heat pumps may be required depending on the configuration. These equipment will require additional maintenance.
- Geo-exchange heat pumps require the use of refrigerants, which are ozone depleting substances that pose an environmental hazard if leaked.

➤Flexibility and Practicality:

- Advanced systems can incorporate hot water heating functionalities by having the refrigerant loop pre-heat domestic hot water tanks.

- Geo exchange systems act as thermal regulators that can heat or cool a building depending on seasonal needs.
- Options for vertical, horizontal, water, and hybrid systems allow for multiple types of system configuration.
- Geo-exchange systems may not be suitable for building retrofits due to their large underground infrastructure and extensive interior equipment needs.

➤Financial Feasibility:

- Geo-exchange systems typically have a low overall asset life cycle costs with relatively short payback periods.
- May be less economically viable for small buildings due to large initial investments required for loop pipes, heat exchangers, and heat pumps.

➤Geo-Exchange Risk Assessment

Risk Type	Risk	Mitigation
Implementation	Certain geological attributes can make drilling very expensive and cause delays in construction timeline.	Include a geotechnical survey in the feasibility study for the geo-exchange system.
Implementation	The system draws more heat during the winter than the ground can receive in the summer. This imbalance will cause the field to deplete and render the system ineffective over time.	Assess the capacity of the field and ensure design stays within its acceptable parameters.
Maintenance	Sites in remote locations may not have the expertise required to service this new technology.	Identify available resources for servicing the equipment as part of the feasibility study.
Environmental	The decommissioning of ground loops can cause leakages of toxic chemicals into the ground.	A licensed water well drilling contractor or an accredited geothermal installer should complete this process. Decommissioning reports should also be provided within 30 days of completion.
Environmental	Drilling activities may disrupt natural permafrost.	The geotechnical survey should include permafrost considerations.
Legal	Geo-exchange system may involve the use of aquifers and bodies of water such as lakes and poses a risk of contaminating the water source. Breaching the ground beyond a certain depth may also require YESAA.	The feasibility study should include aquifer locations to know if the project will impact a water table. Additional time and budget of 6-8 months should be allocated for a YESAA assessment if needed.

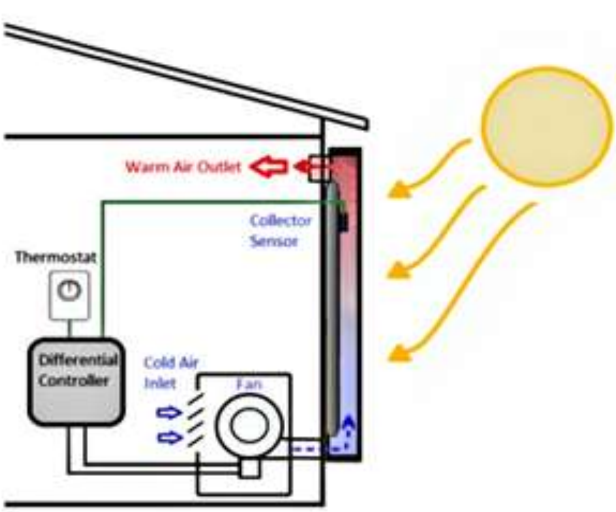
Solar Air/Water Heating

Solar air heating systems are typically passive heating systems which are built over a buildings envelope. A conductive thermal panel absorbs energy from direct sunlight to heat cold air that sits between the panel and the buildings exterior wall. This creates passive ventilation: As the heated air rises and circulates back into the building through a top vent, creating negative pressure that draws in colder air through a bottom vent.

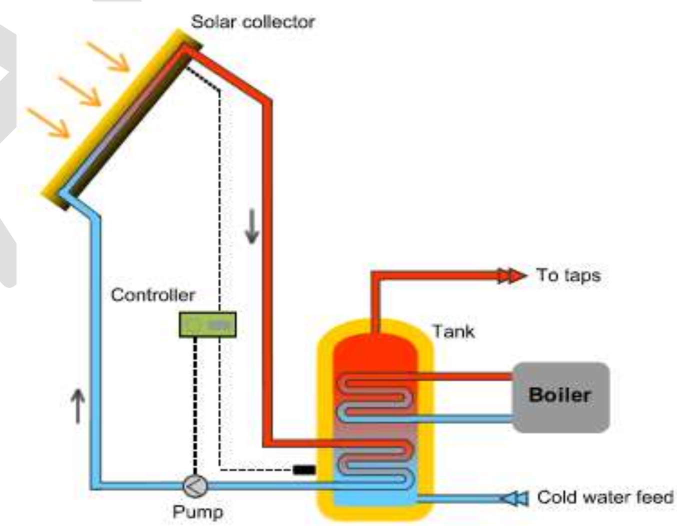
Solar water heating systems come in a variety of designs with different types of collectors and circulations systems. Typically, a non-freezing fluid circulates through solar collectors where it is heated by the sun. This fluid then passes through a heat exchanger transferring the heat to the buildings domestic hot water system. The non-freezing fluid then cycles back to the collectors. Almost all solar water heating systems use active components such as mechanical pumps to circulate fluids through the system.

Solar air and water heating systems can be either active or passive, where active systems use mechanized ventilation to supplement the heating process. Solar air/water heating systems often have seasonal dampers/valves that can be shut in the coldest months and prevent warm air/fluids to exit in the night time when they are no longer effectively heated.

Active Solar Air Heating



Active Solar Water heating



➤Efficiency:

- Solar air systems can offset heating fuel consumption in the shoulder seasons during long daylight hours.
- Solar air heating systems can increase building efficiency by augmenting the insulation value of a building using the additional air space between the exterior wall and panel as additional insulation.
- Poorly functioning dampers and valves may introduce cold air/fluids into the building increasing heating load.

- A solar water heater has little to no GHG savings on a building using an electric DHW heater.

➤Maintenance:

- Passive solar air systems require minimal maintenance since they have no moving parts.
- Passive solar air heating systems have very long lifespans, with weatherization components lasting up to 35 years. Long asset lifecycles reduces the frequency of replacements causing cost savings in the long run. Solar water heating systems last up to 20 years.
- Active solar air systems have mechanical components such as motors and fans, which will have shorter lifespans.

➤Flexibility and Practicality:

- Flexible installation allows these systems to be seamlessly integrated into new building designs.
- Easy application for building retrofits over existing walls and roofs.
- Solar air heating is less effective on small buildings and is not a source of primary heat.
- The effectiveness of solar water heating systems drop drastically during cold months.

➤Financial Feasibility:

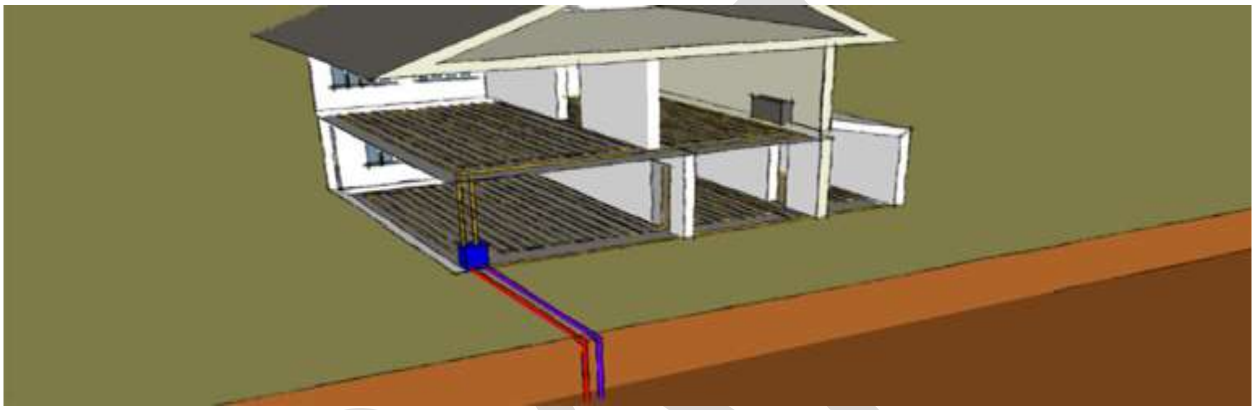
- Mitigates risk associated to rising energy costs by offsetting fossil fuel consumption.
- Solar air heating systems have simple designs and inexpensive materials which make for low overall construction costs.
- Solar water heaters can offset electrical and fuel costs associated with a buildings DHW system.

➤Solar Air/Water Heating Risk Assessment

Risk Type	Risk	Mitigation
Implementation	Cold winter months may reduce the systems effectiveness.	A solar air/water heating systems can have multiple design configurations. A design that increases insulation can allow for increased efficiency in the cold winter months.
Implementation	Low efficiency can arise due to a lack of sun hours on suggested wall/roof.	Solar air/water heating systems should undergo an orientation and efficiency analysis prior to installation.
Implementation	Solar air/water heating systems have not been extensively tested in extreme cold weather.	Feasibility studies can help determine the viability of solar heating projects. An experienced and certified technician with contractual obligations should fulfill the construction of the system.
Maintenance	Solar air/water heating systems should ensure that exterior walls and roofs have long term exterior material installed (tin, steel, concrete, etc.).	Solar air/water heating systems should ensure that exterior walls and roofs have long term exterior material installed (tin, steel, concrete, etc.).

Geothermal Energy

This renewable energy refers to the use of pumps to extract heat from the earth's surface using deep vertical loops. This technology utilizes heat created from the earth's core through the use of deep vertical wells. In 2016, the Government of Yukon and the Canadian Geothermal Energy Association released a report on the potential for geothermal energy in Yukon. According to the Yukon Geothermal Opportunities and Applications report, Yukon's geothermal potential could be more than 1,700 MW of energy. Considering a geothermal system in one of the outlined potential areas could reduce PMDs GHG emissions. High temperature geothermal energy used in binary power plants can generate electricity and be used in a cascading geothermal system to then provide heat to buildings.



➤ Efficiency:

- Increased efficiency can be obtained by using one of Yukon's many geothermal hotspots. Using the Geothermal Opportunities and Applications report and related maps as a guideline for where geothermal should be considered will maximize the effectiveness of a geothermal systems.
- High temperature geothermal energy can power cogeneration units that offer electricity generation along with heating potential.
- Low temperature geothermal energy may require multiple heat exchangers to extract sufficient heat, increasing the amount of space use in the building

➤ Maintenance:

- Geothermal ground loops lasts up to 50 years and inside components last up to 25. These relatively long asset lifecycles reduce the frequency and costs associated with replacements.
- Geothermal systems are entirely sheltered indoors or underground protecting them from weather degradation.

➤ Flexibility and Practicality:

- Geothermal systems can provide a source of hot water allowing you to reduce electricity use by preheating domestic hot water heaters.
- Typically, geothermal power plants are not stand-alone systems and need an external, supplementary back up source of energy (ie: connected to the grid)

➤ Financial Feasibility:

- Asset lifecycle cost relies heavily on the depth and the effective implementation of the systems.
- District systems are recommended due to large initial investments required for drilling, equipment, and system installation.
- Collective heat load must be large enough to justify the large initial investment.

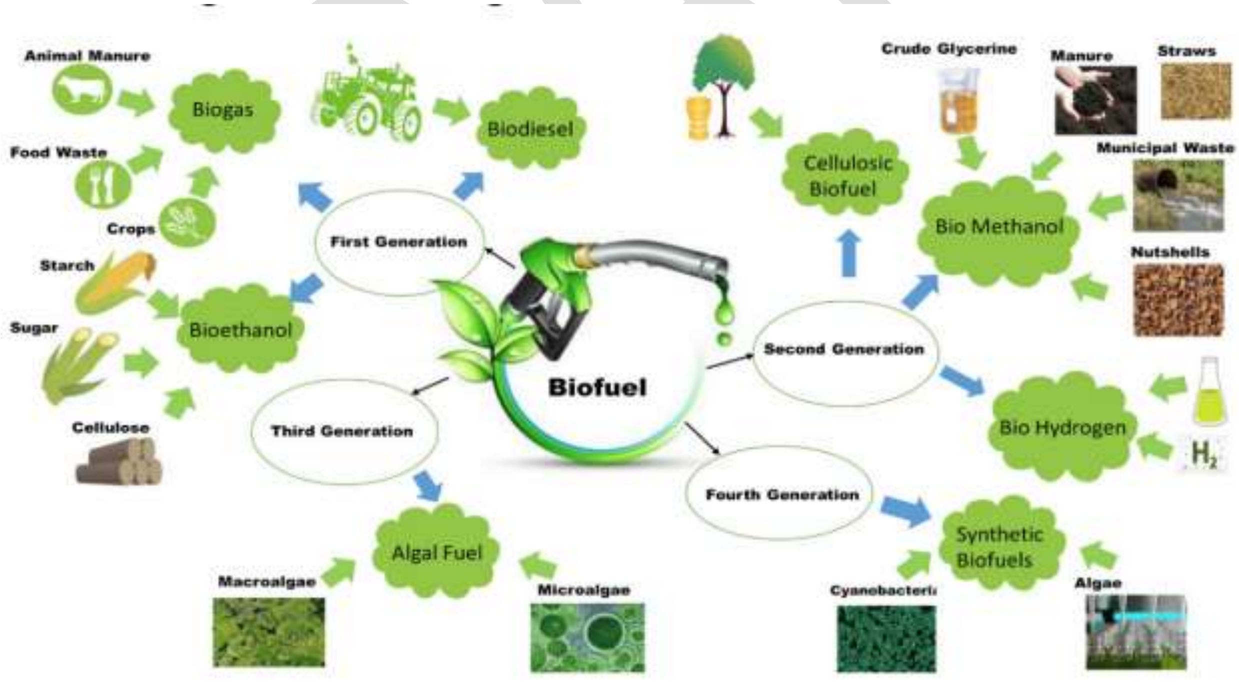
➤ Geothermal Energy Risk Assessment

Risk Type	Risk	Mitigation
Implementation	Certain geological attributes can make drilling very expensive and cause delays in construction timeline.	Include a geotechnical survey in the feasibility study for the geothermal system.
Implementation	Resource risk associated with the existence, size, sustainability, and utilization of geothermal source.	The feasibility study should include a detailed resource report conducted by geologists in conjunction with mechanical contractors and VCL installation technicians.
Environmental	Drilling activities and piping may disrupt natural permafrost.	The geotechnical survey should include permafrost considerations.
Legal	Geothermal systems connected to aquifers pose risks of contaminating the water source. YESSA assessments are expected.	The feasibility study should include aquifer locations to know how the project will impact water tables. Additional time and budget of 6-8 months should be allocated for a YESAA assessment.
Legal	Deep drilling requires YESAA assessment.	Additional time and budget of 6-8 months should be allocated for a YESAA assessment.

Biodiesel, Renewable Diesel, and Waste Vegetable Oil (WVO)

Biodiesel and renewable diesel are liquid fuels produced from renewable sources such as new and used vegetable oils or animal fats and are a cleaner-burning replacement for petroleum-based diesel fuel. Pure biodiesel is made through a chemical process called transesterification where alcohol reacts with naturally occurring oils to create biodiesel. Renewable diesel requires more rigorous refinement and is produced through a series of biochemical and thermochemical processes. Unlike WVO that can only be used in modified diesel systems, biodiesel (abiding by ATSM standards) is much more compatible with existing diesel heating systems and can be blended with petro diesel to be used in existing systems without any major modifications. Blends are labeled as BX with the X signifying the percentage of the mix that is biodiesel. B100 would therefore be pure biodiesel. Although typically more expensive and harder to produce, the refinement of renewable diesel makes it the most compatible with regular diesel.

It is recognized that the availability of biodiesel or WVO in Yukon requires local suppliers or programs that collect and process the fuel. The lack of supply is a significant barrier to entry as such programs do not currently exist in the territory. Our Clean Future includes new requirements for the blending of biodiesel and/or renewable diesel for transportation and electricity beginning in 2025. As the requirements for renewable and biodiesel blending increase in the future, it is expected that the supply and supporting infrastructure of liquid bio fuels will be further developed. Regardless, this section includes information that may be useful in the event where a fuel source becomes available.



[Image from Wikipedia](https://en.wikipedia.org)

➤ Efficiency:

- Biodiesel has a slightly lower energy content (8%) than conventional fuel oil. No significant difference in fuel consumption is observed when using blends of B10 or lower.
- B100 and WVO has the potential to reduce GHG emissions by over 80% on a lifecycle basis. Blends of B20 can reduce GHG emissions by up to 15% according to the US Department of Energy
- Pure biodiesel, renewable diesel, and WVO contains more oxygen then petro diesel, creating enhanced combustion properties over diesel, and results in lower tailpipe emissions.

➤ Maintenance:

- Biodiesel and WVO acts as a solvent and may corrode rubber parts in older furnaces. Additionally, transitioning to these fuels may clog filters if the storage tank use to hold No.2 oil. The biofuels would dissolve any deposits at the bottom of the storage tank and potentially clogs filters.
- WVO systems will require additional maintenance compared to conventional fuels due to its viscosity and need for increased filtering and dewatering.

➤ Flexibility and Practicality:

- Blended biodiesels such as B20 can be used in newer furnaces without any major modifications.
- Storage of these fuels presents a challenge in cold weather as high blends and WVO solidify in cold temperatures.
- Material compatibility is also of concern as biofuels effects natural rubbers in older systems and also reacts with certain metals including copper, zinc, tin, and lead.
- Collection of WVO would require a relatively large amount of resources and coordination to establish long term contracts with local facilities and also create a storage and filtering system.
- Renewable diesel is considered equivalent to regular diesel although it tends to solidify faster in cold temperatures.

➤ Financial Feasibility:

- Operational costs relies heavily on the availability and price of biodiesel blends on the market as well as the resources needed for a WVO collection process.
- Maintenance costs are higher for biofuel systems.
- Bio fuels are expected to be more expensive than conventional fuels.

➤ Biodiesel and WVO Heating Risk Assessment

Risk Type	Risk	Mitigation
Maintenance	Filter clogging due to biofuel dissolving sediments in previously used tank.	Replace the existing tank or slowly scale blended mixes up to B100 or pure WVO to avoid filtration problems.
Implementation	Material compatibility (dissolving seals and metal storage tanks)	Systems operating with high biodiesel blends or WVO should have plastics made from High-density polyethylene (HDPE) and synthetic rubbers such as FKM- GBL-S and FKM- GF-S. Metal storage tanks should also be made of stainless steels (316 and 304) and aluminum as they are unaffected.

Implementation	Availability of biodiesel abiding by ATSM standards (to be used in existing heating systems) and locally sourced WVO.	Possible EOI to determine the availability of ATSM B100 Research on size and appetite for a recycled WVO market. Start with facilities managed (Schools, College, Cafeteria, etc.)
Implementation	Storage and Combustions issues due to biofuel viscosity. WVO needs to be preheated in order to avoid poor atomization, incomplete combustion and carbonization.	Systems can be modified to initially use diesel or a low biodiesel blend and utilize a heat exchanger that preheats the pure biodiesel or WVO. Once the fuel is adequately preheated, the system then runs on pure biodiesel or WVO. Insulated and heated fuel lines/tanks can also prevent fuels from solidifying.
Environmental	When using virgin oils and commercially produced biodiesel, there are similar risks to agricultural production: water depletion and pollution, soil degradation, nutrient depletion and the loss of wild and agricultural biodiversity	Ensure feedstock is sourced from suppliers abiding by agricultural standards and use recycled oils where possible.
Environmental	Biodiesel production from virgin oils will compete with food production for agricultural resources, negatively impacting food security	This risk is not expected to be an issue in the near term as the biodiesel industry is still small in Yukon.