YUKON ENERGY RESOURCES

Takhini Hot Springs Pond (Yukon Government photo, 1997)

This article is part of a series of publications, prepared for the Cabinet Commission on Energy, on the Yukon's energy resources. It provides an overview of alternative energy technologies that have been or could be developed in the Yukon, and the issues affecting their development. The resources reviewed in this article are solar, geothermal, refuse, peat and coal bed methane. This series is intended to encourage responsible investment and to stimulate informed discussion among representatives of industry, government, and members of the public. Appendices of a more technical nature are available separately for each of the articles in this series. You can obtain copies of these appendices through the

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Alternatives

Overview

The Yukon's energy system is dependent on imported petroleum products: heating oil, transportation fuel, diesel for the generators supplementing the hydro-electric grid and diesel for off-grid generators. Wood is used in many homes as the secondary heat source, but other energy resources remain largely undeveloped. These other resources include wood residues from sawmills, coal, wind, small hydro and local oil and gas. In addition to these resources, there are a number of alternative energy resources, which are described in this issue: solar, geothermal, refuse, peat and coal bed methane.

The Yukon receives enough sunshine to make solar energy viable for approximately eight months of the year. Photovoltaics are being combined with other energy technologies by a number of remote households in the Yukon. This source of electricity is expected to become more economical as the rapid decrease in capital costs for photovoltaic systems continues.

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The Yukon's geothermal resource remains largely unknown, but there are numerous thermal springs throughout the territory. None of the springs has temperatures high enough for commercial electricity production, and most are located far from existing communities. Current use of the resource is limited to tourism and to keeping municipal water systems from freezing in two communities.

Energy from waste, or refuse-derived energy, has garnered some interest in recent years. Since the 1980's, used oil has been burned in several commercial and government establishments throughout the territory as an economical alternative to regular heating oil. Municipal solid waste has been studied by the City of Whitehorse as a supply option for a waste-to-energy facility. The City found that a waste-to-energy facility was not economical at this time.

Although the Yukon has substantial coal resources, more study is needed to determine the viability of coal bed methane energy development. No comprehensive study has been done of the Yukon's peat resources thus, more study is also needed to determine the viability of this resource.

All energy developments in the territory must abide by the Canadian Environmental Assessment Act, Yukon First Nations' Agreements and in the near future, the Development Assessment Process. For the energy alternatives described in this article, the biggest environmental concerns are air, noise and water pollution, as well as the aesthetic impact of new energy developments on the landscape.

Table 1. Hours of sunshine for selected Canadian cities.

Whitehorse	1852.4 hours
Prince Rupert, BC	1211.8 hours
Vancouver, BC	1919.3 hours
Victoria, BC	2081.9 hours
Lethbridge, AB	2323.5 hours
Estevan, SK	2499.9 hours
Eureka, NWT	2090.7 hours

Source: Environment Canada, 1997

The Resource

Solar Energy

Although it is seasonal, the Yukon receives close to the same amount of sunshine annually as many regions of Canada. As can be seen from Table 1, Whitehorse receives about 10% less sunshine than Victoria, BC and it receives 35% less sunshine than Estevan, Saskatchewan, which is the sunniest place in Canada. Figure 1 shows how solar energy varies across Canada.

Detailed data of solar radiation are available for Whitehorse and are included in tables in Appendix A. These tables are also available in the Environment Canada Publication: *Solar Radiation Data Analyses For Canada 1967–1976, Volume 6: The Yukon and Northwest Territories* (1985). These tables show how the solar energy available varies with the season. Due to the latitude of Whitehorse, at approximately 61° N, there is a marked difference in solar radiation depending on the season. For example, "mean daily direct solar radiation on a sloped surface" reaches a maximum of 11.750 megajoules per square metre in June, while the maximum for December is 3.327 megajoules per square metre.

The tables also show how the energy captured varies with the direction and the tilt of the measuring instruments. As would be expected, varying the tilt and direction of the instruments throughout the year allows the maximum amount of energy to be received. If this is not possible, a rule used by a Yukon photovoltaics vendor is to install fixed arrays facing South, at a tilt equal to the array's latitude, plus 20 degrees. This makes allowance for winter conditions, when there is the least sunshine, at the lowest angle relative to the horizon.

Present Development

There are a number of people using small scale solar energy in the Yukon. A few businesses and homes have made use of solar thermal energy for hot water heating, and several of solar energy systems make use of photovoltaic arrays to generate electricity. Photovoltaics are most competitive in remote sites, far from the electric grid, especially if they require relatively small amounts of power (typically less than 10 kWp[1]). In these off-grid applications, photovoltaics are typically used to charge

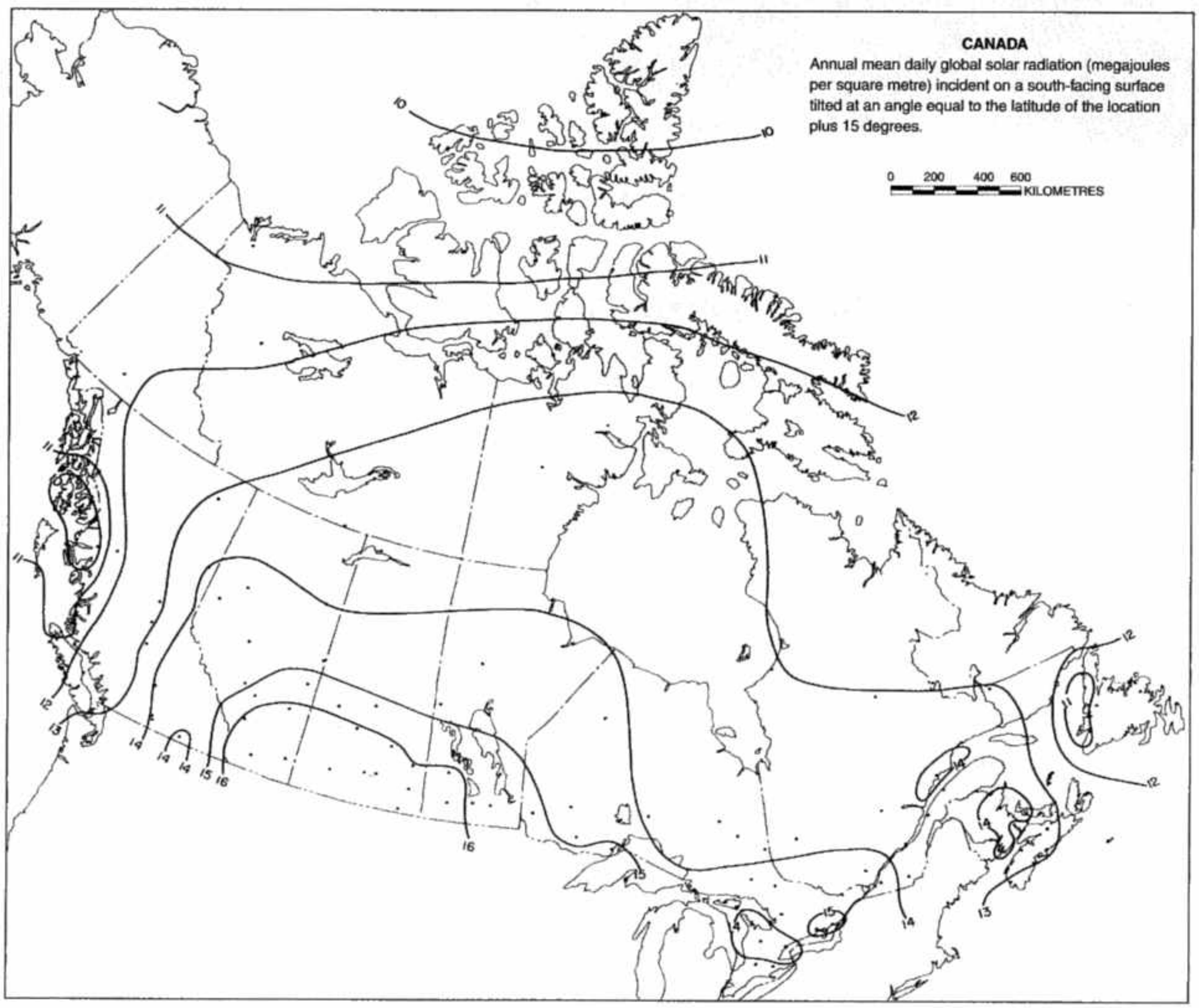
[1] Peak Watt (Wp). The term "Peak Watt" is used to describe how much electric power a photovoltaic module can generate under the Standard Testing Conditions of 1 kW/m^2 of sunlight and 25°C cell temperature.

batteries that temporarily store the energy captured by the modules and provide the user with electricity on demand. Most of these are in the southern Yukon, although there are some in the Dawson City area. It has been estimated that at least fifty of these residential systems have been installed in the Yukon. Telecommunication businesses, highway maintenance camps, park interpretive centres and one demonstration system at Yukon College in Whitehorse also make use of photovoltaics.

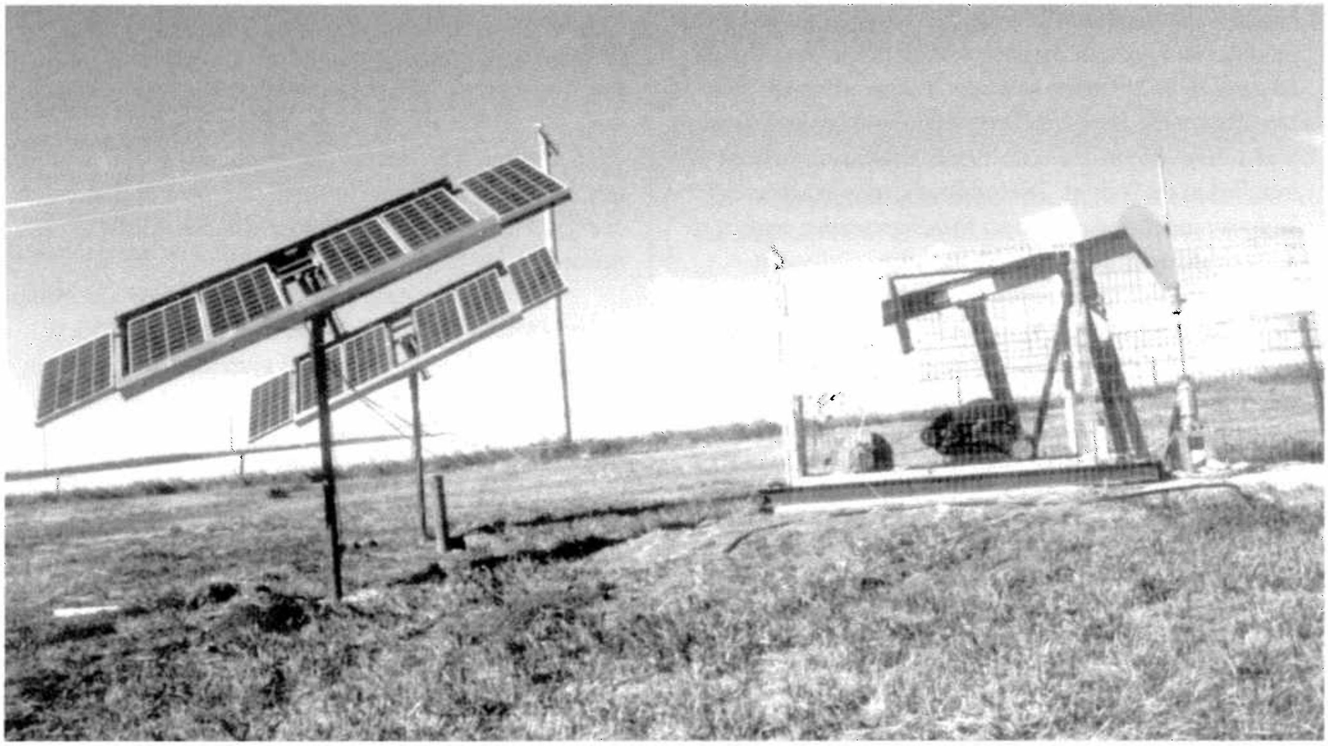
Yukoners using photovoltaic systems to power their homes say that they receive reliable energy eight months of the year. Their systems require very little maintenance, largely because there are no moving parts. (If they have their photovoltaic arrays mounted on a tracking system, then they sometimes have problems with the tracker, especially in extremely cold temperatures. The tracker can give them 40–50% more output than a stationary system, but most of that extra energy is received in the summer when it is least needed.)

The photovoltaic systems vary in cost according to their size. They range from $8,000 for a 2.5 kW system to $15,000 for a 4 kW system.

Figure 1. Annual Mean Daily Global Solar Radiation for Canada



Source: CANMET *Photovoltaic Systems Design Manual (1991)*



Photovoltaic Water Pump. (Yukon Energy Corporation photo, 1996.)

Photovoltaics: The Technology

Solar photovoltaic cells are semiconductor devices made of silicon that convert the energy from sunlight into moving electrons. This avoids the mechanical turbines and generators that provide virtually all the world's electricity today.

The most reliable and low-risk PV technology is crystalline silicon modules (single-Si, poly-Si and ribbon-Si). These PV modules have the highest commercial module sunlight-to-electricity conversion efficiencies (12-15%). They also have a stable outdoor lifetime of over 30 years. As well, their production cost continues to decrease with improvements to the manufacturing process and as sales volume increase.

Amorphous silicon, a thin film technology, is the most commercially available technology today. However, this technology has been plagued with technical problems which has resulted in low efficiency modules (5–8%) and semiconductor material instabilities outdoors. This makes this technology a poor candidate for the remote power market at present.

Balance of system components

Apart from the actual photovoltaic arrays, PV systems require a number of other components in order to be operable. These include:

- inverters, required to convert the DC power produced by the PV module into AC power;
- batteries that temporarily store the electricity to provide energy on demand at night or on overcast days;
- controllers that manage the energy storage to the battery and deliver the power to the load; and
- the structure required to mount or install the PV modules and other components.

Source: CANMET, *Overview of the World Wide Photovoltaic Industry* (1996) and Christopher Flavin, *Harnessing the Sun and the Wind*, in State of the World 1995

Photovoltaics: History

In 1839, the French scientist Edmund Becquerel discoverd that light falling on certain materials could cause a spark of electricity. It was not until Bell Labs in the United States built the first silicon solar cell in 1954 that practical applications for the effect were identified. By the late sixties, solar cells were widely used on U.S. space satellites.

Starting in the late seventies, industrial-country governments and companies invested billions of dollars in advancing the state of photovoltaic technology. By the eighties, solar cells were deployed at telephone relay stations, microwave transmitters, remote lighthouses, and roadside call boxes—applications where conventional power sources are either too expensive or not reliable enough. The technology continues to advance in the 1990s.

Source: *Harnessing the Sun and the Wind*, by Christopher Flavin, in State of the World 1995

Geothermal Energy

Geothermal energy is the heat energy of the earth. Geothermal energy is in the form of hot springs, steam geysers, hot water, or steam. As such, it is most practical to develop in geologically active zones such as the "Pacific Ring of Fire".

The Pacific Ring of Fire is a region which encircles the Pacific Ocean and includes the Yukon and areas where geothermal resources have been developed, such as California. It is an area of crustal movement, which causes frequent earthquakes and volcanic activity. The geology of the region also gives rise to numerous hotsprings. The Yukon has a number of hotsprings and has had volcanic activity in the geologically recent past. *Open File 427* is a study of the Yukon's geothermal springs, conducted in 1976 for Natural Resources Canada. This study describes thirteen geothermal springs in the Yukon, south of Dawson City, and eight more in Northern BC. There are also approximately eighteen springs close to the Yukon-NWT border, along the Mackenzie Mountains (see Figure 2).

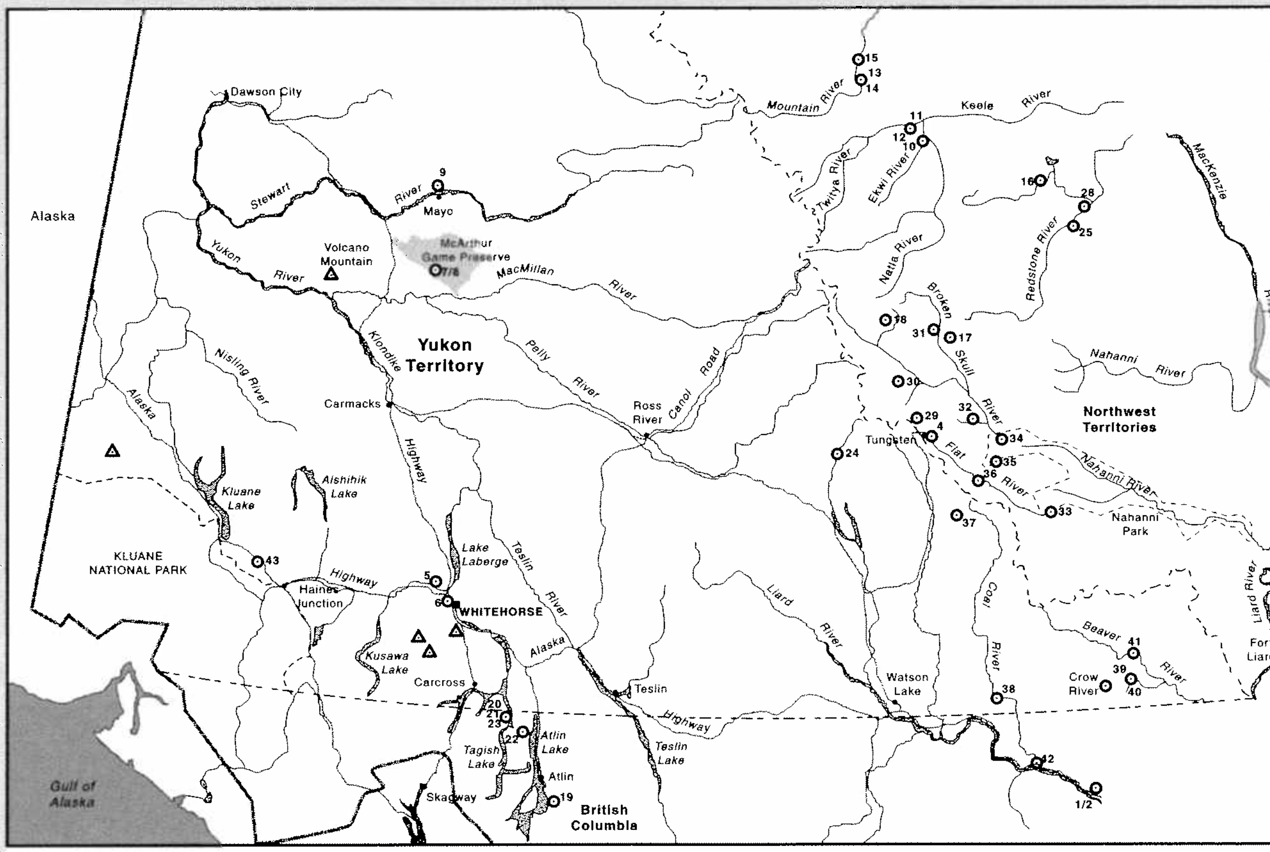
The evidence of volcanic activity in the Yukon suggests that there may still be rock with a high geothermal rank near the surface of the earth. It is possible that the heat energy from the rock could be harnessed, although currently little is known about this potential resource. Areas of the Yukon that geologists cite as warranting further investigation, to determine their use as a geothermal energy resource, are the Cantung, McArthur Springs and the Whitehorse — Takhini areas.

Present Development

In the 1980s the Village of Mayo used a heat pump to upgrade 15°C well water to temperatures that could heat a number of municipal buildings, but after numerous mechanical and electrical problems switched back to oil heat. Currently the City of Whitehorse and the Village of Mayo are using very low grade geothermal energy in the form of warm groundwater, to keep their municipal water systems from freezing in winter.

The Takhini Hotsprings, near Whitehorse, is a commercial tourist attraction. Water from the springs is pumped into an outdoor swimming pool that is open year-round. As well, hot water from the springs is used to heat a portion of the facility's buildings.

Figure 2. Geothermal Springs of the Yukon and Western NWT.



Nahanni		Broken Skull		Mountain-Ekwi		Redstone		Atlin		Non-Grouped	
32	Glacier Lake	31	Broken Hill	15	Mountain 3	16	North Redstone	19	Atlin	1	Liard 1
29	North Cantung	17	Grizzly Bear	14	Mountain 2	25	South Redstone	20	Morin North	2	Liard 2
34	Rabbit Kettle			13	Mountain 1	28	Redstone Jct 2	21	Morin Middle	5	Takhini
36	Flat Fruit	**Cantung**		11	Deca East			23	Morin South	6	Versluce
33	Wild Mint	18	Nahanni Headwater	12	Deca West	**Larson**		22	Jones Lake	7	McArthur
37	Caesar Lake	30	Nahanni North	10	Ekwi	39	Larsen North			8	McArthur
24	McPherson Lake	3	West Cantung			40	Larson South			9	Mayo
		4	East Cantung			41	Pool Creek			43	Jarvis Creek
		35	Hole in the Wall							38	Coal River
										42	Portage Brule

○ Sampled Spring Location, Serial No.
△ Quaternary - Late Tertiary Volcanic Centre

Source: Open File 427, Department of Indian Affairs and Northern Development.

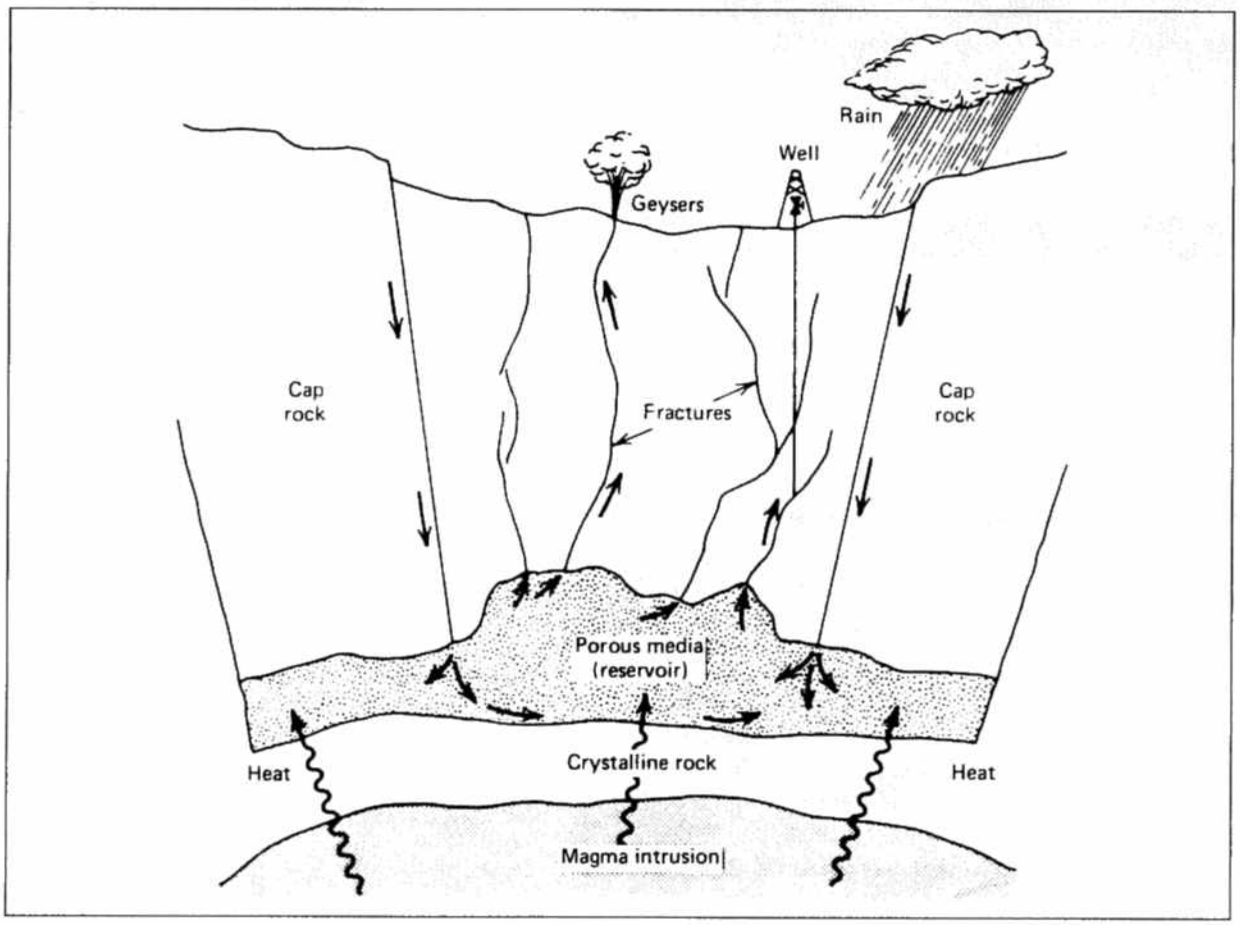
Basic Features of Developable Geothermal Reservoirs

The following features are necessary to make a potential geothermal reservoir a viable energy resource:

1. A heat source (magma intrusion), such as molten rock at a reasonable depth (7 to 15 km);
2. A porous layer of permeable rock to serve as the reservoir;
3. A layer of relatively impermeable cap rock to seal in the geofluid;
4. Fault boundaries to delimit the extent of the reservoir; and
5. The presence of water in the reservoir to replenish the fluid that will be taken from the reservoir during development (although the fluid could be pumped back, as is done in New Zealand.)

The subterranean water extracts energy from the geothermally heated rock as it circulates through permeable layers and fractured rock. The heated water, or steam can then, potentially, be used for heating or for generating electricity.

Figure 3. Essential features of a hydrothermal reservoir



Source: Handbook of Energy Technology and Economics, 1983.

Refuse-Derived Energy

The two sources of refuse-derived energy that have been studied in the Yukon are municipal solid waste and used oil. Interest in using refuse-derived fuel as an energy resource stemmed from the desire to reduce the volumes of garbage that has to be stored in the territory. The City of Whitehorse studied waste-to-energy (WTE) facilities as a way to alleviate the need to open another cell at the City landfill.

Municipal Solid Waste

The amount of energy available from refuse depends on the volume available. With a small population and limited industrial base, the Yukon does not have large volumes of refuse. The City of Whitehorse *Solid Waste Action Plan* (1994) shows that the volume of waste entering the landfill is approximately 20,000 tonnes per year. Approximately 2,300 tonnes of this waste is glass and tin, which does not burn and would have to be removed. The remaining 17,700 tonnes, or 50 tonnes per day, is considered to be a small volume for a WTE facility, as most plants process quantities of 2,000 tonnes per day.

If the organics were removed so that less supplementary fuel (propane or oil) needed to be used to boost combustion, this would remove another 5,600 tonnes, leaving 12,100 tonnes. This volume would be further reduced with increased recycling efforts.

At a power production of 450 kWh per tonne, 12,100 tonnes would furnish 5,445,000 kWh per year (5.4 GWh per year). This is comparable to the proposed third turbine at McInytre Creek which would produce 5.5 GWh/year. The cost for such a WTE facility would be approximately 9 million dollars. The cost of McIntyre Creek #3 would be approximately 5 million dollars.

Currently there are no WTE facilities in the Yukon, except for a few used oil burners, where only the heat energy is recovered.

Used Oil

Used oil can be utilized in WTE facilities as an additive to municipal solid waste to make it more burnable. It can also be used in specially designed burners to heat buildings. Used oil comes from industrial and non-industrial sources where it has been acquired for lubrication. It is unsuitable for its original purpose due to impurities, or the loss of its original properties.

The Yukon Government conducted studies of used oil during the late 1980s and early 1990s. These studies, *Yukon Used Oil Disposal Alternatives* (1989) and *Used Oil Recycling in the Yukon* (1990), were focused on how to manage the accumulating volumes of used oil in the territory, rather than on how to develop the material as a local energy resource. Therefore the studies' emphasis was placed on collecting and transporting the oil for re-refining outside the Yukon. However, the studies did show that there was a potential to collect and redistribute the oil to local businesses and government facilities that had used oil heaters.

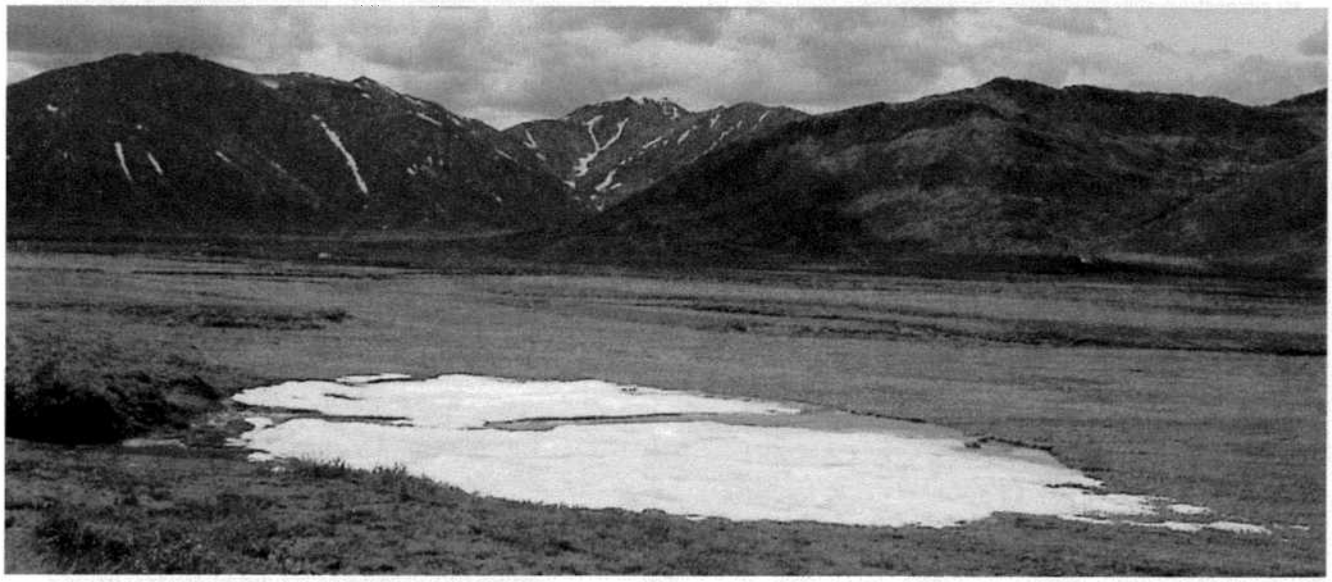
Peat Energy

Peat is made of partially decomposed plant and vegetable matter and inorganic minerals that have accumulated in a water-saturated environment over thousands of years. If left for a long enough period of time, under favourable conditions, peat will turn into coal. Like coal, peat can be used as an energy source. It can be used commercially as boiler feed to produce steam for electric power generation and district heating. As well, research has shown that on the basis of chemistry and kinetics, peat is an excellent raw material for making synthetic fuels. The objective of most of the recent research efforts in various countries is to use peat to produce synthetic fuels. Countries that use peat commercially are Ireland, Finland, and various former Soviet Block countries.

No comprehensive study has been done of the Yukon's peat resources. South and Central Yukon are too dry for peat bogs to form on any significant scale. National studies[2] have identified "sizable" peat deposits in the northern Yukon in the Old Crow Basin, the Blue Fish Basin and the Bell Basin. A representative of Agriculture and Agrifood Canada, in Whitehorse, stated that these deposits are frozen and would be difficult to extract. The remoteness of the peat bogs adds to the difficulty of developing them.

[2] Tarnocai C. and B. Lacell. *Soil organic carbon map of Canada* (1:7,500,000 scale), Agriculture and Agri-Food Canada, Ottawa (1996); National Wetlands Working Group. *Wetlands of Canada*. Ecological Land Classification Series, No. 24., Environment Canada, Ottawa (1988); and Polyscience Publications Inc., Montreal, Quebec.

The 1989 study showed that of the approximately one million litres of used oil generated per year in the Yukon, 21% of that was available for re-use. The 1990 study showed a similar percentage available for re-use (28.6%) with an additional 28.3% available if a waste oil management program was established. Since that time, the Yukon Government has developed *Special Waste Regulations* which allow businesses to obtain permits to collect and burn used oil. Several businesses have obtained permits and are collecting and/or burning used oil. The Raven Recycling Centre in Whitehorse (a non-profit organization) and the Yukon Government also send some used oil out of the territory to be re-refined. (Some of the oil collected by Raven Recycling Centre is used in burners.) A more recent survey has not been done to determine how much oil is still available for additional use.



Peat marsh along Dempster corridor (Yukon Government photo)

Coal Bed Methane

The Yukon is known to have substantial coal resources. (See *Yukon Energy Resources: Coal* — also in this series.) As organic matter is converted into coal, large quantities of methane are produced. This gas can be stored in high concentrations in both the coal and its neighbouring sediments. Coal bed methane is usually of pipeline quality with no processing or cleaning required, apart from water separation. Coal bed methane is usually high in heating value — between 900 and 1,050 BTU per cubic foot.

Coals are ranked into three broad classes depending on the degree of physiochemical change, or coalification, that has occurred. The classes range from lignite, through bituminous, to anthracite. Lignite has undergone the least coalification and anthracite the most coalification. Higher ranking coals with lower water content usually have more methane.

The four most important requirements for economically developing coal bed methane are as follows:

1. Sufficient quantities of gas must have been generated in the geologic past during organic maturation.
2. Sufficient quantities of hydrocarbon gases must have been retained in the coal bed reservoir.
3. By reducing the fluid pressure, gas must be able to migrate through the reservoir at an economically acceptable rate.
4. The total size of the reservoir must be sufficient to justify the cost of development.

Much of the Yukon's coal is ranked as lignite to bituminous and is found in discontinuous and relatively thin, sharply dipping lenses. More study is needed to determine whether or not there is coal bed methane that meets the requirements listed above.

Economic Issues

Solar Energy

Solar energy is recognized by Natural Resources Canada and energy agencies in the United States as a source of reliable, low maintenance energy. These qualities make photovoltaic generators especially suited to providing seasonal power for remote telecommunication sites, highway camps and research stations in the Yukon. Solar energy is becoming increasingly viable as a power source for remote homes, and when combined in a hybrid system, is on the verge of being economical for remote communities served by diesel-based electrical generation.

In the past, the high cost of solar energy made it appear practical only in extremely remote areas that were dependent on helicopter support to replace batteries. Otherwise, it would be chosen as a power source if some element other than economics was the deciding factor (for example, the desire for an emissions free electrical source). However a 1995 CANMET study, *The Value of Using Photovoltaics to Displace Fossil Fuel Consumption on NWT Diesel-Electric Grids* makes the following points:

- The avoided cost value of an energy supply or demand side management option on a diesel grid is considerably different than on a central grid. The avoided cost of an option is comprised of two components, namely energy and power. The energy component includes factors such as fuel, O&M and administrative costs [i.e., the ongoing costs]. The power component reflects the cost of meeting a unit increase in demand at the time of the utility's annual peak demand, i.e., the cost of installing new capacity to meet the increase. The two components are therefore independent and should be accounted for separately. The largest cost saving on central grids usually comes from offsetting power capacity (capacity credit), whereas the largest cost savings on diesel grids should come from simply offsetting kWh production (energy credit). Therefore, although sources such as PV which peak in summer hold little value for a winter peaking central grid utility, they do hold value for a winter peaking diesel grid because of the high year-round energy (kWh) costs, and the low, in relative terms, capacity (kW) cost. In other words, offsetting energy production during the non-peaking summer period is as valuable in avoided cost benefits as offsetting energy during the peaking winter period.
- The principal avoided costs of using PV on diesel-electric grids are reduced fuel consumption and, to a lesser extent, reduced generator start frequency when more than one generator is in use. Reducing start frequency reduces maintenance and replacement costs.
- Even when fuel savings alone are evaluated, the value of PV systems on diesel-electric grids in the north is similar to that of systems now starting to be installed on central-electric grids in the sunny regions of the U.S. As the cost of these systems continues to be driven down by technology innovation and economies of scale, the application of PV to diesel grids in the NWT will start to make economic sense, whether or not hidden environmental costs are considered.

Power and Energy

Power is the rate of doing work. In other words, it is the rate of energy delivery. For electric utilities, the term "power", or "demand", is the rate at which energy is required. Ideally, utilities size electrical generation plants to meet the system's peak power requirement. For example, a hydro dam may be sized to meet the system's peak power requirement on the coldest winter day.

Power is measured in horsepower, watts, and BTU/hour.

For electric utilities, "energy" refers to the capacity for doing work, or amount of energy required, over a period of time. Therefore, when a utility describes energy requirements, it always refers to energy requirements for a month, or a year, or some other time period.

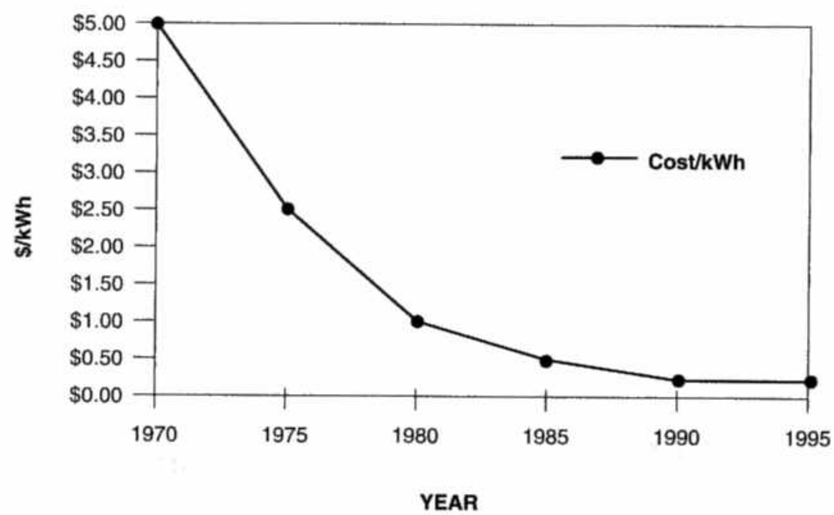
Energy is measured in BTU, GWh, foot pounds and joules.

The cost of solar cells has dropped dramatically since the technology was first developed by Bell Laboratories about forty years ago. In CANMET's *Overview of the World Wide Photovoltaic Industry* (1996) it predicts that the capital cost of photovoltaics will continue to drop due to technological improvements and industry automation.

The price of photovoltaics is only a part of the total cost for a photovoltaic energy system. The balance of system components *(see insert Photovoltaics: The Technology)* can add considerably, to the costs.

Even as the cost of photovoltaics decreases, the technology still has certain limitations. For example, photovoltaics can only generate electricity when the sun shines, so at night, particularly in the winter when the electricity is most needed, the system is not producing. In addition, photovoltaics only produce DC electricity which requires the consumer to either convert to DC appliances (which many 'PV' households have done) or to purchase an inverter to convert to AC.

Figure 4. Price per Kilowatt-hour of Electricity from PV Cells (U.S. $)



Source: California Energy Commission, 1996

Costs for Typical Photovoltaic Systems—1996 (Can $)

Typical Systems Economics	Off-grid Cottage 150 Wp	Off-grid VHF Telecom 300 Wp	On-grid Distributed 2 kWp	On-grid Central 1 MWp
Total system capital costs ($)	$ 3,800	$ 6,700	$ 19,000	$ 10,157,000
Life cycle costs over 20 years (present value 1995 $)	$ 9,000	$ 14,500	$ 27,000	$ 14,193,000
PV system energy costs $/kWh) @ 10% capacity factor [1]	$ 3.46/kWh	$ 2.77/kWh	$ 0.78/kWh	$ 0.81/kWh
PV system energy costs ($/kWh) @ 20% capacity factor	$ 1.73/kWh	$ 1.39/kWh	$ 0.40/kWh	$ 0.41/kWh

Notes

[1]. *Capacity factors. A capacity factor is the actual number of hours of sunlight received per year divided by the total number of hours in a year. For example, Whitehorse receives an average of 1852.4 hours of sunshine per year. If we divide 1852.4 by the total number of hours in a year (8766) we get a capacity factor for Whitehorse of approximately 21%. A capacity factor of 20% is typical for an area of high average solar energy.*

The costs presented above are for "remote" PV systems in Southern Canada. Costs in the Yukon will be higher due to the costs of shipping systems a greater distance.

The table above shows that electrical energy produced by off-grid cottage PV systems costs approximately $1.73 to $3.46 per kWh. This cost is high relative to typical electric utility rates, but comparable with small fossil-fired generators. The capital costs of these systems are usually less than the cost of extending the electric grid.

For the typical VHF telecom site presented here the kWh costs are in the range of $1.39 to $2.77 depending on the particular site. Again, while kWh costs are high, the initial capital cost of installing the PV system with rechargeable batteries is much less than the cost of installing primary disposable batteries every year at the telecom site. For larger industrial systems that use diesel generators for producing electric power, the cost of PV systems, over the operating life of the system, is usually lower than the diesel alternative where considerable annual costs for fuel and maintenance are incurred by the customer. Diesel generators are relatively cheap to buy but expensive to run, whereas PV systems can be relatively expensive to buy but cheap to run. In effect, a customer purchases the "fuel for the next 20 years" when a PV system is purchased.

Source: CANMET "Overview of the World Wide Photovoltaic Industry" (1996)

Refuse-Derived Energy

Municipal Solid Waste

Operating, expanding and finding suitable land for new landfills is costly. Apart from the capital costs of the land, there are costs associated with opening and closing new landfill cells, operation and maintenance costs and ongoing monitoring and maintenance costs after the cells have been closed. For Whitehorse, where one cell is filled approximately every five years, the costs are as follows:

Cell opening:	$400,000
Cell closing:	$100,000
Annual O&M:	$400,000
Annual monitoring:	$25,000

WTE facilities offer the advantage of extending the period a landfill can be used by reducing the volume of waste. This reduces the operating costs associated with landfilling, opening new landfill cells, and purchasing new land to expand the existing landfill, or to open a new landfill.

Of course WTE facilities also have costs associated with their construction and maintenance. In 1994 the City of Whitehorse did an analysis of the usefulness of a WTE facility for incinerating City waste and generating electricity. The city concluded that a WTE facility would not be cost effective in Whitehorse for the following reasons:

- Although a study done for the City in 1993 showed a favourable analysis, after visiting other facilities, the City felt that the 1993 study was optimistic. Even with a ten year pay-back period, other municipalities were finding that regulations, such as air emission regulations, were changing so fast that they had to upgrade their plant before they had finished paying for it. This increased the pay-back period substantially.
- The City had concerns that the amount of sorting required was understated by the manufacturers of WTE facilities, after seeing how much sorting was needed at other plants. The sorting requirement increased the number of staff needed which increased costs.
- There was a problem in locating the plant. The City of Whitehorse Landfill is not located conveniently close to a place that can make use of the heat from a WTE facility. Therefore, the heat would most practically be used to generate electricity. This would entail constructing a

City of Whitehorse Landfill. (Yukon Government photo, 1997.)

generating facility on site and selling the electrical power to the Yukon Energy Corporation: the City would become a Non-Utility Generator. At the time, the City did not believe that it could sell the power to the utility on a steady basis, because the demand for the power was not sufficient. This made the return on investment appear doubtful.

- Water would be required to operate the WTE facility and there is no water source at the landfill site.
- The City would still need to operate the landfill to store all the non-burnable, non-recyclable and non-compostable refuse.
- The City's cost to landfill waste is approximately $30 per tonne, while the cost to incinerate waste in a WTE facility was estimated to be approximately $142 per tonne.

In the future, municipal solid waste could become a more economical form of energy as a supplement to other sources of energy being used in thermal generating facilities. For example, if wood waste from the Yukon's forest industry were being used to generate electricity, then municipal solid waste could possibly be added to the waste wood feed stock.

Used Oil

The cost for used oil burners varies considerably, depending on the manufacturer. For example, a U.S. company sells plans for building burners from used 45 gallon oil drums. The company claims that the burner will take two to three days to assemble and cost from approximately $70 to $280 Canadian. A Manitoba company sells conversion kits, to convert regular oil burners into used oil burners, for approximately $80. In contrast, factory built used oil burners cost from $2,000 to $10,000. (Note that burners made from oil drums would not likely be acceptable for use in the Yukon. Only CSA approved, UL approved, or burners approved by the Fire Marshal can be used in the Yukon.)

Companies promoting used oil burners cite the free fuel as the biggest cost savings for their customers. In the Yukon, this is true for businesses with a permit to burn their own used oil. The costs to obtain used oil through businesses permitted to collect it vary. A list of the businesses permitted to collect used oil is available from the Yukon Government's Department of Renewable Resources, Environmental Protection Branch. Permits for used oil burners can also be obtained from the Environmental Protection Branch.

Geothermal Energy

One of the most significant issues associated with geothermal energy is the cost of its development. As exploration techniques and development technology improve, more geothermal resources are becoming viable. However, at this time drilling wells for exploration, production, and injection account for 25 to 50 percent of the cost of generating electricity from geothermal resources. Also, much of geothermal drilling technology originates from the oil and gas industry. This technology is often unsuitable for the high temperatures, hard rock, and highly corrosive fluids common to geothermal resources.

If the Yukon's geothermal energy resources were to be developed further, then they would most likely be used for their heat energy, directly, rather than for generating electricity. This is because most of the known resource is too low in temperature to be used to generate electricity. The warmest springs in the Yukon are in the 45°C–55°C range. A resource of approximately 100°C–180°C is required to produce the steam needed for economical electrical generation. Indirect methods imply that there may be steam at depth, but again, more exploration would be needed to determine this. Using the heat energy from geothermal resources is only practical if it is used close to the source of the heat. Currently, most of the known resources are too remote to be viable for development.

Hydrogen Fuel Cells in Hybrid Systems

Hydrogen fuel cells are devices that convert hydrogen into electricity through electrochemical reactions. The process also produces heat, water and carbon dioxide, depending upon the fuel used. Unlike storage batteries, which have a limited life, electrical energy can be produced as long as fuel and air are fed to the cell. As such, they are similar to a diesel generator which produces electricity as long as it is "fed" diesel. However, unlike a diesel generator a fuel cell produces electricity with no moving parts.

While hydrogen fuel cells are not an energy source, they are mentioned here because of their potential to be used with alternative energy sources, to make those sources more viable. Systems that use one form of electrical generation in combination with another form are known as hybrid systems. An example of a hybrid system is where a diesel generator is used to backup a wind generator. A fuel cell could be used instead of a diesel generator in a hybrid system. The advantages of using a fuel cell over a diesel generator are:

- reduced CO_2 emissions;
- reduced noise;
- reduced maintenance, because electricity is produced with no moving parts; and
- fuel flexibility (hydrogen can be obtained from natural gas, coal-gas, methanol, landfill gas and other fuels containing hydrocarbons).

Like diesel generators, fuel cells are modular, so they can be sized in steps to meet a changing demand.

Fuel cell systems have extremely low or zero emissions, depending upon the fuel used—fuel cells using hydrogen as a fuel will emit only water vapour and nitrogen. Hence, transport vehicles using hydrogen can be categorized as zero emission. Other vehicles may use methanol and reform it to hydrogen. These vehicles would not be classified as zero emission, but their emissions would be extremely low. Both methanol and hydrogen can be produced from natural gas and there is some consensus that eventually hydrogen will be made from renewable resources, such as solar, wind or biomass.

Five types of fuel cells, distinguished by the type of electrolyte material used, dominate current research and development activities: alkaline, phosphoric acid, molten carbonate, solid oxide and proton exchange membrane (PEM). According to the 1994 *Fuel Cells for Transportation* study prepared by the Los Angeles County Metropolitan Transportation Authority, the PEM is the "strongest candidate for all transportation applications". Ballard Power Systems is a B.C. company that specializes in the development and commercialization of PEM fuel cells. The company has delivered over 50 PEM fuel cells and fuel cell systems for testing, evaluating and validating to customers in North America, Europe and Japan. Currently, Ballard is developing a commercial prototype of a hydrogen fuel cell transit bus.

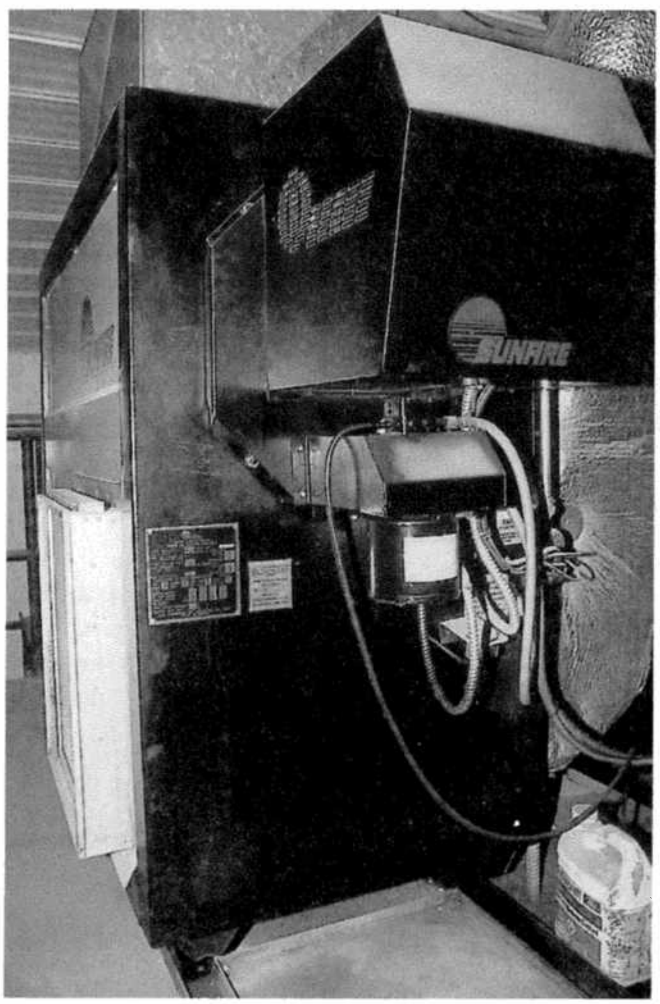
Sources: KPMG Project Report, *Estimated Economic Impacts and Market Potential Associated With the Development and Production of Fuel Cells in British Columbia*, http://www.env.gov.bc.ca/epd/epdpa/ar/eeiampaw.html#1 (1996); Morgantown Energy Technology Center "High Efficiency Power Production from Fuel Cells"; and Jim McMullen of Delphi Internet. *Fuel Cell FAQ*

Regulatory Issues

All developments on public land must go through an environmental screening process in order to secure land use and water use permits. *The Canadian Environmental Assessment Act* specifies the requirements for environmental review. The Development Assessment Process (DAP) will be the Yukon's new assessment process once legislation is in place. Sections of some First Nations' Agreements may also apply to some developments. More detail on each of these structures follows:

Canadian Environmental Assessment Act (CEAA)

CEAA enables the Federal Government to assess the environmental and to a lesser extent, the social and economic impacts of resource development on Federal lands. CEAA is also used when the Federal Government proposes a project, financially supports a project, or regulates a project (such as by issuing a water license). CEAA attempts to document the environmental effects of a proposed project and determine the need to mitigate these effects, to modify the project plan, or to recommend further assessment. CEAA does not apply on First Nations' Settlement Lands.



Used Oil Burner. (Yukon Government photo, 1997.)

Development Assessment Process (DAP)

DAP was negotiated and agreed to as part of the *Yukon First Nations' Umbrella Final Agreement.* It is intended to provide a comprehensive and integrated way to assess resource and other development in the Yukon. DAP will consider environmental, social, and economic impacts, as well as the impacts on the heritage resources and the culture of Yukon First Nations people. Unlike CEAA, it will apply to developments on Territorial (Commissioner's) land and settlement lands, as well as Federal (Crown) land. DAP is intended to replace CEAA for development assessment in the Yukon. When passed, in 1998, DAP will become law in the Yukon.

Yukon First Nations' Agreements

Individual First Nations' Agreements flow from the *Yukon First Nations' Umbrella Final Agreement.* Among other items, these agreements detail how resources may be developed on land that is owned by each First Nation. For example, members of a First Nation may require a share in a development on their traditional territory. The details differ for each agreement, and not all First Nations have their Agreements completed.

Other Regulations

New energy developments will be required to comply with the standards set out in the Yukon air emissions regulations, which are currently being developed under the *Environment Act (Yukon).* Burner ash and fly ash from WTE facilities can be hazardous and may be subject to the *Special Waste Regulations*, under the *Environment Act, (Yukon).* Finally, geothermal electrical generation is noted under Schedule II of the *Yukon Waters Act*, as one of the types of developments that must comply with the *Yukon Waters Act.*

Non-Utility Generation

If developers are interested in selling power, they can do so under the *Public Utilities Act—1986*. They would be known as a "Non-Utility Generator", or NUG. NUGs may sell power to a single customer or a franchised utility. The Act states that a transmission line is allowable only if it "does not duplicate any existing or planned facilities of any public utility".

For NUGs wishing to connect to the existing grid, the main customer will likely be the utility that owns that grid. In such an arrangement, the NUG would negotiate an agreement for sale with the utility. Currently, the Yukon utilities have not entered into any such arrangements. However, the Yukon Energy Corporation issued a request for "expressions of interest" from non-utility generators in September 1996. The utility is interested in considering NUG power as a supply option in its Supply Option Review.

Environmental Issues

Solar Energy

At first glance photovoltaics seem like an environmental panacea. A U.S. Department of Energy publication states that photovoltaics are

> *"clean, reliable and don't pollute while being used. In addition, they are modular, so the system can be added to as the need arises and the budget allows. And, because photovoltaics have no moving parts, they are virtually maintenance free."*

When the full life cycles of photovoltaic systems are considered, the environmental impacts become apparent. The main environmental impacts result from air emissions and water pollution during material extraction and cell production, and the disruption of the local environment from large-scale construction, during the manufacturing stage of photovoltaics. Reduced air quality results from the production of collector support materials (such as glass, aluminum, and steel), the processing of metallurgical-grade silicon, and emissions of toxic gases from extraction and refining operations. Some of the toxic materials used in photovoltaic manufacturing are gallium arsenide, cadmium telluride and copper indium diselenide. There are also impacts during array manufacture, waste product disposal, and the decommissioning of depreciated or defective equipment.

Refuse-Derived Energy

There are two main environmental issues associated with refuse-derived fuel. The first is the disagreement on the usefulness of this method in reducing the amount of waste going into landfills. The second is the problem of dealing with pollutants from waste-to-energy (WTE) facilities.

Waste reduction

WTE facilities reduce the amount of refuse that must be landfilled by approximately 40 percent. This extends the life of existing landfills and reduces the total amount of land used for sanitary landfilling. Although this is seen as an environmental benefit by some, others see it as having negative environmental impacts in the long term. For example, in consultations with the City of Whitehorse during its Solid Waste Management Review, some environmentalists argued that incinerating waste removes the incentive to recycle additional materials as the technology for doing so becomes available or economical. For example, used tires are currently not recycled in Whitehorse. If used tires were incinerated in a WTE facility in Whitehorse, then they would add to the volume of refuse going into the facility and thus the amount of power it would be able to produce. However, if in the future a way were found to economically recycle these tires (non-consumptively), then there may be some resistance to doing so because it would reduce power production.

Pollutants

Wastes from WTE facilities are comprised of air emissions and ashes left after burning. The greater the ability of an incinerator to prevent air emissions, the greater the toxicity of the incinerator ashes. The ashes are often classified as hazardous wastes which have specific waste disposal requirements, thus increasing the costs of landfilling these wastes.

Photovoltaic Array on roof of Dredge #4 Interpretive Centre (Courtesy of Environment Canada, Parks)

There is a possibility that toxic air emissions will be released when waste is burned, resulting in harmful effects downwind of a WTE facility. An example of this occurring is illustrated by the study, *Emission Survey Monitoring Report* (1992), which assessed the volume of contaminants emitted from two used oil burners in Whitehorse. The study states:

"The ["A"] unit grossly exceeds the BC standards in every contaminant category, while the ["B"] unit exceeds the particulate and SO_2 standards, complies with the HCl and is borderline on the other contaminants. Both units emit extremely high concentrations of zinc and the ["A"] unit emits very high lead content as well."

Conversely, some studies have concluded that WTE facilities actually reduce air pollutants, particularly emissions that contribute to the Greenhouse Effect. In a study done by Hunter F. Taylor called *Municipal Waste-to-Energy Facilities Reduce Greenhouse Gas Emissions,* the author states that WTE facilities have

"high temperature combustion (1,800°F), extended furnace residence time, and increased overfire air quantities, all of which contribute to a more complete combustion of the fuel. And whereas these features were initially adopted to minimize organic and carbon emissions from the furnace, they also eliminate the emission of combustible gases such as CH_4[3] and minimize—if not eliminate—N_2O."

The author concludes that

"Because of the completeness of combustion achieved by modern WTE facilities, and because of the offset in fossil fuel combustion resulting from the energy exported by the WTE facility, a ton of MSW disposed in a landfill... generates about 25 times more greenhouse gas emissions than a ton of MSW combusted in a modern WTE facility. Even with hopeful estimates for CH_4 energy recovery, WTE is 10 times more desirable than landfilling."

Geothermal Energy

The three most commonly cited environmental issues associated with developing geothermal energy resources are

1. the aesthetic impact;
2. pollution; and
3. developmental and operational hazards.

Aesthetic impact

The aesthetic impact of developing a geothermal resource could become an issue if it alters an existing tourist attraction. Many of the Yukon's geothermal springs are not regularly visited by tourists because of their remoteness, so conflicts may seem unlikely. However, developing a geothermal resource in an area of wilderness could generate conflict with a public whose concern for wilderness areas has been rising.

Pollution

Geothermal plants are a potential source of air, water and noise pollution:

- they may emit air pollution from dissolved gases in geothermal fluid, such as CO_2 and hydrogen sulfide;
- water may become polluted from disposing of spent geothermal fluids, which may contain

[3] CH_4 (Methane) is a gas which contributes to the Greenhouse Effect. It contributes 25 times as much (by mass) to the effect as CO_2.

arsenic, mercury, or boron in small but environmentally significant amounts; and

- they may be a source of noise pollution from drilling and flow testing which usually continues for the life of the plant as units are added and old wells retired and replaced with new ones.

Developmental and operational hazards

Land subsidence may occur at a geothermal development, if large quantities of subterranean water are withdrawn. This should not occur in fractured formations in otherwise hard rock. Other hazards include well blowouts, pipeline ruptures, major equipment failures, or induced seismic activity resulting from faulty reservoir practices. The risk of well blowouts is greatest with the initial drilling when little is known about the reservoir.

Credits
Prepared for the Cabinet Commission on Energy
by the
Department of Economic Development

Glossary of Energy Terms

BTU/hour	A BTU (British Thermal Unit) is a unit of energy, equal to the energy required to raise one pound of water one Fahrenheit degree. Burning a wooden match releases approximately one BTU of heat energy.
GWh	Gigawatt hour (one million kWh)
joule (J)	a unit of energy (metric). One kilowatt hour equals 3.6 million joules. Raising a sandwich from your plate to your mouth requires approximately one joule of energy.
kWh	kilowatt hour, a unit of energy, the product of power and time. A person can work steadily at an output of approximately 100 watts, and therefore 10 hours of hard labour would result in one kilowatt hour of work.
kWp	The small "p" stands for peak, and refers to the output of a system, usually a photovoltaic panel, under ideal conditions, i.e. direct sunlight, ideal temperature, etc.
MSW	An acronym for "municipal solid waste"
MW	megawatt, one million watts or one thousand kilowatts
Watt (W)	a unit expressing the rate of energy use. One watt is equivalent to one joule used in one second.
WTE	An acronym for "waste to energy"

Reader Survey

Please take a few minutes to answer the following questions so that we can better meet your needs for information about energy resources in the Yukon. Please return it to us at: Yukon Economic Development, Box 2703, Whitehorse, Yukon, Y1A 2C6

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Did you find the information useful?

Has this issue improved your understanding of the Yukon's alternative energy resources?

Would you recommend this publication to your colleagues?

Are there any other topics you would like to see covered in later publications?

Appendices available with this issue are:

___ Appendix A Solar Radiation Tables for Whitehorse, Yukon

___ Appendix B CANMET's *Photovoltaic Systems Design Manual* (Will be ordered on request)

Please check the ones you would like us to send to you.

If you would like copies of the appendices available with this publication, or additional copies of this publication please write your mailing address below.

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