Economic Development from Renewable Energy

Yukon Opportunities

A discussion paper prepared for the Yukon Economic Forums
by the Pembina Institute for Appropriate Development

Barbara Campbell
Andrew Pape, MRM

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Pembina Institute
for Appropriate Development

About this Paper and the Yukon Economic Forums

This discussion paper is one of several documents prepared in support of the Yukon Economic Forums. It outlines aspects of introducing renewable energy technologies into the mainstream Yukon economy. It discusses technologies and their resource potential in the Yukon and describes some of the economic, social, and environmental benefits of using renewable energy. The paper features case studies of renewable energy use that point to potential applications in the Yukon and offers a selection of key actions for implementing renewable energy, focusing on overcoming typical energy market barriers.

The Yukon Economic Forums are bringing people together to discuss opportunities for healthy, diverse and long-term economic development in the north. More information on the Forums is available on request.

telephone: (867) 393-6434 fax: (867) 393-6214
email: economicforums@gov.yk.ca
website: http://www.forums.gov.yk.ca/

About the Pembina Institute

The Pembina Institute is an independent, citizen-based organization involved in environmental education, research, public policy development and corporate environmental management services. Its mandate is to research, develop, and promote policies and programs that lead to environmental protection, resource conservation, and environmentally sound and sustainable resource management. Incorporated in 1985, the Institute's main office is in Drayton Valley, Alberta with another office in Ottawa, and research associates in Edmonton, Calgary, and other locations across Canada.

The Pembina Institute
Box 7558
Drayton Valley, AB T7A 1S7
tel: 780-542-6272 fax: 780-542-6464
e-mail: piad@pembina.org
URL: www.pembina.org

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1.0 Tapping into Renewable Energy

The term "renewable energy" refers to the generation of heat and electricity from natural resources that are not depleted over time. Examples of renewable energy resources include the wind, sun, water, and trees or other forms of biomass that can regenerate after some of the resources are used. By contrast, non-renewable energy supplies, such as oil, natural gas, coal and other fossil fuels, are essentially finite and are used up in the production of heat and electricity. Renewable energy is a cornerstone of a sustainable society – that is, a society that has a healthy economy and environment over many generations.

However, some renewable energy resources are not necessarily sustainable over the long-term because of associated environmental and social impacts. For example, certain dams built to generate hydro power have negative environmental impacts on watersheds, fish, and adjacent lands, and some biomass resources are harvested too quickly to fully regenerate in a renewable fashion. Thus, sustainable, or "green," energy, is really what is needed to serve our energy needs over the long term.

Green energy resources and technologies are based on sustainably-managed renewable resources that minimize:

- greenhouse gas emissions,
- local or regional air quality impacts,
- significant community impacts,
- impacts on watersheds, landscapes and biological diversity, and
- contributions to toxic waste build-up.

In this discussion paper, the term renewable energy refers to those resources and technologies that demonstrate both indefinite resource availability and "green" characteristics. Worldwide, there are numerous renewable energy applications that generate heat and/or electricity using different resources and technologies, but this paper reviews only those that are most appropriate for near-term application in the Yukon. These are:

- Water – run-of-river hydroelectric facilities that have no water impoundment or flooding characteristics, and generally operate at a small scale (less than 20 megawatts of capacity) with no water storage reservoirs;
- Solar – solar energy for space heating (passive solar building designs), heating water (active solar hot water collectors), and for generating electricity (photovoltaic modules);
- Biomass – gasification and/or combustion of fire-killed timber, wood waste products from forestry operations, or other biomass resources (such as agricultural wastes) to generate heat and/or electricity;[1] and
- Wind – harnessing the wind's energy through the use of wind generators, from individual turbines or from wind energy farms of multiple turbines.

Renewable energy can be used to generate electricity at one of three scales: providing electricity to the utility grid, integrating with diesel units in off-grid communities, or powering remote loads (such as communications repeaters, remote lodges) with diesel and/or battery backups in some cases. Biomass heating applications can be as diverse as wood stoves for individual buildings and community-scale district heating systems.

Other renewable energy technologies and resources include geothermal heat and power, heat pumps, tidal and wave power, ocean thermal energy, and hydrogen fuel cells. For more information on these sources, see the Pembina Institute's paper "Canadian Guide to Green Power Sources."[2] These sources are not profiled here due to their lack of technical development for northern Canadian applications.[3]

Energy Conservation and Efficiency

The type of energy supply, as described above, is important in energy planning, but conservation and efficiency measures are also central considerations. Conservation means reducing the demand for energy by reducing the need for services that use energy – such as motor vehicle transportation or home heating – without negatively affecting quality of life in the home or the workplace. Examples include reducing on-the-job transportation needs by combining trips, or reducing home heating during periods when people are not at home. Energy efficiency measures produce the same amount of energy service by using more efficient technologies that require less energy input. Examples include using halogen light bulbs to provide the same amount of light with less energy than incandescent bulbs, or using a more efficient motor vehicle.

Energy conservation and efficiency are key parts of sustainable energy management that should be promoted alongside the use of renewable energy resources. In many cases, energy conservation and efficiency actually enhance the economic performance of renewable energy by facilitating the use of smaller infrastructure and by managing energy use around the availability of renewable energy resources.

2.0 Renewable Energy Resources and Applications in the Yukon

The Yukon has abundant renewable energy resources due to its sunny conditions, broad forest cover, tall mountains, extensive watersheds, and windy alpine areas and valleys. Key types of resources and their development potential are highlighted briefly below, but the main factors in deciding whether, how and when to develop them include:

- the location,
- the quality of the energy resource, and
- the capital costs of developing resources.

Key Renewable Energy Resources

Hydro

Hydroelectricity potential is very site specific, requiring a river or stream with both a reasonable volume of water and vertical drop from the natural slope of the stream bed.[4] For example, a stream with 500 feet of vertical drop and 200 gallons per minute of water flow (152 metres and 756 litres per minute) could produce around 11 kilowatts (kW) of electricity continuously,[5] enough to provide the annual energy needs of at least five homes.[6] However, micro-hydro facilities can be developed on streams with as little as 50 feet (15 metres) of vertical drop as long as there is enough water in the stream.

It costs between $2 and $5/Watt to develop a full hydroelectric generating system with annual energy output ranging from 40% to 70% of the peak output.[7] The generating price of small hydro facilities varies between $0.05/kilowatt-hour (kWh) and $0.20/kWh, depending on the capital costs and capacity factors.[8]

The Yukon's many rivers and streams are characterized by low flows except during spring run-off. There are, nevertheless, four utility-owned hydro sites[9] and several privately owned micro-hydro systems[10] in the Yukon. However, some of these sites would not qualify as "green" power because of watershed alterations through diversion and/or water impoundment. A Northern Canada Power Commission study identified 33 potential hydro sites under 20 MW, indicating a significant resource potential in the Yukon.[11] Additional potential micro-hydro sites under 150kW are not included in that figure.

Wind

Wind energy turbines generate electricity from the velocity of wind, and several sizes of wind energy turbines are commercially available. These vary from 300 Watts capacity for battery charging applications to 1.5 megawatts (MW) capacity for grid-interconnection configurations, with many increments in between. This means wind turbines can supply individual homes or entire neighbourhoods. Like hydro, wind energy potential is very site specific. A telltale sign of an optimal wind energy site is the growth pattern of trees angling away from the prevalent winds. Wind turbines operate most efficiently at wind speeds around 12 metres per second (28 miles/hr), but can operate at wind speeds as low as 2 metres/second (5 mph).[12]

The capital cost of wind energy systems for generating electricity varies from about $2/Watt to $8/Watt, with the larger-scale technologies being more cost-effective.[13] The generating price of wind facilities varies between $0.10 per kilowatt-hour (kWh) and $0.63/kWh, depending on capital costs and capacity factors.[14]

Yukon Energy Corporation has a 150 kW wind facility at Haeckel Hill. Approximately 12 small, non-commercial wind turbines now operate in the Yukon, and wind monitoring studies have demonstrated reasonable potential in Whitehorse, Destruction Bay, Dawson City and Old Crow.[15] One issue with the use of wind energy turbines in the Yukon is the build-up of rime-ice on the blades during winter. This technical issues has been researched by Natural Resources Canada,[16] Yukon Energy Corporation, the Boreal Alternative Energy Research Center, and the Renewable Energy Research Laboratory at the University of Massachusetts.[17] The Haeckel Hill turbine has a built-in heater to remove rime ice.

Biomass (Wood)

Wood can be used to generate electricity as well as heat, using a variety of combustion technologies. Wood stoves are the most common, as they are often used to heat air and water for buildings. Efficient wood stoves can be considered "green" and "renewable" if they maximize combustion efficiency and minimize smog-causing air pollutants such as nitrous oxides, volatile organic compounds, and sulphur dioxide. These technologies can be built on many scales – from heating a small home to heating an entire institutional or commercial building. District heating systems can even use biomass to provide heat for a whole community. Biomass can also be used to generate electricity, with some systems producing both heat and power. These are typically built on a scale of 500 kW to 60 MW and could thus provide power for a small town to a city twice the size of Whitehorse.

Biomass technologies vary widely in cost, depending on the type of technology used, the cost of wood, and other factors. In general, wood heating is seen as an economical choice for space heating in all jurisdictions, although it is not often used for heating water in western Canada. For electricity generation, the unit-generating price of biomass facilities varies between $0.06/kWh and $0.26/kWh.[18]

Wood has been an important fuel throughout the Yukon's past, and continues to be a key energy resource. Timber that is left standing after forest fires is an important source of wood for energy. The energy content of "fire-killed" timber that becomes available each year due to forest fires would be enough to heat every building in the Yukon for 30 years.[19] It is not always economic to harvest and transport this wood, but in certain cases, it may make sense for communities that are close to a firekill to consider developing a district energy system. Several wood chip boilers are already in place in the Yukon, including the school in Pelly Crossing (300kW), Elijah Smith School in Whitehorse (1.2MW), Klondike Central Heating in Whitehorse (1.8MW), the Band offices in Haines Junction (1.2MW), the Little Salmon/Carmacks First Nation building in Carmacks (0.6MW), and the Kluane First Nation building in Burwash Landing (0.6MW).[20]

Solar

Solar energy can be used to produce electricity or hot water. Passive solar building design techniques maximize solar gain to provide building heating and lighting benefits. Solar collectors capture the sun's thermal energy to heat water, and photovoltaic modules produce electricity directly from the sun through a semiconductor device (like a computer chip).

Passive solar building design techniques use high-efficiency windows and designs to maximize solar gain by having south-facing windows and landscaping features that minimize shading in winter. The designs also try to maximize solar energy absorption in walls to provide heating benefits, and to maximize natural light to reduce the electricity costs of lighting buildings during the day. The R-2000 standard includes several passive solar features. The energy savings of a passive solar home will vary from 25% to 50% of a home's annual heating needs.[21] If passive solar design techniques are integrated into buildings at the time of construction the cost premium is between 0 and 20% because the additional costs for windows and insulation can be offset by cost reductions in heating infrastructure and ventilation systems.[22]

Solar thermal collectors can generate between 20% and 60% of a home's hot water supply in an economically-efficient manner.[23] A typical payback on capital cost investment for residential systems is between 8 and 20 years, depending on the fuel previously used to provide hot water.[24]

Photovoltaics (PVs) are a highly modular technology that can be designed at a specific size for the application. The capital costs of full electricity generating systems using PVs varies from $16/W to $19.70/W.[25] The generating price of PV facilities ranges from $0.98/kWh to $3/kWh, depending on the capital costs and capacity factors.[26]

Although the sunlight is seasonal, the Yukon receives nearly the same annual amount of sunshine as many, more southerly, regions of Canada. Whitehorse receives only 5% less sun than Vancouver on an annual basis, and 35% less than

Estevan, Saskatchewan, which is the sunniest place in Canada. Some remote homes, telecommunications sites, highway maintenance camps and park facilities are already using photovoltaics and a few businesses and homes use solar energy for hot water heating.

Applications in the Yukon

Renewable energy could have many applications in the Yukon, including:

- Solar water heating for homes, offices, or other buildings, during the spring, summer, and fall.
- Solar space heating for homes or offices through passive solar building design techniques.
- Biomass space and water heating for homes, offices, other buildings with individual wood boilers/stoves, or entire communities through district heating systems.
- Hydro, wind, and biomass systems to provide electricity for off-grid communities, working in tandem with existing diesel generators and reducing overall diesel consumption.
- Hydro, wind, biomass, and solar PV systems to provide electricity into the utility grid, thus reducing overall diesel consumption during winter peaking periods.
- Hydro, wind, and solar PV electrical systems to provide power for remote applications (e.g., homes, cottages, tourism lodges, camps, communications sites, parks offices, or other electricity uses), providing power into previously un-powered areas, or reducing the consumption of fuel with existing diesel generators.

3.0 Economic Benefits of Renewable Energy

Developing and using renewable energy generates a wide variety of economic benefits, many of which are described below.

Job Creation and Skill Development

Job creation is a key part of economic development activity and healthy economies. When more people are working, the benefits extend beyond the income earned from those jobs. Benefits occur when workers spend part of their income in the local economy, generating spin-off benefits known as the “multiplier effect.” This increased spending creates economic activity (jobs and revenues) in other sectors such as retail, restaurant, leisure and entertainment. A dollar spent in the Yukon has a multiplier effect of about $1.20 to $1.50 in the Yukon economy, depending on the sector in which the spending occurs.

More Employment

Renewable energy projects can create more jobs per dollar invested than conventional energy-supply projects. A review of some 30 studies of employment in the energy sectors in North America showed that renewable energy projects can create twice as many jobs as conventional energy projects, per dollar invested. This review showed that a one million-dollar investment would create 12 jobs in alternative energy supply versus seven jobs in conventional energy supply,[27] depending on the type of project; hydro projects, for example, have lower employment than biomass projects per dollar spent on the project. The number of jobs also depends on how many stages of production are carried out in the region, as more jobs will be created if the materials and technologies are processed and manufactured locally. Solar thermal energy investments in Canada are estimated to create 28 jobs per $1 million.[28] But investments in energy efficiency and conservation yield the most employment, averaging 37 jobs per $1 million invested, due to the labour-intensive nature of the work.

What does this mean for the Yukon? For the Yukon, it is useful to compare small-scale renewables (e.g., wind, micro-hydro, solar thermal), energy efficiency measures (including passive solar design), diesel generator technologies, and centralized hydroelectricity facilities. Table 1 illustrates the benefits that could be expected by investing in different resources and technologies.

Table 1. Job Creation Impacts of Key Components of Energy Technologies[29]

Energy Resource Type	Job Creation Benefits Full-Time Equivalents (FTE)
Average for alternative energy (renewable and other low-emission)	12 FTE
Energy efficiency, including passive solar building design	37 FTE
Solar energy (hot water)	28 FTE
Solar energy (PV electrical)	8 FTE
Wind energy technologies	6 FTE
Biomass generators	22 FTE
Diesel generators	4 FTE
Small hydroelectricity	8 FTE
Centralized hydroelectricity	4 FTE

Local Jobs

Small-scale renewable energy projects are often located close to where the energy is used. This means that these projects, and the jobs they provide, are more geographically dispersed than would be the case for centralized energy sources, such as large hydroelectricity.

The manufacturing jobs, which can be up to 50% of the total jobs for small-scale renewable energy technologies,[30] will not likely benefit the Yukon, as many renewable energy technologies are produced in centralized locations to achieve certain economies. The manufacture of diesel generators also takes place outside the Territory, but this stage may only account for 15-25% of the total jobs associated with those technologies.[31]

Systems design, installation and construction jobs for all technologies will be localized, along with the positions associated with ongoing management of the facility. This applies in particular to energy efficiency technologies and passive solar building designs where a significant portion of project costs is often in the labour for design and installation.

With the diesel option, payment for fuel goes out of the Territory, accounting for approximately 50% of the costs; most of the jobs are located outside as well. In contrast, certain renewable energy technologies, such as solar and wind, do not incur fuel costs and, for those that do, the revenue from those costs remains in the Yukon. For example, with biomass, the fuel cost is for labour to collect and distribute the wood, while for hydroelectricity, the water license fee is collected by the government on behalf of the populace.

In terms of distribution and jobs, renewable energy appears to offer an attractive economic development option for the Yukon, compared with diesel generators. Energy efficiency – the best job creator of the competing energy options in Table 1 – can also be attractive, provided that design expertise is available in the Yukon; this is a reasonable assumption given the existence of established engineering and architectural firms in Whitehorse.

New Skills

Developing renewable energy resources involves developing new skills. Employment opens up in a variety of sectors and involves highly skilled work. For example, renewable energy projects require plumbers, electricians, designers, architects, and engineers, as well as specialists in the particular field, such as micro-hydro or wind power.

Job Creation Success Stories – *Solar Thermal Technologies*

The Solar-2000 project included the installation of over 60 solar domestic hot water heaters in several locations in Canada, assisted by the federal government and other partners.[32]

The technology used is the Solar Boiler by Thermo-Dynamics Ltd. (TDL) of Dartmouth, Nova Scotia. The TDL technology can provide up to 60% of a household's hot water supply from the sun, although this figure is likely smaller in the Yukon. Based on the numbers presented above on the Yukon potential, solar energy could feasibly provide up to 45% of annual hot water needs, with energy savings of about eight Gigajoules (GJ) per year.[33]

In Bedford, Nova Scotia, 46 homeowners purchased systems at a specially financed rate so they could make monthly payments for the equipment. The overall investment per system was about $4,000 to the equipment supplier, covered in part by the federal government.[34] During the two-year period when the project was underway, Thermo-Dynamics Ltd. had approximately two employees dedicated to the project – 1-2 for installations, and a portion of their office and manufacturing staff.[35] Assuming two dedicated employees to the project for two years, and a total investment of about $200,000, the job creation per million dollars invested would be about 10 jobs for two years, or 20 annual person jobs.

Financial Savings

Many of the renewable energy applications in the Yukon could be cost-effective applications, meaning that investors in new technologies will save more money from reduced fuel use or power bills than they originally invested in project capital. The technology descriptions above include an assessment of the approximate generating cost of electricity technologies and the approximate financial savings for heating technologies. These should be compared with typical energy production costs and consumer prices in the Yukon.[36]

Most businesses and organizations will require a payback of less than five years to consider an investment worthwhile. In contrast, some homeowners are willing to make investments that have longer paybacks, depending on how the investment affects convenience, aesthetic qualities and other "quality of life" factors.

A preliminary assessment of specific renewable energy applications suggests that the following have the potential to be cost-effective compared with diesel oil, grid electricity, and propane fuel use:[37]

- micro-hydro, solar PV, and small-scale wind for remote applications, such as tourist lodges, camps, telecommunications stations, homes, cottages, and marine applications;
- solar water heating applications throughout the Yukon, particularly for apartment buildings, commercial and institutional buildings with high hot water consumption, and homes that are currently heating water with high-cost-propane, oil, or non-subsidized electricity;
- passive solar building design techniques that maximize solar gain during heating periods;
- where resources are available, small biomass, micro-hydro and wind turbine systems installed on the community distribution grid in high-cost, non-integrated communities (e.g., Pelly Crossing, Old Crow), operating in conjunction with diesel generators and reducing their fuel consumption.[38] These resources could be owned by a utility or consumers, depending on electricity tariff options; and
- micro-hydro installations connected to the Whitehorse-Aishihik-Faro (WAF) grid, providing year-round power production benefits and potentially reducing utility consumption of peaking resources (e.g., diesel). These resources could be owned by a utility or consumers, depending on electricity tariff options.

Some characteristics of renewable energy systems that contribute to their economic attractiveness are described below.

Declining Equipment Costs

In general, renewable energy technologies are mass-produced in centralized plants in the US, Europe, or southern Canada. Although many of these are emerging technologies, only recently introduced to the market, in the long run, the manufacturing concentration will lead to lower capital costs. For example, the world wind energy generating capacity grew by 35% (1,566 MW) in 1997 alone. Similarly, the world sales of solar PV cells grew by 21% (125.8 MW) in 1997.[39] These incredible growth rates will eventually have the effect of reducing capital costs, as has occurred in the computer semiconductor industry in the last decade.

Low or No Fuel Costs

The cost of renewable energy technologies is concentrated in their equipment and design costs, and most have no fuel costs. Exceptions to this are hydro power, which often requires the payment of a water license fee to the government, and biomass, which requires a payment for wood.

Low Maintenance Costs

Certain renewable energy technologies have low maintenance costs, such as solar PV modules, hydroelectricity systems, solar thermal collectors and passive solar designs. Wind generators and biomass energy systems require some maintenance.

Financial Savings Success Story 1 – *Purcell Lodge Micro-Hydro System* [40]

Purcell Lodge is a year-round alpine eco-tourist resort in the Rocky Mountains near Golden, BC. A micro-hydro electrical system was installed at the Lodge in 1992 to offset the usage of a 12kW diesel generator, reducing emissions and providing financial savings. The 12kW run-of-river hydro system was installed by Energy Alternatives of Kamloops. The system utilizes a pelton wheel, a 2600-foot long penstock made of 6-inch pipe, and an electronic load governor to generate AC power from a nearby stream. The system provides about 15% of the heating load in the winter, and all the electrical needs of the Lodge, virtually eliminating the use of the diesel generator.

The small hydro system cost $35,000 to install, and operating costs are about $500 per year. The annual fuel savings are approximately $7,500 per year for diesel and $500 per year for propane. Annual helicopter expenses related to fuel transportation were previously $8,000 per year, a figure that was vastly reduced through the installation of the micro-hydro system. Therefore, the simple payback on the original investment is under three years.

The annual diesel energy savings are about 4,000 gallons (15,200 litres), propane savings are about 370 gallons (1,400 litres), and greenhouse gas emission reductions amount to about 43.6 tonnes.[41] The elimination of noise and local emissions from the generator is considered to be a large benefit for the type of clientele the Lodge attracts: eco-tourists who want peace and quiet with the natural surroundings.

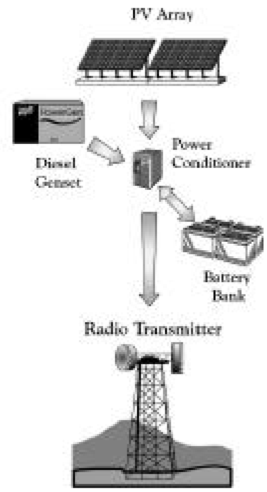
Although this project is relatively small, many other sectors provide opportunities for replicating this application on a similar scale, among them the agriculture, aquaculture, forestry, oil and gas, tourism, telecommunications, and mining industries; and remote properties such as homes, businesses, and cottages. A study commissioned by the federal government outlined the energy consumption trends of remote communities across Canada, accounting for a population base of 196,255 people. The study estimated that about 9.15 petajoules of oil (1.5 million barrels of crude oil equivalent) are consumed per year to generate electricity in remote communities, much of which could be offset with hydro, biomass, wind, and solar resources. The deployment of many of these renewable technologies would generate enough savings to cover the cost of their implementation within three to ten years.

Financial Savings Success Story 2 – *Hybrid Power System for Telecommunications Station* [42]

NorthwesTel Inc. installed a solar PV array in 1997 at a remote microwave radio repeater in the Nahanni Range Mountains of the NWT, 2,600 metres above sea level (see Figure 1). Before the installation, the system was powered by diesel and a battery bank to reduce run-time and fuel consumption and to increase reliability. By adding the 1.5kW PV array, 75% of the electrical needs of this site can now be supplied by solar energy, making it unnecessary to run the generators for most of the summer. This high-energy contribution depends on successfully managing rime-icing of the solar panels to enable them to produce power between November and February. However, these months are not high solar energy periods, so the energy benefits from managing rime ice in this case are not so significant.

Several hundred communications sites in northern Canada could be cost-effectively converted into hybrid solar PV-diesel systems. The total technical potential in the NWT alone is 0.5 MW.

Figure 1. NorthwestTel Solar PV-Diesel Powered Microwave Radio Repeater



The solar PV system reduces diesel fuel costs, which are extremely high due to the helicopter transportation to the site. Capital costs of the solar PV system were about $52,000; 24% of this was the cost of the PV modules, 12% for the mounting structure and controls, 18% for a 34 kWh battery bank, and 45% for transportation and installation. The solar PV system yields annual savings of about $8,250 in diesel fuel and $2,250 in other savings, giving an expected payback period on investment of about five years. Some of the financial benefits include lower maintenance costs at the site due to the reduced load on the generator, and increased reliability stemming from a redundancy of power sources, thus reducing the need for helicopter flights into the site. For low-power systems such as VHF radio towers, solar PV systems can have payback periods as short as one year, compared with primary batteries.[43]

Economic Diversification

The Yukon is continually seeking to diversify its economy. More varied economic activity in different sectors strengthens the overall economy because there are more ways to generate revenues. If one or two sectors experience a downturn, fewer people are affected because there are other activities on which to rely. It is like having a number of investments in a portfolio – or simply, “not putting all your eggs in one basket.”

Investing in renewable energy can help diversify the economy. Instead of one or two main sources of energy supply (such as oil or coal), there can be numerous sources spread across a range of technologies, depending on what resources are available in any particular location (wind, solar, biomass, etc.). This also means a variety of work in different fields, as described under “Job Creation and Skill Development,” above.

New Business Activity

Investing in a new wind energy turbine, creating markets for solar hot water heaters, developing and managing a biomass plant, and designing and installing micro-hydro systems all create new business activity. New income is generated as these products and services are supplied. To the extent that it exceeds other work, such as selling diesel fuel, then it is an increase in business and economic activity, with increased revenues. These revenues are earned by businesses and individuals, and some is paid to government in taxes.

Keeping Dollars in the Yukon

The section on "Local Jobs" discusses the extent to which the spending and employment would be located in the Yukon. When local energy investment dollars are spent on projects in the Yukon instead of going elsewhere, then more money stays within the Territory. For example, the Territory has an abundant biomass resource in the form of fire-killed wood. If this resource is tapped using local expertise and effort, then the resource itself and the people supporting its development are both from the Yukon. This helps to keep dollars in the Yukon rather than draining them out of the region as happens with the purchase of diesel fuel from external suppliers. The money earned flows through the regional economy, causing spin-off effects and generating additional local wealth. As an example, a dollar invested in the logging industry results in $1.50 in overall economic activity in the Territory, which is one of the highest multiplier effects among the various sectors of the economy.

Spreading the Wealth

The geographic distribution of small-scale sustainable energy projects means that the business activity, jobs, and revenues are created in many communities across the Territory, instead of in just a few centralized locations.

Economic Diversification Success Story – Oujé-Bougoumou, Québec

In 1992, the Cree First Nation community of Oujé-Bougoumou, Québec (population of 650) in the James Bay region installed a village-wide district heating system based on biomass resources. In 1997, 135 homes and a number of public buildings were connected to the central boiler through a network of piping. All homes in Oujé-Bougoumou exceed the R-2000 energy efficiency standard. The project currently includes a central plant with a 1.4 MW waste sawdust boiler, a 1.4 MW peaking oil boiler, and a 1 MW oil backup system. In 1995, biomass provided 85% of the energy used to fuel the system, yet accounted for only 15% of the fuel costs. The system required $2.5 million in capital costs and $238,000 in annual operating and maintenance costs and has reduced the flow of money out of the local economy for fuel or electricity purchases. The project was financed almost entirely from local development funds. Although the project does not offer large financial benefits compared to using electricity for heating, it was pursued because of the environmental, community economic development, local employment and self-sufficiency benefits. As a result of this development, the community received a United Nations award in 1995 for being a "sustainable community."

Investment and Trade Benefits

The increased flow of money into the Yukon economy – when funds from external sources are invested here and when local businesses provide products and services to customers outside the Territory – means more economic benefits and opportunities. Renewable energy projects and related services can help increase investment and trade by increasing the expertise of Yukoners. This expertise could, in turn, be exported to other circumpolar jurisdictions such as Alaska, Siberia, NWT, and northern BC. Initial local investment in renewable energy strengthens the base of the industry and helps it to capture these new opportunities.

Riding the Wave of Success

The renewable energy industry, and the sustainable energy sector in particular, has grown rapidly in recent years. The wind energy industry grew ten-fold between 1990 and 1998, with a 35% growth in sales in 1997 alone – from 1,566 MW to 2,100 MW.[44] It is estimated that in 2020 wind energy could provide more electricity worldwide than all of Europe consumes today. Sales of solar electrical cells increased by 21% between 1997 and 1998 – from 125.8 MW to 151.7 MW. Major advancements have occurred in sustainable energy technologies, and demand for green energy is rising while prices fall. This substantial international market growth combined with lower capital costs could benefit the Yukon by attracting renewable energy development dollars and by the potential to export expertise developed here.

Attracting Investment Dollars from Outside

A key economic opportunity lies in attracting investment dollars to renewable energy developments in the Yukon. Companies that emit large amounts of greenhouse gases are one group of potential investors. Large companies in the oil and gas sector (and other sectors) are seeking investment opportunities that implement sustainable forms of energy and reduce greenhouse gas emissions. Such companies would like to offset some of their greenhouse gas emissions by investing in clean technologies such as renewable energy. Renewable energy providers in the Yukon could generate emissions reductions and sell them through emerging greenhouse gas trading mechanisms, which are described later in this report in the section “Participation in Emerging Greenhouse Gas Credit Trading Markets.”

Exporting Know-How

Another economic opportunity is providing renewable energy development and maintenance services in circumpolar jurisdictions. Yukoners with specific technical training and experience in operating renewable energy projects in the north are in a good position to export their expertise. Providing this service as a consultant or developer brings revenues back into the Territory, profiles the success of the renewable energy sector in the Yukon, and helps other regions to achieve the benefits of renewable energy. This emerging market in renewable energy and energy efficiency products and services has already taken shape in Alaska and the NWT, but there is still room for growth in those and other jurisdictions.

Much of Canada’s recent, rapid growth in renewable energy has been concentrated in remote northern communities. For example, sales in the solar PV market grew from 2.6 MW to 3.4 MW between 1996 and 1997. The vast majority of that market is in off-grid applications, which are concentrated in northern and marine situations.

The “off-grid residential” market grew by 39% in the same year and the “non-residential” market grew by 33%.[45]

It may be preferable for Yukon professionals to focus on the development and export of technical knowledge in a niche area of renewable energy. For example, the Yukon Energy Corporation has already developed expertise in dealing with rime-icing considerations with wind generators – knowledge that can be transferred to both solar and wind energy markets across the arctic.[46] Alternatively, the experience of the Yukon engineering community with hydroelectricity developments could be exported to other mountainous jurisdictions with adequate precipitation.

Investment and Trade Success Story – *Renewable Energy Projects in Circumpolar Jurisdictions*

The North American leader in renewable energy system design, sales, installations and customer support in circumpolar regions is Northern Power Systems, based in Vermont and owned by New World Power Corporation. They have developed various systems in circumpolar locations, including several in each of Alaska, northern Alberta, northern Norway, Chile, Argentina, and Antarctica. Their focus is on wind-diesel hybrid systems. One such system is in St. Paul Island in Alaska. The Tanadgusix Corporation, owned by First Nations, operates an airport/industrial complex that was previously supplied by a local diesel grid on the island. The cost of diesel was US$0.34/kWh. An autonomous wind-diesel system provides electricity (including hot water and space heating) to the complex at an average price of about $0.20/kWh, using a 225kW wind turbine and 2 x 150kW diesel generators.[47]

Atlantic Orient Corporation, with a subsidiary in Canada has installed one of their 50kW turbines in Kotzebhue, Alaska; Sachs Harbour, NWT; Rankin Inlet, NWT; and Big Trout Lake, Ontario. All of these installations have reduced diesel costs and provided payback periods on investment of five years or less. Atlantic Orient also installed a wind-diesel system in Siberia to generate power to pump oil in the extremely cold environment.[48]

These case studies point out the diversity of renewable energy activities already underway in circumpolar jurisdictions. These developments have been facilitated by First Nation corporations and organizations, non-First Nation private sector companies, electric utilities, and government departments. To date, only a portion of the potential market for renewable energy technologies in northern applications has been tapped. Canada alone has over 300 remote communities with a total population of about 200,000 people, the vast majority of whom are in the north.[49]

Participation in Emerging Greenhouse Gas Credit Trading Markets

Renewable energy technologies can generate heat and electricity without producing greenhouse gas (GHG) emissions. In contrast, diesel generators, coal power, natural gas combustion, and other energy derived from fossil fuels do create GHG emissions. Rising levels of these greenhouse gases (mainly carbon dioxide) have been linked to climate change, which is now a prominent international issue. Canada has signed two international agreements designed to address the climate change issue: the United Nations Framework Convention on Climate Change and the Kyoto Protocol.[50] If ratified, the Kyoto Protocol will require Canada to reduce its national emissions to 6% below 1990 levels between the years 2008 and 2012. This will require a 25% reduction in emissions below current business-as-usual forecasts.[51] In the future, corporate emitters of greenhouse gases will have the option of reducing emissions in their own operations or purchasing GHG "credits" from companies that do reduce emissions. Renewable energy producers could play an important role in creating credits. The financial value of such credits has ranged from about $1/tonne to $50/tonne in Canada to date, depending on the type of emission reduction project and the robustness of the emission reduction.[52]

Emission reduction "credit" trading involves a buyer (such as an electric utility) and a seller (such as a renewable energy company). Potential benefits of credit trading to the seller include:

- receiving additional revenue for renewable energy production, according to the amount of GHG reductions that are being produced;[53]
- arranging capital cost financing from a larger industrial player (the buyer of the credits) at a low interest rate;
- gaining access to closed energy markets (In the electricity sector, for example, a renewable energy player may not normally have access to selling power on the grid, but if the electric utility purchases credits, they may arrange access); and
- increased public profile for their projects due to the multiple project benefits.

Potential benefits of credit trading to the buyer include:

- using the credits in the future as an alternative to reducing their own emissions under future regulations;[54]
- purchasing credits could provide them with more flexibility to reduce the cost of complying with future regulations as they have a choice of reducing their own emissions or paying somebody else to reduce emissions; and
- purchasing credits can provide public and customer relations benefits, as it demonstrates a commitment to environmental management.

What does this mean for the Yukon? Effectively, the Yukon could create economic wealth from the sales and transfer of GHG emission reduction credits to southern-Canadian emitters of greenhouse gases to enable them to comply with future regulations. It is estimated that the GHG credit trading market will be worth billions of dollars by the time the Kyoto Protocol takes effect, provided that it is ratified by a majority of industrialized countries and effectively becomes an international law.

Several GHG credit trading mechanisms have been established in Canada and internationally. The Greenhouse Gas Emission Reduction Trading initiative (GERT)[55] has endorsed various energy projects, including: a 12MW hydroelectric project in Newfoundland; a wood-waste cogeneration system in Powell River, BC; and a landfill gas project in Surrey, BC. Several other renewable energy projects have been submitted for review, including a solar thermal system for heating a swimming pool in Lilloet, BC, and 1.2 MW of wind energy capacity in southwest Alberta.

Emissions trading under the Kyoto Protocol will allow governments or companies in industrialized countries to meet their commitments to reduce greenhouse gas emissions by: a) investing in projects in other countries that reduce GHG emissions (e.g., Joint Implementation, Clean Development Mechanism), or b) purchasing surplus allowances to emit greenhouse gases from other countries (e.g., International Emissions Trading).

GHG Credit Trading Case Study – *Suncor-Vision Quest Wind Electric Offset Trade* [56]

In 1998, Suncor Energy, a major player in the Alberta oil and gas market, purchased a variety of GHG credits linked to renewable energy and energy efficiency projects. Suncor is planning a large expansion of its oilsands operations near Fort McMurray, Alberta, which would contribute to a significant increase in the company's GHG emissions from about 5.7 megatonnes (Mt) in 1997 to about 9.3 Mt in 2002. However, Suncor plans to offset some of the growth in emissions by purchasing GHG credits of up to 4.4 Mt, with a portion of those offsets from renewable energy projects. To put that purchase into perspective, 4.4 Mt is equivalent to the emissions from a 600 MW coal-fired power plant, while the entire generating capacity of the Yukon is 134.3 MW.

Suncor Energy paid about $87,000 for GHG offsets from a wind energy farm in southwest Alberta owned and operated by Vision Quest Wind Electric, based in Calgary. The wind energy is sold into the Alberta Power Pool, causing other electricity generators in the Alberta market, mostly coal producers, to reduce their production. As a result of this deal, Vision Quest was able sell part of the output of its first two 600 kW wind turbines. Since that time, they have installed two new wind turbines.

4.0 Environmental and Social Aspects of Renewable Energy

There are many environmental and social benefits of renewable energy that go hand-in-hand with the economic benefits.

Environmental Benefits

The environmental benefits of harnessing renewable energy resources are achieved only when these resources are developed at a sustainable level, such as on a small scale. The environmental benefits of renewable energy consist primarily of impacts that do not occur, or are lessened, by replacing non-renewable energy resources with renewable ones.

Reduced Air Pollution

Many forms of renewable energy, such as solar, wind and hydro do not produce air pollution, although biomass does have air emissions that can negatively affect air quality. If one looks at all phases (the life-cycle) of developing a technology, some air emissions do result from manufacturing and transportation.

Lower Greenhouse Gas Emissions

In 1995, the Yukon emitted 570 kilotonnes of greenhouse gases, measured in units of carbon dioxide. This is about 20 tonnes per capita, roughly the same as the Canadian average. Renewable energy produces little to no greenhouse gases that contribute to climate change. The combustion of biomass emits carbon dioxide, but this can be reabsorbed by sustainably managed re-growth of biomass.

Lower Impacts on Watersheds

A large hydro facility is a renewable energy project, but can have substantial environmental impacts and is not considered sustainable energy. Even a small project such as the Aishihik dam has impacts on natural and cultural resources. Generally, sustainable hydro projects are smaller scale and have lesser impacts.

Reduced Transportation of Energy Resources

Sustainable energy projects often involve harnessing renewable energy resources close to the site where the energy will be used. This means less environmental impact from the transportation of energy resources, as tends to occur with petroleum fuels.

Maintaining Natural Resources for the Long Term

Sustainably managed renewable energy resources can be used over the long term and, also importantly, their use reduces the need to deplete non-renewable energy resources.

Environmental Risks and Trade-Offs

The development of renewable energy resources is not without environmental impact. For example, hydro facilities alter stream flow, wind turbines change the aesthetic qualities of the landscape, the manufacture of solar panels requires the use of chemical solvents, and the use of biomass affects the forest and related ecosystems. Wood burning can lower air quality in a region. However, if renewable energy developments are built at an appropriately small scale and managed well for long-term sustainability, environmental impacts can be minimized.

There are always trade-offs between resources and the impacts of their use and development. The substitution of renewable resources for non-renewable ones means the reserves of the latter, such as oil and gas, will last longer. Some forms of renewable energy reduce greenhouse gases, but have other impacts. There are trade-offs within the renewable energy category too, and the selection of supply options depends on the situation and the type and extent of impacts that are acceptable.

Social Benefits

Improved Health

People's health can improve when a type of energy generation that has negative impacts, such as poor air quality or water pollution, is replaced by a source of "green" energy. A report by the David Suzuki Foundation estimates that as many as 16,000 Canadians die prematurely each year and tens of thousands more suffer from respiratory ailments due to air pollutants.[57] The report discusses how climate change, increased by the burning of fossil fuels, is expected to worsen this problem.

Consumer Choice

With the addition of alternative forms of renewable energy, consumers have a greater choice of supply options; more and more are choosing green energy products and services in jurisdictions where these are offered. The City of Calgary's GREENMAX program, discussed in the final section of this report, has had a higher than expected uptake on its program whereby customers pay more to include wind as a source of their electricity.

Greater Self-Reliance

Individuals and communities can achieve greater self-reliance when they get their energy from local renewable resources. This provides local economic activity and gives the community greater security that it can provide for itself. By harnessing renewable resources that are sustained and not depleted, communities maintain a resource base over the long term. This strengthens local economies and keeps the environment healthy.

Work Opportunities

The development of renewable energy resources can provide employment and training opportunities.

Technological Advances

Research into different methods of generating energy from renewable resources can be advanced by improving the technologies for application in northern settings. For example, much work is being done in the Yukon on resolving problems associated with rime ice building up on wind turbines, by using black and heated blades.

5.0 Strategic Direction for Renewable Energy in the Yukon

The Yukon Green Power Initiative was announced by the government in 1999 and is being developed by the Yukon Development Corporation. Various renewable energy initiatives, focused on electricity generation, are being considered within this $3 million project. Elements include: an education and training component, money for research and development, installation programs including a production incentive, and green power marketing mechanisms such as net metering and green rates.

The $1 million Energy Efficiency Initiative, also started in 1999, aims to reduce greenhouse gases by saving diesel fuel. It has commercial lighting, domestic hot water and heating, and other program elements, all of which complement efforts to switch to renewable sources of energy that also reduce emissions from diesel. The $2 million Wind Generation Initiative will see the installation of a new wind turbine in the Yukon. The Yukon Energy Commission released a report in 1998 called "Opportunities for Community Energy Management in the Yukon,"[58] which includes some important recommendations for renewable energy as well.

These initiatives include some important elements of a comprehensive renewable energy strategy. Examples of such program initiatives already implemented in other jurisdictions are provided below.

Net Metering

Net metering allows utility customers to produce some of their own power and "bank" it on the utility system for later use. To the extent they produce power, the amount generated and fed to the grid is deducted from their utility bill(s) for a given period. Net metering would support small-scale renewable energy technologies that are installed at the premises of the electricity consumer who owns the technology.[59] It would support micro-hydro, small-scale wind, and solar PV technologies for on-grid application or in communities that rely on diesel. It has the effect of displacing utility generation of electricity from diesel or hydroelectricity.

One example is the Public Service Commission of Wisconsin, which authorized net metering in 1993 and applied it to all utilities under the Commission's jurisdiction. In addition, several rural electric co-operatives are voluntarily offering net metering programs. The Wisconsin programs apply to customer-owned electricity generation facilities under 20 kW, regardless of energy source.

Financial Support Mechanisms for Renewable Energy

Governments can implement financial support mechanisms to develop and deploy renewable energy technologies. These can be directed at producers or consumers of renewable energy and can take various forms:

- subsidies, low-interest loans, loan guarantees, or special tax treatment to reduce the capital costs associated with the construction and installation of renewable energy technologies;
- taxes on conventional energy sources that make renewable energy sources more competitive; or
- credits awarded on a "per unit of energy" basis to either producers or consumers of renewable energy.

Table 2 compares the financial mechanisms and level of support provided by several countries for renewable energy.

Table 2. Financial Support Mechanisms for Renewable Energy[60]

Country	Capital Cost Subsidy	Other Fiscal Measures
Canada	• Provides a 25% capital cost rebate for limited applications[61] over three years.	• Tax write-off for pre-development expenses for renewable energy facilities.[62]
Denmark	• 30-50% subsidy for some renewable energy developments including combined heat and power (including biomass).[63]	• 15-30% subsidies are available to consumers for the purchase of solar hot water heating systems. • Producers receive a credit of 0.1-0.27 DKr/kWh.[64] • Carbon tax has been implemented.
Germany	• 100 million DM[65] capital subsidy program for solar, heat pumps, small hydro, wind, and biomass.	• Low interest loans provided for wind, hydro, biomass and solar installations through public bank.[66]
Japan	• Incentives representing 10% of cost for small-hydro, 20% for geothermal, 50% for wind and up to 67% for solar PV in buildings.	• Subsidies of 11.1 billion Yen in 1997 for solar PV, totaling 12,900 systems.[67]
The Netherlands	• Tax deductions of 40-52% on capital costs of renewable energy technologies.	• Renewable energy exempted from energy taxes and value added taxes. • Carbon tax has been implemented.
United Kingdom	• Grants for biomass production.	• Non-fossil fuel obligation (NFFO) levy charged on conventional electricity systems to subsidize renewable energy systems.
United States	• Investment credit for solar and geothermal projects.[68]	• Several producer and consumer subsidies funded through levies.[69] • Production tax credit for biomass and wind.[70]

Financing Programs

One major barrier to renewables is the lack of access to financing capital. Banks do not lend smaller customers money to purchase renewable energy systems because the technology application is not widespread in Canada. The government could intervene to help and facilitate financing options. Financing mechanisms could support solar thermal technologies, energy efficiency, passive solar design, and the purchase of small-scale renewables for use with net metering.

West Kootenay Power has a financing program for heat pump purchases or building heating and cooling projects. The program is geared to help potential buyers get over the hurdle of the initial investment in the technology. It is aimed at the one-third of utility customers who do not have access to natural gas heating, and therefore tend to rely on electric heating. The utility estimates the energy savings that would accrue compared with the use of electric baseboard heaters, and provides a rebate to the customer of one cent per kilowatt hour. Based on an average of 10,000 to 15,000 kWh per year in savings, the total rebate to a customer is typically $1,000 to $1,500, compared with up-front costs of $8,000 to $12,000. This results in a payback on investment of about result in a payback of 5 to 8 years. About 150 heat pump rebates have been provided.

Green Power Rate

A "green power" rate gives electricity consumers the option of purchasing renewable energy, usually at a price premium over and above their regular utility rate.

ENMAX, the City of Calgary's electric system, started its GREENMAX program in 1998. Aimed initially at residential customers, the program will soon be expanded to include commercial customers. Customers pay $7.50 per month for a 125-kWh block of green electricity or $15.00 per month for 250 kWh.[71] The green power is produced by the wind energy facilities of Vision Quest Wind Electric. The program was launched with a billboard campaign, but local wind energy companies had been involved in public education for at least a decade prior to the GREENMAX offer. Customer response has exceeded expectations, with 1000 blocks having been sold by December 1998.

Community Energy Management

Community Energy Management (CEM) includes passive solar building designs, solar thermal technologies for hot water, and various measures to implement small-scale renewable energy at a community level. It also supports the implementation of district heating systems similar to the one described in Oujé-Bougoumou, Québec. CEM provides for the community framework to support renewable energy. Without it, there may be issues around land use planning, building and infrastructure permits, and local energy supplies for off-grid communities that could create barriers for the successful implementation of renewable energy.

A case study presented by the Yukon Energy Commission[72] outlines the benefits of a CEM program assuming the following measures:

- energy efficiency improvements in homes and offices;
- 15% of the electricity supply in off-grid communities met by micro-hydro and wind power;
- 50% of the waste heat from diesel generators in off-grid communities is captured and distributed to nearby buildings through a district heating system;
- biomass district heating systems are installed in grid communities with a capacity to meet 15% of the heating needs of those communities; and
- land-use and transportation planning promoted energy efficiency.

The benefits of this program (assumed to be in the year 2011) include the following:

- $17.5 million in energy expenditure savings;
- $10.6 million in program costs; and
- 1.1 million GJ of energy savings.

The above illustrate the types of programs being planned for the Yukon Green Power Initiative and associated initiatives. These are all vehicles that can be used to tap the economic potential of renewable energy in the Yukon.

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Notes

[1] The Pembina Institute also states that biomass resources used for heat and/or power should not divert resources from more economically and environmentally beneficial uses such as the manufacture of lumber products, agricultural fertilization products, or others.

[2] To be released in early November, 1999 – available at http://www.pembina.org

[3] Ground-source heat pumps could be viable in the Yukon in areas with little permafrost.

[4] Hydroelectricity facilities can also be developed by creating a vertical drop from a dam – although this characteristic is incompatible with "green" facilities.

[5] Energy Alternatives Design Guide – 7th Edition. 1-800-265-8898.

[6] Assuming a capacity factor of 60%, and an average annual electricity consumption of 10,000 kWh.

[7] Based on the micro-hydro systems in Pape, 1999 and the Purcell Lodge case study below with a 50% capital cost adder for increased costs in the Yukon. Although larger-scale systems have more engineering and physical works infrastructure, the capital costs are also offset by a larger generating capacity.

[8] Assuming an annual borrowing rate of 10% with a 20 year financing term, operating costs of $0.01/kWh, capital costs of between $1/kW - $5/kW, and annual capacity factors between 40% and 70%.

[9] Whitehorse Rapids, Aishihik, Fish Lake, Mayo.

[10] For example in Fraser, B.C., on the Yukon-B.C. border servicing a highway service station.

[11] Yukon Economic Development, 1997.

[12] The Windseeker 503 turbine has a cut-in wind speed of 5 mph and peaks at 28 mph. The Bergey Excel 10kW turbine has a start-up wind speed of 7.5 mph and peaks at 29 mph. The Atlantic Orient Corporation 50kW turbine has a cut-in of 10.2 mph and peaks at 25.3 mph.

[13] Reference: 10 kW, 25 kW, and 80 kW wind energy systems in Pape, 1999 and from data from the Canadian Wind Energy Association (http://www.canwea.ca) with a 50% mark-up for increased capital costs in the Yukon associated with transportation and de-icing equipment costs.

[14] Assuming an annual borrowing rate of 10% with a 20 year financing term, operating costs of $0.02/kWh (Pape, 1999), capital costs of between $2/kW - $8/kW, and annual capacity factors between 20% and 40%.

[15] Paraphrasing a personal conversation with John Maissan.

[16] Energy Diversification Research Laboratory, Varennes, Québec.

[17] Antoine Lacroix – researcher at UM in Amherst, MA.

[18] The low cost resource is the production costs for the 60MW Inland Pacific plant in Williams Lake, B.C. – also in line with the high-end costs predicted for a cogeneration system in B.C. (http://www.ei.gov.bc.ca/~electricitytaskforce – see Final Report, Appendix E). The high cost resource is in Pembina Institute, 1992 (500kW Salton Condensor turbine).

[19] This is also equivalent to about 10 times the energy of all the hydroelectricity produced at Whitehorse Rapids and Aishihik, and all the imported petroleum products used by all sectors of the economy for all purposes.

[20] SESCI, 1999.

[21] CMHC, 1998.

[22] Personal communication with Richard Kadulski, Architect (kadulski@direct.ca).

[23] Makuck and Harrison, 1993.

[24] Pape, 1999 (2).

[25] Pape, 1999.

[26] Assuming an annual borrowing rate of 10% with a 20 year financing term, no operating costs, capital costs of between $16/kW - $19.7/kW, and annual capacity factors between 10% and 25%.

[27] "Jobs" are defined as person-years of employment, i.e. one person working for one full year. Ten people working full time over a two year period equals 20 person years of employment.

[28] Derived from figures received from the Canadian Solar Industries Association.

[29] These figures are from the 1997 Pembina Institute report for Environment Canada "Comparative Analysis of Employment from Air Emission Reduction Measures". It should be noted that they represent available data from certain projects, averaged together where appropriate. The exact job creation depends on the project, the regional economy, and how many stages of production are included.

[30] The Pembina Institute undertook a preliminary analysis of the distribution of jobs for a 10kW micro-hydro installation, based on information provided in Pape, 1999. About 50% of the costs were for the equipment, 33% for the design and equipment distribution mark-up, 16% for the installation, and 1% for maintenance.

[31] Also based on a preliminary analysis of the Pembina Institute based on information provided from a distributor of diesel generators.

[32] Canada Centre for Mineral and Energy Technology. http://www.nrcan.gc.ca/es/etb/cetc/facts/cetc02ib.htm

[33] Product literature on TDL WEB page (http://www.thermo-dynamics.com)

[34] The retail cost of the equipment was about $3,000 at the time. Installation and maintenance costs of two person working days (@ $500/day)

[35] Andrew Pape was employed by the federal government on the project during that period and is familiar with the installation procedure.

[36] See Yukon Energy Commission – Technical Paper (http://www.energy.gov.yk.ca).

[37] This list was derived by the Pembina Institute based on previous client work in both southern and northern Canada. Where possible, individual references are given. However, some of the assumptions on cost effectiveness may not be applicable in the Yukon. As such, a pre-feasibility study for each of these applications should be completed.

[38] Pembina Institute, 1992.

[39] Brown et al, 1999.

[40] Contact ABC Wilderness Adventures (250-344-2639) or Energy Alternatives (250-679-8589) for information.

[41] Using an emission coefficient of 2.73 tonnes of CO_2 / 1000 litres of diesel, and 1.5 t/1000l for propane.

[42] International Energy Agency, 1999.

[43] IEA, 1999 (2).

[44] Brown et al, 1999.

[45] Dignard-Bailey and Filion, 1999.

[46] See the case study above – *Financial Savings Success Story 2 – Hybrid Power System for Telecommunications Station*.

[47] http://www.northernpower.com

[48] Atlantic Orient Corporation Literature. info@aocwind.net

[49] SESCI, 1999.

[50] http://www.unfccc.de

[51] This figure was determined from the national GHG emissions forecast – Environment Canada.

[52] Emission reductions can be created from a variety of actions such as: (1) developing a renewable energy project to reduce diesel consumption; (2) protecting a forest from being cut down; and (3) using more efficient technologies to extract oil and gas; among others. In the case of (1), the project is permanent and it provides a variety of additional benefits to the community where it is installed (e.g., jobs, local environment improvement). In (2), the benefits are also widespread, but the emission reduction is not permanent if the trees get cut down or burn down. Thus, the value of the emission reduction is smaller because it is less permanent. In (3), these technologies are also positive for the financial bottom-line of the oil & gas company, and may be occurring already – thus, it may be difficult to claim a "credit" on something that is occurring anyway.

[53] This indicates that a project which reduces diesel consumption is preferable to one that reduces grid hydroelectricity use. In the latter case, the emissions of hydroelectricity are virtually zero – thus no reduction occurs if it is replaced with another form of renewable energy.

[54] It is important to note that GHG emissions have global impacts and thus, an emission reduction has the same effect on the global atmosphere regardless of the location of the reduction. That is not to say that project which reduce GHG emissions create additional benefits such as local environment improvement, economic development, etc., which are localized.

[55] http://www.gert.org

[56] From the Suncor VCR Submission (http://www.vcr-mvr.ca/registry\out\C0031-Vcr.PDF).

[57] David Suzuki Foundation. *Taking Our Breath Away – the Health Effects of Air Pollution and Climate Change.* 1998.

[58] Yukon Energy Commission, 1998.

[59] For more information, see Pape, 1999. (http://www.davidsuzuki.org/Acrobat/Clean.pdf).

[60] From Pembina Institute, 1999 (2).

[61] Solar and biomass thermal technologies – mostly in the commercial sector, excluding solar pool heating.

[62] Canadian Renewable Energy and Conservation Expense (CRCE). Only a small part of total project expenses are eligible.

[63] Combined heat and power.

[64] On average in 1997, US$1 = 6.604 DKr.

[65] In 1997, US$1 = 1.734 DM

[66] The Deutsche Ausgleichsbank.

[67] In 1997, US$1 = 121 Yen.

[68] The investment credit (Section 1916 of the Energy Policy Act of 1992) provides a 10% investment credit for most solar and geothermal technologies.

[69] California, Connecticut, Illinois, Massachusetts, Montana, New Jersey, New York, Pennsylvania, and Rhode Island.

[70] The production tax credit (Section 1913 of the *Energy Policy Act*) supports wind and closed-loop biomass for electricity produced in stations brought on line before July 1, 1999. The Clinton Administration has proposed a five-year extension.

[71] The average household in Calgary consumes approximately 550 kWh of electricity per month.

[72] Yukon Energy Commission, 1998.