Report 117

Alternative Energy Sources and Associated Education and Skills Requirements

Prepared for

The Northern Labour Market Information Clearinghouse Project

By

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Chapter 1
Introduction

I. Purpose of Study

This report has been prepared for the Northern Labour Market Information Clearinghouse Project in response to an expressed desire to gain a better understanding of alternative energy sources and their associated educational and skills requirements. It should be viewed as a "long-range" planning resource to help stakeholders with: 1) considering whether to proceed with the development of curriculum; and 2) developing some of the potential specific content of the curriculum.

In order to arrive at the report's conclusions and recommendations, it attempts to review each of the alternative or renewable energy sources of interest from the following perspectives:

- **Technological Aspects:** including an overview of the technology and infrastructure requirements, history of the technology, advantages and disadvantages and costs.
- **Business and Public Policy Aspects:** including an overview of the global, Canadian and Alberta markets and trends; public policy and strategy and other regulatory or business issues and concerns.
- **Training and Labour Market Implications:** including direct and related careers and occupations, Specialized knowledge requirements, and existing and planned educational programs in Canada and other parts of the world.

II. Methodology

Due to the relatively small scope of the project, secondary (already published) sources accounted for the majority of the data. However, in some instances, it was necessary to initiate more detailed discussions when data proved to be more limited.

III. Organization of Report

The structure of the balance of the report is as follows:

- Chapter 2 – Key Background Information
- Chapter 3 – Wind Energy
- Chapter 4 – Solar Energy (Photovoltaic and Thermal)
- Chapter 5 – Fuel Cells
- Chapter 6 – Small-scale Hydro
- Chapter 7 – Earth Energy
- Chapter 8 – Cogeneration
- Chapter 9 – Biomass (Ethanol, Biodiesl, Wood Waste Products)
- Chapter 10 – Biogas (Anaerobic Digestion)
- Chapter 11 – Summary of Conclusions and Recommendations

In addition, there are two appendices:

- Appendix 1 – provides a brief discussion of four other forms of alternative and renewable energy (Geothermal Energy, Wave Energy, Tidal Energy and Nuclear Energy) in order to provide perspective.

- Appendix 2 – provides a listing of individuals and organizations contacted over the course of the assignment.

Report Limitations

This report should be viewed as a "preliminary inquiry" into the field of alternative energy: one upon which future research can be focused according to the findings and more specific priorities, needs and circumstances. As with many emerging fields, there is a wide body of literature; however, it was not always organized and presented in keeping with the unique needs of this study. Furthermore, there are issues with the timeliness of some data and inconsistencies and gaps with the type and level of detail in other instances. This report attempts to deal with subject matter that is technically complex, and for which a variety of options for combinations are possible depending upon specific circumstances. It is not possible to provide a completely comprehensive analysis. In this regard, it is hope that experienced planners may also be able to draw additional conclusions and insights based upon some of the information provided.

Chapter 2
Key Background Information

The purpose of this chapter is to provide select background information that will help users to better understand and use the findings of the overall report.

I. Overview of Principal Efforts To Date Regarding Determination of Renewable Energy Training Needs at the Community College Level

There are two reports that might be considered "required reading" for those having an interest in planning for alternative renewable energy training.

- The February 2004 report entitled *"The Challenges and Opportunities Facing Renewable Energy Industries: Public Education and Technical Training"* completed by the Association of Canadian Community Colleges, and submitted to Natural Resources Canada, is one of the first attempts to come to grips with the Community College level training needs of the "renewables" sector. While somewhat dated already, the report is very useful background for obtaining and overview of trends, policies, other resources, barriers, issues and players within the community college sector.

- A second important document entitled *"Strategic Plan for Renewable Energy Training at Canadian Community Colleges and Institutes"*, completed in September of 2004, provides a summary of the proposed strategy for dealing with renewable energy training at the community college level.

II. Updated Summary of Canadian Community College Level Programs Related to Alternative and Renewable Energy

Within Canada, the state of affairs with respect to alternative and renewable energy training at the community college level is still somewhat amorphous. In some instances, program intentions have been announced; however, have not developed into tangible outcomes for a variety of reasons such as funding priorities. Furthermore, in some cases, related programs are integrated by extension or modification of curriculums, making it difficult to easily isolate the renewable and alternative components. There also would appear to be scope for improvement of information flow and partnering in the development of curriculum. The Association of Canadian Community Colleges does not maintain a record of enrolment numbers at present, with the reluctance of colleges to provide such information being one principal reason for not so doing. Based upon discussions with staff at the Canadian Association of Community Colleges [1], and other research, the following is believed to be a reasonably accurate summary of the status of renewable energy programs in Canada by province.

British Columbia

Northern Lights College (Dawson Creek) is developing "shorter "Continuing Education "train the trainer" programs in relation to Solar Thermal Energy. The key contact is Bob Haugen (250) 784-7509.

[1] Personal conversation with Lise Robitaille, Renewable Energy Programs Coordinator. Tel: (613) 746-2222, Ext 3131

Malaspina College (Nanaimo), led by Dr. David Drakeford, has been active in the strategic planning process for renewable energy training within community colleges; however, details of current programming are somewhat vague. A two-year diploma with renewable energy components is to be introduced by 2008, and a degree program is contemplated in the following years.

BCIT (Burnaby) has had some involvement with solar PV training at the continuing education level in conjunction with CANSIA (Canadian Solar Industry Association), and according to Chris Carter, Vice President of Fuel Cells Canada, has started to integrate fuel cells into automotive training. Richard Plett (604) 456-8063 is a suggested contact for the latter.

Langara College (Vancouver) has developed, as part of an "Environmental Stewardship Program", a series of one day or less Continuing Education programs dealing with the following topics:

- Net-metering and Renewable Energy NEW
- Energy Savings for Small and Medium Sized Businesses
- Triple E Home Energy Planning - Easy, Economical, Efficient
- Community Energy Planning NEW
- Solar Hot Water Heating Past and Present

For more information call Cora Van Wyck at 604-323-5971 or email cvanwyck@langara.bc.ca

Douglas College (Vancouver) has a Building Environmental Systems Program that equips graduates with the ability to operate a building of any size efficiently and economically by developing a full range of practical knowledge reinforced by workplace competency. Subjects include:

- BESS 1100 - Building Systems - A Practical Overview
- BESS 1101 - Heating
- BESS 1102 - Air Conditioning and Refrigeration
- BESS 1103 - Air Handling and Preventative Maintenance
- BESS 1104 - Electrical Systems
- BESS 1105 - Controls
- BESS 1106 - Water Treatment
- BESS 1107 - Pipe Systems Design
- BESS 1108 - Air Systems Design
- BESS 1109 - Hospital Systems
- BESS 1110 - Energy Efficiency in Large Building

According to the Canadian Association of Community Colleges, the program is "owned" by Seneca College in Ontario.

Information and links to other British Columbia programs of potential interest may be found at:

http://www.bcsea.org/education/college.asp

Alberta

Lethbridge Community College (Lethbridge) has implemented a wind turbine maintenance program, partly in conjunction with manufacturers such as Vestas and General Electric.

SAIT Polytechnic (Calgary), in conjunction with the establishment of the Centre for Energy, has introduced renewable components to the existing Power Engineering programs. Duke Anderson, Dean of Science and Technology (403) 284-8292 is the key contact.

NAIT (Edmonton) – has a solid oxide fuel cell that is used in part for the Power Engineering Program; however, there are no "stand-alone" fuel cell courses at this time. Consideration is being given to developing a Continuing Education course related to fuel cells.

Saskatchewan

No known programs at present

Manitoba

No known programs at present

Ontario

St Lawrence College (principal campus in Kingston) - arguably the Canadian leader in renewable energy curriculum at the Community College level, has established, in conjunction with European partners, the "World Wind Energy Institute". The college has the intent of extending the concept to other forms of renewable energy. In addition, the college currently offers a one-year Renewable Energy Technician and two-year Renewable Energy Technologist diploma program.

Lampton College (Sarnia) - the Alternative (Sustainable) Energy Engineering Technology Program (ALTE) is a three year program with a co-op component, which will provide students with a combination of theory and application skills in current and emerging energy technologies. Graduates will deal with the integration of current energy sources along with newly developing alternative energy distribution systems. These specialists will be given the technical and applied knowledge in renewable energy concepts combined with energy efficient design principals.

Centennial College (Toronto) has begun to develop and present short, customized continuing education programs covering a range of renewable energy issues.

Humber College (Toronto) has an Environmental Systems Engineering Technology - Energy Management program that is two semesters in length. This program gives graduates a broad and intensive knowledge of the design, operation and installation of energy systems for residential, commercial and industrial complexes. For more information, please reference: appliedtechnology.humber.ca/programs/envSys/index.

Willis College (Ottawa) is a private college that has developed a suite of on-line diploma courses covering a range of feasibility and assessment issues associated with various forms of alternative and renewable energy. The programs make heavy use of RETScreen International technology developed by Natural Resources Canada.

Seneca College (Greater Toronto area) has a number of Renewable Energy related programs and courses delivered via on-line and classroom methods:

- Photovoltaic Technician Program – on-line and delivered in conjunction with the Kortright Centre. Please reference the following link for more information: http://eto.senecac.on.ca/renewable/photovol.html

- There are also Wind Energy, Geothermal and Solar Thermal Energy programs; however, the associated links were not functioning over the duration of this project.

- Other courses include: **BGR 261 - Renewable Energy Technologies I.** Studies in this subject cover the fundamentals of solar water heating, wind power, geothermal, photovoltaic systems, fuel cells, and alternative fuel technologies. The pre-requisite is BGR 161

Quebec

Groupe Collegia, CEGEP de la Gaspesie et des Iles de la Madeleine (Gaspe) has a program related to wind turbine maintenance. The program length is approximately 1,400 hours. At present, course material is only in French.

New Brunswick

Bathurst Community College (Bathurst) - has begun to develop continuing education programs related to Solar PV as well as Ground Source Heat Pumps.

III. Terminology

Throughout the course of this report, reference is made to a number of terms for which is may be useful and more efficient to provide an explanation or definition at this juncture:

Measures of Power Production and Consumption

- **KiloWatt (KW)** - A unit of electrical power equal to 1,000 watts or approximately 1.3 horsepower. A 100-watt light bulb burning for 10 hours uses one kilowatt-hour. 1 KW of power would be equal to approximately 50% of the daily requirements of an average household.
- **MegaWatt (MW)** – A unit of electrical power equal to 1 million watts. For reference, 1 MW of installed capacity will supply enough power for about 550 homes.
- **GigaWatt (GW)** – A unit of electrical power equivalent to 1 billion watts. The requirements of nations are often measured in GW units.
- **TerraWatt (TW)** – A unit of electrical power equivalent to 1 trillion watts. For perspective, in the year 2000, the global hydroelectric power generating capacity was approximately 2.7 TW.
- With respect to each of the above, a reference may be in the context of the hourly generating electrical capacity of a facility or the annual generating capacity.

On occasion, reference is also made to a "TH" (thermal) or "e" (electrical) distinguishing the difference between thermal and electrical use.

Other Terminology

- **DC Power** – is derived from a power source, such as a battery, and outputs a constant voltage over time.

- **AC Power** – is the type of power derived from an electrical socket and is more common. An AC source of electrical power changes constantly in amplitude and regularly changes polarity. Through the use of transformers and inverters, the strength of the power can be increased or decreased. AC power is now more common than DC power.

IV. Renewable and Alternative Energy In Context

Global Situation

The publication "Renewables 2005: Global Status Report", prepared by the Copenhagen, Denmark based Renewable Energy Policy Network for the 21st Century, is an excellent reference for a concise and well-written overview of the status of the global renewable energy sector. Based upon the report, it is possible to make the following observations:

- "New Renewable" power capacity totals 160 GW worldwide (excluding large hydropower), about 4 percent of global power sector capacity of approximately 3.8 TW. Developing countries have 44 percent of this capacity, or 70 GW. The following table provides a summary of global "new" renewable energy production capacity by type.

GLOBAL RENEWABLE ENERGY POWER PRODUCTION CAPACITY IN 2004

Type	Indicator
Small hydropower	61 GW
Wind power	48 GW
Biomass	39 GW
Geothermal power	8.9GW
Solar PV	4.0 GW (2.2 GW off grid/1.8 GW grid-connected)
Solar thermal power	0.4 GW
Ocean tidal power	0.3 GW
Sub-total	**160 GW**

Large-scale hydro capacity would add an additional 720 GW to the figure above bringing the total closer to 17%.

- About $30 billion was invested in renewable energy worldwide in 2004 (excluding large hydropower), a figure that compares to conventional power sector investment of roughly $150 billion. Investment in large hydropower was an additional $20–25 billion, mostly in developing countries.

Canadian Situation

By comparison, the total installed generation capacity at the end of 2003 was projected at 112 GW, which included hydro power, coal, nuclear, natural gas, oil-fired, wood-fired, tidal, and wind plants Total national electrical energy demand in Canada in 2004 was 602 TW.

Alberta Situation and Projections

As of January 1, 2006, Alberta's electrical generation capacity (less interconnections of approximately 800 MW from British Columbia and 150 MW from Saskatchewan) was approximately 11,477 MW. Of this amount, "traditional" generating sources accounted for 97.4%

of the total. Of this figure, non-renewable sources (coal and gas) accounted for 10,013 MW, or 88% of the total, and hydro accounted for 854 MW or 7.5% of the total. The following table provides a summary of the major components of Alberta's capacity and their relative percentages.

ALBERTA'S ELECTRICAL GENERATING CAPACITY AS OF JANUARY 1, 2006

Source	Capacity (MW)	Percentage of Total
Coal	5,840	50.9%
Gas	4,277	37.3%
Hydro	900	7.8%
Wind	275	2.4%
Biomass	178	1.6%
Fuel Oil	8	0.1%
Total	**11,477**	**100.0%**

Additions in the Period 1998 to 2005

Alberta's electrical generating capacity has grown significantly, spurred by deregulation of the electrical industry as a result of the passage of Electrical Utilities Act in 1995. Between 1998 and 2005, approximately 3,900 MW of new capacity came on-line. Of the total, cogeneration was the largest component accounting for almost 66% of the provincial total. The percentage of total cogeneration capacity associated with the NADC region was approximately 33%. In addition, cogeneration accounted for over 88% of the capacity added to Northern Alberta. The following table provides additional details of capacity additions in the 1998 to 2005 period on a province-wide basis and also shows the Northern Alberta additions as a percentage of the respective provincial and NADC region totals.

CAPACITY ADDITIONS (MW) 1998-2005 AND NORTHERN ALBERTA PROPORTIONS

	Total Additions	Percentage of Total	Additions in the NADC Region	Percentage of Provincial Total	Percentage of NADC Total
Cogeneration	2,542.8	65.7%	1,293	33.4%	88.5%
Biomass	122	3.2%	105	2.7%	7.2%
Wind	247.7	6.4%	0	0.0%	0.0%
Hydro	51.7	1.3%	12.7	0.3%	0.9%
Natural Gas	458.1	11.8%	51	1.3%	3.5%
Coal	450	11.6%	0	0.0%	0.0%
Total	**3,872.3**	**100.0%**	**1,461.7**	**37.7%**	**100.0%**

Additional details of the additions including owners, locations, size and type can be obtained by referencing the following Alberta Energy web site:

http://www.energy.gov.ab.ca/537.asp

Capacity Additions for the Period 2006 to 2009 and Beyond

Based upon current plans of owners and applications submitted to approving authorities, an additional 4,900 MW of capacity is planned for the period 2006 to 2009 and beyond. Of this amount, coal, cogeneration and wind power are the three single largest components. Coal will account for 1,640 MW, or approximately 34% of the total; however, there are no significant coal related capacity additions in the NADC region. Cogeneration projects account for 1,583 MW or

32% of the total. The vast majority of these projects (1,498 MW or 95% of cogeneration projects) will be in the NADC region. Wind power will also play a major role, accounting for 1,036 MW of capacity additions (21% of the total); however, none will be in the NADC region. Additions associated with hydro-electricity (namely the proposed run of river dam near Dunvegan) will account for 100MW, or 2% of the provincial total. The following table provides additional details of capacity additions proposed for the 2006 to 2009 and beyond period on a province-wide basis and also shows the Northern Alberta additions as a percentage of the respective provincial and NADC region totals.

CAPACITY ADDITIONS (MW) 2006 TO 2009 AND BEYOND NORTHERN ALBERTA PROPORTIONS

	Total Additions	Percentage of Total	Additions in the NADC Region	Percentage of Provincial Total	Percentage of NADC Total
Cogeneration	1,583	32.4%	1,498	30.6%	84.7%
Biomass	15	0.3%	0	0.0%	0.0%
Wind	1,036	21.2%	0	0.0%	0.0%
Hydro	100	2.0%	100	2.0%	5.7%
Natural Gas	345	7.1%	0	0.0%	0.0%
Coal	1,640	33.5%	0	0.0%	0.0%
Bitumen	170	3.5%	170	3.5%	9.6%
Total	**4,889**	**100.0%**	**1,768**	**36.2%**	**100.0%**

Additional details of the additions including owners, locations, size, dates and type can be obtained by referencing the following Alberta Energy web site:

http://www.energy.gov.ab.ca/537.asp

Employment Impact

Based upon work originally undertaken by the Pembina Institute but published in an article of the Clean Air Coalition [2], some factors have been developed to estimate the employment impact of certain energy projects at various stages. The impacts, along with an indicator of the degree of confidence (High, Medium and Low) in the estimates are summarized in the following table, which forms the basis of some of the employment impact discussion in subsequent chapters.

Renewable Electricity Type	Parts Manufacturing (Job-years/MW)	Development & Construction (Job-years/MW)	Operation & Maintenance (Jobs / MW)
Wind (onshore)	3.04 (H)	0.88 (H)	0.10 (H)
Run-of-river Hydro	0.50 (M)	10.80 (M)	0.22 (M)
Photovoltaics	18.80 (M)	7.10 (H)	0.10 (H)
Geothermal	- (L)	4.00 (M)	1.70 (M)
Biomass	- * (L)	2.00 (L)	0.95** (H)

*Biomass manufacturing is included in development and construction
**Includes fuel collection

[2] www.cleanairrenewableenergycoalition.com/documents/FINAL%20Employment%20Predictions%20-%20Oct%2028.pdf

Overview and Comparison of Costs

The following table provides an overview and comparison of the cost and expected trends by the year 2020 for a range of energy sources.

COSTS OF RENEWABLE ENERGY COMPARED WITH FOSSIL FUELS AND NUCLEAR POWER

Technology	Current cost (U.S. Cents/kWh)	Projected future costs Beyond 2020 as the Technology matures (U.S. cents/kWh)
Biomass Energy: • Electricity • Heat	 5-15 1-5	 4-10 1-5
Wind Electricity: • Onshore • Offshore Solar Thermal (insolation of 2500 kWh/m^2 per year)	 3-5 6-10 12-18	 2-3 2-5 4-10
Hydro-electricity: • Large scale • Small scale	 2-8 4-10	 2-8 3-10
Geothermal Energy: • Electricity • Heat Marine Energy: • Tidal Barrage • Tidal Stream • Wave	 2-10 0.5-5.0 12 8-15 8-20	 1-8 0.5-5.0 12 8-15 5-7
Grid connected photovoltaics: • 1000 kWh/m^2 per year (UK) • 2500 kWh/m^2 per year (developing countries • Stand alone (including batteries)	 5-80 20-40 40-60	 ~ 8 ~ 4 ~ 10
Nuclear Power	4-6	3-5
Electricity grid (from fossil fuels): • Off peak • Peak • Average • Rural electrification	 2-3 15-25 8-10 25-80	Will decline with technological progress; however, many technologies already mature and may be offset by rising fuel costs
Cost of central grid supplies, excluding transmission and distribution: • Natural gas • Coal	 2-4 3-5	Will decline with technological progress; however, many technologies already mature and may be offset by rising fuel costs

Source: Renewables 2005 Global Status Report

The figures are based upon global averages and may differ from the specific cost data presented in some of the subsequent chapters. However, it is useful to be able to make comparisons derived from a sole source.

Chapter 3
Wind Power

The purpose of this chapter is to provide an analysis of some of the major characteristics, trends and issues associated with the wind power industry that may have a bearing on the need for related training at colleges in Northern Alberta.

I. Technological Aspects

Overview

Wind power is the kinetic energy that is present in moving air. It is caused because the sun heats the earth at different rates depending on whether the area is cloudy, clear, or under water. In warm areas the air rises and becomes less dense. The rising air creates a low-pressure area. Cooler air from adjacent higher-pressure areas moves towards the lower pressure areas. This air movement is wind.

The amount of potential energy depends primarily on wind speed, but is also affected slightly by the density of the air, which is determined by the air temperature, barometric pressure, and altitude. Air is denser in the winter than in the summer. Therefore, a wind generator will produce more power in the winter than in summer at the same wind speed. At high altitudes (in mountains) the air pressure is lower, the air is less dense, and less power is produced. The power and energy output increases dramatically as the wind speed increases. Therefore, the most cost-effective wind turbines are located in the windiest areas and are mounted on tall towers.

A wind turbine works the opposite of a fan. Instead of using electricity to make wind, turbines use wind to make electricity. The wind turns the blades, which spin on a shaft; the shaft is connected to a generator and produces electricity. The more air that passes by the blades, the faster the blades rotate, and the more electricity the wind generator will produce. A larger rotor area is able to collect more wind and produce more electricity with lower speeds. There are two types of wind turbine:

- Vertical axis wind turbines, in which the transmission axis is perpendicular to the ground; and
- Horizontal axis wind turbines, in which the transmission axis is parallel to the ground and in line with the horizon. These turbines are the ones most commonly used today.

In order to determine if a wind energy system is feasible, there must be an adequate wind supply. A wind energy system usually requires an average annual wind speed of at least 15 km/h. The following table represents a guideline of different wind speeds and their potential in producing electricity.

WIND SPEEDS AND ELECTRICITY PRODUCTION POTENTIAL
(METRES PER SECOND AND KILOMETRES PER HOUR)

Average wind speed	Suitability
Up to 4 m/s (about 15 km/h)	Not Suitable
5 m/s (18 km/h)	Poor
6 m/s (22 km/h)	Moderate
7 m/s (25 km/h)	Good
8 m/s (29 km/h)	Excellent

History

Humans have used wind energy for thousands of years. As recently as the 1920s, over a million wind turbines pumped water and provided electricity to farms in North America. More recently, higher energy costs, a growing interest in "green and renewable" sources of energy associated with climate change concerns, more aggressive government incentives and de-regulation of the electricity industry in provinces such as Alberta, have caused a resurgence in the interest in wind power.

Advantages and Disadvantages

Advantages of Wind Power

- A pollution-free, infinitely sustainable form of energy.
- No fuel is required.
- Greenhouse gases or other toxic or radioactive waste byproducts are not created.
- It is generally quiet and does not present any significant hazard to birds or other wildlife. When large arrays of wind turbines are installed on farmland, only about 2% of the land area is required for the wind turbines. The rest is available for farming, livestock, and other uses.
- Landowners often receive payment for the use of their land, which enhances their income and increases the value of the land.
- Ownership of wind turbine generators by individuals and the community allows people to participate directly in the preservation of our environment. Each MW of electricity that is generated by wind energy helps to reduce the 0.8 to 0.9 tonnes of greenhouse gas emissions that are produced by coal or diesel fuel generation each year.

Disadvantages of Wind Power

- Because wind farms are comprised of large numbers of turbines, each mounted atop tall towers, they can often be seen for a long distance. Where this is true, the question arises as to whether the visual impact is undesirable; opinions will vary from location to location.
- Some people may be concerned about noise from wind turbines. Two potential types of noise from turbines are mechanical and aerodynamic. *Mechanical noise*, produced by parts rubbing against or hitting other parts, has virtually disappeared in modern wind turbines, as a result of improved engineering. *Aerodynamic noise*, which is the swishing sound the blades make as they pass the tower, has also been greatly reduced as a result of improved aerodynamic blade design.
- Wind turbines will not operate or run efficiently when the location is improperly sited because wind speeds are affected.

Cost Issues

The cost of wind energy is determined by: the initial cost of the wind turbine installation; the interest rate on the money invested; and the amount of energy produced. Modern wind turbine generators cost about $1500 per kilowatt for wind farms that use multiple-unit arrays of large machines. Smaller individual units cost up to $3000 per kilowatt.

In good wind areas, the costs of generating electricity range between $.05 and $.10 per kilowatt hour. This is a significant decrease from $ .30 per kWh less than 10 years ago. By comparison, in remote areas, generating electricity with diesel generators can exceed $0.25 per kilowatt hour.

Major energy reviews by the British government and the US Department of Energy predict that, in 2020, the cost of wind energy (on-shore and off-shore) will range from 3.4 to 5.5 cents per kWh in US dollars. (David Milborrow, *Windpower Monthly*, January 2002). The report, *"Renewables 2005 Global Status Report",* suggests that onshore wind power costs will decline to $US .02 to .03 per kWh by 2020. If these estimates hold true, wind power will be one of the cost effective sources of energy in the future.

II. Market Trends and Characteristics

Global Market Indicators [1]

Wind power is the world's fastest growing energy source, increasing in excess of 30% annually for the past five years. At the beginning of 2004, worldwide wind-generated capacity exceeded 39,000 MW. BTM Consultants projects global wind energy capacity will be 95,000 MW by 2008 and 194,000 MW by 2013.

In 1999, over $3.5B was invested in farms that use wind energy. Most of the investment was spent in Europe where conventional electricity costs are higher and where political motivation to reduce greenhouse gas pollution is greater. In Denmark, for example, wind-generated electricity now provides about 10 % of national needs and is scheduled to provide 50 % by 2030.

The global wind turbine industry comprises about a dozen major firms located in Europe with annual revenues of about of $100M per year. The Danish wind turbine industry is larger than the fishing and agricultural industries combined.

Canadian Market

Large Wind Turbines

In general, in comparison to other countries, Canadian use of wind energy has been small because of low electricity prices, and energy surpluses. Other barriers have included issues related to training and standards such as: Licensing of practitioners; Inspections of installations; Home pre-purchase inspectors; CSA U/L Certification of Equipment; and city planning staff.

However, particularly in relation to the "market" aspects, the situation is changing rapidly. Installed wind power capacity in Canada has experienced an average annual growth rate of 44% over the past five years. As of December 2003, wind energy accounted for approximately 3% of Canada's total energy production. The installed capacity was 317 MW, with an estimated 765 GWh (Giga or 10^9) of wind energy was produced that year. By December 2004, the wind energy capacity was 444MW and by May 2005, a total of 683 MW of wind power had been installed in Canada. Alberta currently has the highest installed capacity, totaling 275 MW; however, both the provinces of Quebec and Ontario have awarded contracts for 990 MW (Mega or 10^6)and 355 MW respectively to be built during the next few years.

[1] www.canwea.ca/en/QuickFacts.html

The following table provides an overview of the sites, dates of installation, generating capability and ownership for the major wind energy installations in Canada as of 2005.

MAJOR WIND ENERGY INSTALLATIONS IN CANADA (2005)

Wind Farm/Site	Installed	Total Power (kW)	Company
Prince Edward Island		**13,560**	
Aeolous	Aug 03	3,000	Aeolous PEI Wind
North Cape	Nov 01-Apr 04	10,560	Prince Edward Island Energy Corp
Nova Scotia		**35,260**	
Glace Bay	Nov 05	1,600	Cape Breton Power
Grand Etang, Inverness County	Oct 02	660	Nova Scotia Power
Halifax	Nov 05	600	Renewable Energy Services Limited
Little Brook	Oct 02	600	Nova Scotia Power
Pubnico Point	Jun 04 - May 05	30,600	Atlantic Wind Power Corp.
Springhill Project	Dec 05	1,200	Vector Wind Energy
Québec		**212,250**	
Le Nordais (Phase 1 - Cap Chat)	Mar 99	57,000	Axor
Le Nordais (Phase 2 - Matane)	Sep 99	42,750	Axor
Matane	Jan 98	2,250	Hydro-Québec
Mount Copper Project	May 04	9,000	3Ci and Creststreet Asset Mgt Ltd
Mount Copper Project (Phase 2)	Jun 05	45,000	3Ci and Creststreet Asset Mgt Ltd
Mont Miller Project	Jun 05	54,000	Northland Power Income Fund
Parc eolien du Renard	Sep 03	2,250	Groupement eolien Quebecois
Ontario		**14,610**	
Ferndale	No v 02	1,800	Sky Generation
Huron - Kincardine	Nov 02	9,000	Huron Wind
Pickering	Oct 01	1,800	Ontario Power Generation
Port Albert	Dec 01	660	Private
Tiverton	Oct 95	600	Ontario Power Generation
Toronto waterfront	Jan 01	750	Windshare
Yukon		**20,610**	
St.Leon Project	Jul 05	19,800	Algonquin Power Income Fund
Haeckel Hill (Whitehorse)	Jul 93	810	Yukon Energy Corportion
Saskatchewan		**111,760**	
Centennial Wind Power Facility	Dec 05	90,000	SaskPower International
Cypress Wind Power Facility	Sep 01-Dec 03	10,560	SaskPower
Sunbridge	Sep 01	11,200	Suncor & Enbridge
Alberta		**275,470**	
Castle River Wind Farm	From Nov 97	39,540	Vision Quest Windelectric
Cowley Ridge Wind Farm	Dec 93-Sep 00	21,400	Canadian Hydro Developers, Inc
Cowley Ridge North Wind Farm	Oct 01	19,500	Canadian Hydro Developers, Inc
Lundbreck	Dec 01	600	Lundbreck Dev Joint Venture A
McBride Lake	Jun 03	75,240	ENMAX/Vision Quest
McBride Lake East	Dec 01	660	Vision Quest Windelectric
Magrath	Sep 04	30,000	Suncor, Enbridge, EHN
Sinnot Wind Farm	Nov 01	6,500	Canadian Hydro Developers, Inc
Summerview	Apr 02	1,800	Vision Quest Windelectric
Summerview	Sep 04	68,400	Vision Quest Windelectric
Tallon Energy Project	Jan 04	750	Tallon Energy
Taylor Wind Project	Dec 04	3,400	Canadian Hydro Developers
Vestas Prototype	Sep 04	3,000	Visionquest/Vestas
Waterton Wind Turbines	Nov 97-Jan 02	3,780	Vision Quest Windelectric
Weather Dancer I	Dec 01	900	Epcor/Peigan Nation Reserve
Total		**683,520**	

Industries that are related to wind energy include manufacturers of rotor blades, control systems, inverters, towers, and small wind turbines as well as wind resource assessment firms and wind farm developers.

The following manufacturers are operating in Canada. Wenvor Technology of Guelph, Ontario and Plastique Gagnon of Quebec are developing small wind turbines in the 20-30 kW size. Novelek Technology of New Brunswick has developed 10- and 25-kW inverters for the commercial wind turbine market. Composotech Structures of Goderich, Ontario is manufacturing blades for 10-kW to 1.5-MW wind turbines. The company produces rotor blades on speculation for wind turbine manufacturers and also has a generic blade design, suitable for turbines in the 750 to 900 kW range.

Alberta Situation and Potential

Currently, most operations in Alberta are in the Pincher Creek area; however, the industry is expanding into other areas including Magrath, Taber, and Fort Macleod. The following companies have operations in Southern Alberta:

- AREVA T&D Canada Inc. (www.areva-td.com)
- Canadian Hydro Developers, Inc. (www.canhydro.com)
- EHN Wind Power Canada Inc.
- Enbridge Inc. (www.enbridge.com)
- Enmax (www.enmax.com)
- Epcor (www.epcor.ca)
- Suncor Energy Inc. (www.suncor.com)
- Talon Energy Corp. (www.tallonenergy.com)
- Vistas (www.vestas.com)
- Vision Quest Windelectric (www.visionquestwind.com)
- Wind Power Inc.(www.windpower.ca)

In early 2006, these companies had a large wind turbine generating capacity of 275 MW, equivalent to 2.6% of the Alberta total. Over the next three to four years an additional 247 MW of capacity will be installed, all in Southern Alberta.

There are also some very recent indicators of a potential industry in more northerly regions. A memorandum of agreement between AltaGas Income Trust (AltaGas or the Trust)(TSX: ALA.UN) and Aeolis Wind Power Corporation (Aeolis) was announced on May 12, 2006 to jointly pursue the development of up to a further 300 MW of wind power in British Columbia, near Dawson Creek (the Bear Mountain Wind Power Project). This development arguably suggests that there **could** be potential for wind energy projects in Northwestern Alberta. It is advised that this development be monitored closely.

Small Wind Turbines (SWTs)

The following comments are based upon a recent report[2] completed by the Canadian Wind Energy Association.

SWTs (from 300 W to 300 kW), divided into three categories:

- Mini wind turbines with a rated power output from 300 Watts up to 1000 Watts;
- Small wind turbines (above 1 kW and up to 30 kW), and;

[2] http://www.smallwindenergy.ca/en/Overview/SmallWindCanada.html

- Medium wind turbines (above 30 kW, up to 300 kW).

At present, the market for SWTs in Canada is relatively small, although it has experienced some growth in the past five years. A survey of retailers, distributors and manufacturers of SWTs revealed the following:

- **Annual Sales -** are in the range of 600 to 800 units per year, with a total rated output of between 800 kW and 1,000 kW. This represents roughly $4.2 million in annual sales, including $2.3 million for mini wind turbines, $1.2 million for small wind turbines and $0.7 million for medium wind turbines.
- **Total Installed Capacity - t**here are currently between 2,200 and 2,500 SWTs installed in Canada, 90% of which fall into the mini wind turbine category. The total combined capacity of all SWTs is estimated to be between 1.8 MW and 4.5 MW, equivalent to the capacity of one to three modern utility-grade wind turbines. Their total annual output is roughly 7.5 GWh per year, or the amount of electricity consumed by approximately 750 Canadian homes. The most active current markets for SWTs are in four areas: battery charging, on-grid residential, farms & commercial, and northern communities.

The Canadian SWT supply chain consists of approximately 130 retailers/distributors and six manufacturers of commercial SWTs. The distributors and retailers are concentrated in Ontario (55%), Quebec (15%), Alberta and British Columbia (8% each). Most of these companies are new entrants to the market, and the top 10 distributors/retailers account for roughly 90% of all Canadian sales by volume. Most retailers are engaged in SWT sales either as a sideline business, or as one element of a larger service and retail offering. The majority of SWTs installed in Canada originate from the United States, with 96% of reported sales in Canada attributed to three U.S. manufacturers: Bergey, Southwest Windpower and Aeromax.

However, as outlined below, realization of the full potential would result in the installation of over 140,000 SWTs with a total capacity of over 600 MW and an annual energy output of 1 TWH. This would result in investments of roughly $3 billion CDN, with just over half of that amount spent on the turbines themselves and the remainder spent on balance of system (BOS) and installation. In the battery charging and residential markets, it is likely that the turbine investment would primarily benefit U.S. and, to a lesser degree, European manufacturers unless new Canadian manufacturers enter the market. Investments in farms & commercial markets would likely benefit Canadian manufacturers, while investments in northern communities would benefit Canadian, European and U.S. manufacturers.

SUMMARY OF SMALL-SCALE WIND MARKET POTENTIAL

Market	Average Capacity (kW)	Total Potential (units)	Total Capacity (kW)	Energy Output (GWh/yr)	Total Investment ($million)		
					Turbine only	BOS & Installation	Total System
Battery Charging	1	8,000	8,000	14	22	29	51
On-grid residential	3	120,000	360,000	631	1,080	1,080	2,160
Farms & Commercial	20	12,300	246,000	431	541	271	812
Northern & Remote*	50	58	2,900	5	6	3	10
Total		**140,358**	**616,900**	**1,081**	**1,650**	**1,383**	**3,033**

* This is a low estimate based on a 1998 NRCan study assessing the viable potential for wind-only systems in northern communities. Other NRCan studies have indicated that the total technical potential for wind-diesel hybrid systems is as high as 173 MW, corresponding to the total average system power demand.

III. Canadian Public Policy and Strategy

Research and Development

The main vehicle of technical support at the national level is the Wind Energy Research and Development (WERD) Program, at Natural Resources Canada. The main elements of the Wind Energy R&D program are: Technology Development, Resource Assessment, Test Facilities, and Information/Technology Transfer.

The focus of the Canadian national wind energy program continues to be on R&D to develop safe, reliable, and economic wind turbine technology to exploit Canada's large wind potential, as well as supporting Field Trials. The program also supports a national test site: The Atlantic Wind Test Site (AWTS) at North Cape, Prince Edward Island for testing electricity generating wind turbines and wind/diesel systems. The program supports new technology development activities related to:

- Components for wind turbines in the 600 kW to 2 MW range;
- Small to medium size wind turbines (10 kW to 275 kW) for use in agro-business, and to
- Supplement diesel-electricity generation in remote communities; and
- Wind/diesel control systems for wind/diesel hybrids in remote communities.

The government is also studying the impacts and regulation of offshore wind farms in the context of large projects off the coast of British Columbia and in the Great Lakes of Ontario.

Researchers at the University of Alberta [3] have developed prototypes of simple, relatively inexpensive and easy to repair new small-scale wind turbines that can generate power at very low wind speeds. While the technology is not ready for commercialization, there may be significant potential for application in more remote and northern communities.

Market Development and Stimulation

The main constraints for wind energy development in Canada are the lower cost of conventional energy and a surplus of generation capacity in many areas. However, in a few jurisdictions these factors are changing. In some provinces, such as Alberta and Ontario, surplus generation is rapidly declining. Some of the key government initiatives to stimulate the wind energy industry are outlined below.

- The most influential market stimulation instrument so far is the federal government's Wind Power Production Incentive (WPPI) program for wind energy developers. Qualifying wind energy facilities receive an incentive payment of 0.01 CAD per kWh of production. The incentive is available for the first 10 years of production and helps to provide a long-term stable revenue source. The program is intended to help address climate change and improve air quality. Originally slated for 1,000 MW to be built by 2007, the program has recently been expanded to 4,000 MW to be built by 2010. Interest in WPPI has been high. By December

[3] http://www.expressnews.ualberta.ca/article.cfm?id=6792

2004, the program had registered Letters of Interest applications totaling 192 projects and 11,000 MW of capacity.

- Currently, the federal Income Tax Act provides an accelerated rate of write-off for certain capital expenditures on equipment that is designed to produce energy in a more efficient way or to produce energy from alternative renewable sources. Recently, the tax write off has been increased from 30% to 50% per year, on a declining balance basis.

- The government has also extended the use of flow through share financing for intangible expenses in certain renewable projects, through the Canadian Renewable and Conservation Expense (CRCE) category in the income tax system. With CRCE, the Income Tax Act allows the first, exploratory wind turbine of each section of a wind farm to be fully deducted in the year of its installation, in a manner similar to the one in which the first, exploratory well of a new oil field can be written off.

- The federal government has established a Green Power Purchase program. This program allows developers to sell electricity, generated by wind and other forms of renewable energy, to the government at premiums negotiated through a competitive process. As a byproduct of the federal program, wind power producers have built additional wind plants, and green energy is being sold to private, provincial, and municipal consumers.

- Provincial and territorial governments are being encouraged to provide additional support, and a number of provinces have begun to develop their own complementary programs. For example, Quebec has awarded contracts for 990 MW and is expected to launch another Request for Proposals (RPS) for 1,000 MW to be built between 2006 and 2012. Ontario has also recently awarded contracts for 355 MW to be built by 2007 and is expected to launch another RPS for 2,500 MW of clean energy production. Both of these provinces and Nova Scotia intend to provide net-metering for small wind projects. Other provinces have set goals and/or RPS for wind energy.

- Finally, the Wind Energy Atlas is a massive database of high-resolution wind statistics for all of Canada, making Canada one of the largest countries in the world to have a comprehensive Wind Energy Atlas across its entire territory. The Wind Energy Atlas was created with WEST, the Wind Energy Simulation Toolkit, a sophisticated computer-modelling program developed by scientists with Meteorological Service of Canada (MSC), in partnership with their colleagues at Natural Resources Canada. WEST allows planners of wind energy projects to look both backward and forward in time to generate a detailed picture of wind patterns for any location in Canada. This means wind farms can be situated with greater precision, and, by reducing the need for extensive field studies to verify wind conditions in a given area, development of new projects can move much more quickly. The Atlas can be found on the Internet at: http://www.windatlas.ca.

- With respect to small wind in Canada, at present, there is relatively little support in terms of incentives, R&D, policies and education. The past ten years have seen a number of small programs that provide regional assistance, but as of yet there has not been a comprehensive set of measures aimed at increasing market penetration.

IV. Education and Skills Requirements

Number and Types of Jobs Within the Industry

In February 2005, the Canadian Wind Energy Association (CanWEA), with the support of Industry Canada, contracted Insightrix Research to carry out a quantitative economic survey of the Canadian wind energy industry.[4] This survey was intended to not only provide a "snapshot" of the current state of the industry, but also to serve as a benchmark for subsequent annual surveys that chart industry growth. Some of the findings of relevance to this project, based upon responses from 99 of 152 companies contacted are summarized below:

- Overall, it is estimated that the industry provides the equivalent of 720 full-time direct jobs (expressed as full-time equivalent employment, or FTE). The total annual payroll associated with these jobs is just under $50 million. If indirect impacts are included, the study concluded that 1,370 jobs result from the presence of the wind industry in Canada. On average, firms have 4.4 "wind-dedicated" positions per company. This indicates that although the Canadian wind industry is growing, firms within it remain relatively small. A November 2005 presentation [5] made by Don Young, Dean of the St Lawrence College School of Engineering and Computer Technology and School of Skilled Trades suggests that a typical wind energy project employs one person per 1MW during construction and one person per 10MW during operation, and that the technical maintenance requirements for wind turbines are one person per 10 to 15 turbines.

- Most firms (over 95%) are involved in post-manufacturing. The survey found that very few firms are engaged in manufacturing of either entire turbines or components. Over 95% reported that their activities focus only on the development, installation and services sector. Most firms (80%) are involved only with large, utility-scale wind turbines. Only one in five respondents indicated that they work with small wind turbines (i.e. those with a rated capacity of 300 kW or less). Only 13% were engaged in research and development.

- The types of activities of the companies responding to the survey were categorized as summarized in the following table.

Type of Activity	Percentage of Firms
Project Development	24%
Consulting	19%
Other services (law, transportation, insurance etc.)	13%
Construction Services	10%
Service Provider	9%
Power Producer	9%
Operations and Maintenance	9%
Components Manufacturer	4%
Turbine Manufacturer	3%

While there are many specialists in the wind energy industry, typical jobs(excluding common jobs in administration) in rough order of prevalence are:

[4] http://www.canwea.ca/downloads/en/PDFS/Economic_Impact_Report_Summary_-_August_2005.pdf
[5] http://www.pollutionprobe.org/Happening/pdfs/developingenergywkshpnov14-15/young.pdf

- Developer
- Designer/installer
- Design engineer/design consultant
- Wind Assessment consultant
- Regulation/Implementation Consultant
- Turbine maintenance worker
- Electrical maintenance worker
- Manufacturing Plant worker
- Technical Sales

Within Alberta, Turbine and Electrical Maintenance Workers are considered the two categories of greatest applicability for community college students. A brief overview of the occupations, qualifications and skills required are discussed below.

Wind Energy Turbine Maintenance Worker

Description

Wind energy turbine maintenance workers maintain all structural and mechanical aspects of one or more wind farm sites. They monitor performance, trouble-shoot mechanical and structural problems, perform regularly-scheduled maintenance tasks, and document all maintenance activity. This job may also be combined with the responsibilities for wind energy electrical maintenance.

Qualifications

There are no certification requirements for wind energy turbine maintenance workers. Three years of technical training or related experience in mechanical and structural trades is required. Hands-on experience of turbines, rock-bolting and guy-wires is highly desirable.

Knowledge, Skills and Aptitudes Required

- Knowledge of mechanical concepts
- Knowledge of turbine parts and operation for sites being maintained
- Knowledge of structural concepts
- Knowledge of safety practices
- Skill of mechanical repair
- Skill of reading and analyzing performance data
- Skill of reading design documents
- Skill of installing guy wires
- Skill of testing
- Skill of manual dexterity
- Skill of producing maintenance documentation
- Aptitude for trouble shooting
- Mechanical aptitude

Wind Energy Electrical Maintenance Worker

Description

Wind energy electrical maintenance workers maintain all electrical aspects of one or more wind farm sites. They monitor performance, trouble-shoot electrical problems, perform regularly-scheduled maintenance tasks, and document all maintenance activity. This job may also be combined with the responsibilities for wind energy turbine maintenance. In public utilities, "grid side" electrical work does not differ from that related to other forms of electrical generation.

Qualifications

There are no certification requirements for wind energy electrical maintenance workers. Three years of technical training or related experience in utility electricity is required. Hands-on experience of electrical instrumentation, cabling, and transformers is highly desirable. Utility-level electrical and physical safety training is necessary.

Knowledge, Skills and Aptitudes Required

- Knowledge of electrical concepts including inverters, transformers, cabling and transmission
- Knowledge of utility-level electrical and physical safety practices
- Knowledge of the electrical equipment specific to the sites being maintained
- Skill of high voltage electrical repair
- Skill of reading and analyzing performance data
- Skill of reading electrical design documents
- Skill of testing
- Skill of manual dexterity
- Skill of producing maintenance documentation
- Aptitude for trouble shooting
- Mechanical aptitude

The report *"Renewable Energy Industry - Situation Analysis of the Knowledge, Competencies, and Skill Requirements of Jobs in Renewable Energy Technologies in Canada"* can be referenced for a comprehensive discussion of descriptions, qualifications and skills required for the other types of occupations in the sector.

Related Education and Training Activities

According to the Canadian Wind Energy Association [6], there are four general types, or categories of wind training courses in Canada. An overview of each, along with a table that provides more detail pertaining to specific programs follows. The details may now be out of date.

Category 1 – General Courses on Wind and Renewable Energy (i.e. "Renewables 101"): This category refers to colleges and university programs that provide general instruction on a range of renewable energy technologies, including wind (note that these courses often address energy conservation as well). These are offered either as start-to-finish certificate programs, or as re-training courses for existing trades people. Individuals coming out of these programs do not necessarily go on to work in the wind industry. All programs require completion of high school or equivalent as a prerequisite except the program at Centennial College, which requires Certification as a millwright, industrial electrician, diploma or degree in engineering. The following table summarizes Category 1 programs.

[6] http://www.canwea.com/downloads/en/PDFS/Education_and_Training_Programs_-_January_2006.pdf

CATEGORY 1 PROGRAMS IN CANADA

Institution	Program Title	Contacts / Scope of Program / Notes
St. Lawrence College, Kingston ON	Two diploma programs offered: • Energy Systems Engineering Technician (started September 2005) • Energy Systems Engineering • Energy Systems Engineering Technology	• Duration: 2 year technician; 3 year technologist • Certificate program approved by Ontario Ministry of Training Colleges and Universities The program develops an understanding of heating, ventilating, and air-conditioning systems with an emphasis on energy conservation and alternative energy systems for small institution, commercial and residential applications. Practical hands-on training at the onsite "Energy House" with solar air and water systems, photovoltaic systems, wind power generation, heat pumps and emerging technologies is core to the program. • www.sl.on.ca/fulltime/F1002.htm • energyhouse.ati.sl.on.ca/
Lambton College, Sarnia ON	Alternative Energy Engineering Technology (T073) course	Three year program with a co-op component which will provide students with a combination of theory and application skills in current and emerging energy technologies • http://www.lambton.on.ca/Programs
Seneca College, Toronto ON	Integrated Energy Systems program (non-certificate)	• Website: http://eto.senecac.on.ca/renewable/ • Offered through the Centre for the Built Environment • Program under development
Centennial College, Toronto ON	Wind Energy Generation, Conversion and Control	Addresses both large and small wind energy systems
Sault College, Sault Ste. Marie ON	Scheduled for Fall 2007: Wind Energy Training Centre and a supporting Wind Energy Training Program.	• Website: www.saultc.on.ca • November 8, 2005, announced a $1,120,000 investment to develop a new Wind Energy Training Centre and a supporting Wind Energy Training Program. The Wind Energy Training Centre, scheduled for Fall 2007, will include a fully operational pilot scale wind turbine and training facility (including an electromechanical instrumentation lab).
New Brunswick Community College Saint John, NB	"Buildings, Energy and Environment" as 2nd year option of Mechanical Engineering Technology Program	• 2 years duration • Focus on HVAC – wind energy is also covered but in less depth. • Looks at Alternative Energy sources and Environmental Planning • Nationally accredited by CTAB • http://www.nbcc.ca

Category 2 –Technical Training: This category includes highly technical courses on wind-specific subjects (e.g. wind turbine maintenance/installation, wind farm operation, blade manufacturing, wind resource assessment etc.). Individuals graduating from these programs will almost always go on to work in the wind industry. The program requires "Attestation of Collegial Studies (ACS) as a pre-requisite. The following table categorizes Category 2 programs.

CATEGORY 2 PROGRAMS IN CANADA

Institution	Program Title	Contacts / Scope of Program / Notes
Groupe Collegia, CEGEP de la Gaspesie et des Iles de la Madeleine	Two courses offered: Wind turbine maintenance Instrumentation, automation and robotics	• The ACS program in Wind turbine maintenance, which lasts 1,395 hours, began in Gaspé on July 5, 2004 (first graduates in September 2005). • French only – course is being translated into English • http://www.collegia.qc.ca/gaspe/maint_eolien.htm

Note: There is also training provided at Lethbridge Community College.

Category 3 – Research and Development: This includes universities and research institutions that have developed programs and facilities designed for wind-specific R&D projects and education (usually associated with Technical Universities). Graduates from these programs are usually engineers in a general field (e.g. electrical, mechanical etc.) who have some degree of specialization in wind. The following table summarizes Category 3 programs.

CATEGORY 3 PROGRAMS

Institution	Program Title	Contacts / Scope of Program / Notes
University of Waterloo	Green Energy Research Institute Sustainable Technology Education Project	Professors conduct research on wind and other technologies Developing a "Wind Energy Research Facility" Seeking partnerships with industry on blade design, power electronics
University of New Brunswick	Works with AWTS No specific programs offered	Currently, the researchers at the University of New Brunswick are focusing on the development of innovative power electronic converters and advanced control strategies for variable speed wind turbine systems.

Category 4 – Workshops: This includes general interest workshops on small wind turbines and other renewable energy systems. These course usually last from one day to one week, and are attended by individuals with a personal interest in small wind systems. The following table provides details of a Category 4 program.

CATEGORY 4 PROGRAM

Institution	Contacts / Scope of Program / Notes
True North Workshops, Ferndale, ON	• Hands-on training on small wind systems • http://www.truenorthpower.com/trainning.htm

Other Training Related Issues

While there appears to be interest in wind energy related training, there are a number of issues that need to be considered, resolved or standardized:

- At present, there are differing views as to whether wind energy designer/installers should be treated as a unique trade or whether existing trades people should obtain wind energy training as part of their specialty.

- Opinions also differ in terms of the form of training. Some respondents believed that an on-line course in various aspects of wind energy including regulation and interconnection considerations as well as the more technical considerations would be very useful, particularly since those in remote locations would be less likely to be able to access training in a centre. However, since remote locations might or might not have access to the Internet, this type of course should be available in CD or disk format to be more accessible.

- All respondents believed that hands-on exposure to the technology is essential to be effective. There is some interest in a suite of courses, which would provide basic education in a range of renewable energy technologies. Many designer/installers, distributors and component salespeople combine more than one type of technology in their lines of business.

- Because much of the wind energy development in Canada is commercial in nature, and because the "grid side" of the business does not vary from that of other types of energy generation, there is a good base of training and experience in the utilities of today for electrical maintenance.

- Mechanical maintenance is particular to the equipment installed. More and more developers are contracting back to manufacturers for this type of maintenance. After general mechanical training is obtained, the manufacturers are providing the training required for these positions.

- It might be more efficient to have maintenance people who were conversant with both the electrical and the mechanical/structural aspects of wind installations, particularly in the north where travel is an issue. This interest was somewhat echoed by private developers.

- There is no particular demand for training in the wind energy manufacturing jobs and the manufacturing base is very small. However, there is a shortage of reliable wind energy assessment consultants and the industry is united in its desire to address issues associated with unfriendly regulation and a host of interconnection barriers across the country.

- Meteorology programs should be encouraged to add wind site assessment modules in order to meet current and expected demand for this type of specialty. Community college level legal programs built around the suite of legal and public relations issues associated with wind energy would also be useful, although the industry is more interested in changing the regulatory and interconnection environments than in accommodating those that exist today.

V. Potential Contacts and Advisors

In addition to the individuals and companies referenced throughout this Chapter, there are a number of organizations and individuals with a wide array of additional resources and contacts that may be of benefit or interest to Clearinghouse planners including:

1. Association of Community Colleges

Lise Robitaille, Training and Development Officer, Renewable Energy Program, 200 – 1223 Michael Street North, Ottawa, Ontario K1J 7T2
Tel: (613) 746-2222 Ext 3131
E-mail: lrobitaille@accc.ca

2. **CANMET Energy Technology Centre - Ottawa**
Natural Resources Canada
580 Booth Street, 13th Floor
Ottawa, Ontario
Canada K1A 0E4

3. **Canadian Wind Energy Association**
http://www.canwea.ca/en/TheCanweaTeam.html

Chapter 4
Small Scale Hydro

The purpose of this chapter is to provide an analysis of some of the major characteristics, trends and issues associated with the small-scale industry that may have a bearing on the need for related training at colleges in Northern Alberta. It is understood that one of the factors that has caused interest in this energy form is the proposed dam on the Peace River near Dunvegan.

I. Technological Aspects

Overview

A small-scale hydroelectric facility requires that a sizable flow of water and an adequate head (drop or fall) of water are available, without building elaborate and expensive facilities. Small hydroelectric plants can be developed at existing dams and have been constructed in connection with water level control of rivers, lakes and irrigation schemes. Many small-scale hydroelectric projects are "run of the river", meaning that the stream flow is not impeded as with some dams. By using existing structures, only minor new civil engineering works are required, which reduces the cost of this component of a development. Small-scale hydro stations are classified in the table below.

Size of Hydroelectric Facility	**Power Output**
Micro	100 kW or less – typical supply for one or two houses
Mini	100 kW to 1 MW – typical supply for a small factory or isolated community
Small	1 MW to 30 MW – typical NUG development and low end of range for supply to a regional or provincial power grid

For reference and perspective, 1 MW of installed capacity will supply enough power for about 550 homes. This assumes that the facility is able to generate, on average, about 65% of its full capacity. Generation is limited during periods of low stream-flow, caused, for example, by low precipitation or temperatures low enough to freeze the stream.

Generation and Transfer of Power and System Components

Generation and Transfer of Power

Power can be supplied by a small, mini and micro hydro system in two ways: Battery Based (DC power) and AC Direct systems. A very brief overview of each follows.

Battery-Based Systems - power is generated at a level equal to the average demand and stored in batteries. Batteries can supply power as needed at levels much higher than that generated and during times of low demand, the excess can be stored. Most home power systems are battery-based. They require far less water than AC systems and are usually less expensive. Because the energy is stored in batteries, the generator can be shut down for servicing without interrupting the power delivered to the loads. Since only the average load needs to be generated in this type of system, the pipeline, turbine, generator and other components (discussed below) can be much smaller than those in an AC system. Very reliable inverters are available to convert DC battery power into AC output (120 volt, 60 Hz). They are used to power most, or all, home appliances, and make it possible to have a system that is nearly indistinguishable from a house using utility power. The input voltage to the batteries in a battery-based system commonly ranges from 12 to 48 Volts DC. If the transmission distance is not great, 12 Volts is often high enough. A 24 Volt system is used if the power level or transmission distance is greater. If all of the loads are inverter-powered, the battery voltage is independent of the inverter output voltage and voltages of 48 or 120 may be used to overcome long transmission distances. Although batteries and inverters can be specified for these voltages, it is common to convert the high voltage back down to 12 or 24 Volts (battery voltage) using transformers or solid-state converters. Wind or solar power sources can assist in power production because batteries are used. Also, DC loads (appliances or lights designed for DC) can be operated directly from the batteries. DC versions of many appliances are available, although they often cost more and are harder to find, and in some cases, quality and performance vary.

AC-Direct Systems - This is the system type used by utilities; however, it can also be used on a home power scale under the right conditions. If enough energy is available from the water, an AC-direct system can generate power as alternating current (AC). This system typically requires a much higher power level than the battery-based system. In an AC system, there is no battery storage. This means that the generator must be capable of supplying the instantaneous demand, including the peak load. The most difficult load is the short-duration power surge drawn by an induction motor found in refrigerators, freezers, washing machines, some power tools and other appliances. Even though the running load of an induction motor may be only a few hundred Watts, the starting load may be 3 to 7 times this level or several kilowatts. Since other appliances may also be operating at the same time, a minimum power level of 2 to 3 kilowatts may be required for an AC system, depending on the nature of the loads. In a typical AC system, an electronic controller keeps voltage and frequency within certain limits. Unused power is transferred to a "shunt" load, such as a hot water heater. The controller acts like an automatic dimmer switch that monitors the generator output frequency cycle by cycle and diverts power to the shunt load(s) in order to maintain a constant speed or load balance on the generator. There is almost always enough excess power from this type of system to heat domestic hot water and provide some, if not all, of a home's space heating.

<u>System Components</u>

An intake collects the water and a pipeline delivers it to the turbine. The turbine converts the water's energy into mechanical shaft power. The turbine drives the generator, which converts shaft power into electricity. In an AC system, this power goes directly to the loads. In a battery-based system, the power is stored in batteries, which feed the loads as needed. Controllers may be required to regulate the system.

Pipeline: Most hydro systems require a pipeline to feed water to the turbine. The exception is a propeller machine with an open intake. The water should pass first through a simple filter to block debris that may clog or damage the machine. The intake should be placed off to the side of the main water flow to protect it from the direct force of the water and debris during high flows. It is important to use a pipeline of sufficiently large diameter to minimize friction losses from the moving water. When possible, the pipeline should be buried. This stabilizes the pipe and prevents critters from chewing it. Pipelines are usually made from PVC or polyethylene although metal or concrete pipes can also be used.

Turbines: Although traditional waterwheels of various types have been used for centuries, they are not usually suitable for generating electricity: They are heavy, large and turn at low speeds and require complex gearing to reach speeds to run an electric generator. They also have icing problems in cold climates. Water turbines rotate at higher speeds, are lighter and more compact. Turbines are more appropriate for electricity generation and are usually more efficient. There are two basic kinds of turbines:

- ***Impulse machines*** use a nozzle at the end of the pipeline that converts the water under pressure into a fast moving jet. This jet is then directed at the turbine wheel (also called the runner), which is designed to convert as much of the jet's kinetic energy as possible into shaft power. Common impulse turbines are pelton, turgo and cross-flow. The pelton is used for the lowest flows and highest heads. The cross-flow is used where flows are highest and heads are lowest. The turgo is used for intermediate conditions. Most developed sites now use impulse turbines. These turbines are very simple and relatively cheap. As the stream flow varies, water flow to the turbine can be easily controlled by changing nozzle sizes or by using adjustable nozzles

- In **reaction turbines**the energy of the water is converted from pressure to velocity within the guide vanes and the turbine wheel itself. Some lawn sprinklers are reaction turbines. They can operate on as little as two feet of head and spin themselves around as a reaction to the action of the water squirting from the nozzles in the arms of the rotor. Examples of reaction turbines are *propeller* and *Francis* turbines. An advantage of reaction machines is that they can use the full head available at a site. An impulse turbine must be mounted above the tailwater level and the effective head is measured down to the nozzle level.

Generators: Most battery-based systems use an automotive alternator. If selected carefully, and rewound when appropriate, the alternator can achieve very good performance. A rheostat can be installed in the field circuit to maximize the output. Rewound alternators can be used even in the 100-200 Volt range. For higher voltages (100-400 Volts), an induction motor with the appropriate capacitance for excitation can be used as a generator. This will operate in a small battery charging system as well as in larger AC direct systems of several kilowatts. Another type of generator used with micro hydro systems is the DC motor. Usually permanent magnet types are preferable. However, these have serious maintenance problems because the entire output passes through their carbon commutators and brushes.

Batteries: Lead-acid deep-cycle batteries are usually used in hydro systems. Deep-cycle batteries are designed to withstand repeated charge and discharge cycles typical in RE systems. In contrast, automotive (starting) batteries can tolerate only a fraction of these discharge cycles. A micro hydro system requires only one to two days storage. In contrast, solar PV or wind systems (discussed earlier) may require many days' storage capacity because the sun or wind may be unavailable for extended periods. Because the batteries in a hydro system rarely remain in a discharged state, they have a much longer life than those in other RE systems. Ideally, lead-acid batteries should not be discharged more than about half of their capacity. Alkaline batteries, such as nickel-iron and nickel-cadmium, can withstand complete discharge with no ill effects.

Controllers: Hydro systems with lead-acid batteries require protection from overcharge and over-discharge. Overcharge controllers redirect the power to an auxiliary or shunt load when the battery voltage reaches a certain level. This protects the generator from overspeed and overvoltage conditions. Overdischarge control involves disconnecting the load from the batteries when voltage falls below a certain level. Many inverters have this low-voltage shutoff capability.

History

The oldest machines for capturing the energy of moving water were waterwheels. In the days before electricity, it was common to use water wheels to provide the power for mills that ground grain or cut lumber. To start the mill, the miller simply opened a gate to let the water flow over the top of the wheel. The water wheel was connected to a massive millstone or metal saw blade through a system of gears. Water for the wheel usually came from a small dam and reservoir, called the millpond.

The use of water for the generation of electricity started in Canada near the end of the 19th Century. A hydroelectric generating facility was installed in 1882 at Chaudière Falls on the Ottawa River and supplied current to two arc lamps for a sawmill on Middle Street in Ottawa. In 1885, Ottawa became the first city in North America to sign a contract for the lighting of all of its streets. Even at the beginning of the century, it was evident that small, local, hydro developments could not, in the long term, supply the rapidly increasing power needs of the growing number of towns and villages. During the early period, the public utilities that had been formed were proponents of both large and small hydro. However, they had initiated a process of rationalization, which led to larger generating units and the development of sites with large potential to achieve economies of scale and provide the lowest cost, reliable electrical energy to the consumer. As a result of this evolution in scale, the financial viability of small-scale hydro in grid-serviced areas was severely curtailed and in most cases, eliminated. Many small-scale hydro plants were decommissioned following World War II because small-scale units and their potential sites became progressively less economical to maintain and operate by public utilities.

Advantages and Disadvantages

Advantages

- ***They have relatively small space requirements* -** Small-scale hydroelectric developments do not take up much space and they rarely cause significant shoreline flooding or required river diversions. Large-scale projects, however, can create adverse environmental impacts such as shoreline flooding. Most of the negative environmental impacts of small-scale hydroelectric developments can be avoided in part or in whole by a good design and appropriate construction and operating practices.

- **T*hey can help in reducing risk of transporting fuel supplies (fossil fuel generation)* -** Fuel supplies must be transported over long distances. The risk of fuel spills is significant, especially in remote areas of Northern Canada where the roads can be ice covered and the environment is ecologically fragile. In urban Canada, the risks to public safety from collisions or derailments in crowded road or rail corridors are also significant.

- ***Socio-economic benefits* -** The most obvious social benefit of small hydroelectric developments is the supply of reliable low-cost (and inflation-proof) electric energy to provide the comforts of modern living. Small-scale hydroelectric developments can provide a competitive source of reliable and inflation- proof energy. Small-scale hydroelectric energy is an especially attractive alternative to traditional high-cost diesel generation that currently provides electric energy in most remote communities across Canada.

- ***Business benefits*** **-** Over the last decade, the small-scale hydroelectric industry has contributed about $100M per year to the Canadian economy in manufacturing and services and added about 30 to 50 MW yearly to Canada's power supply. Canada's small hydroelectric manufacturers and service providers, such as consultants and financiers, also export to overseas customers.

Disadvantages

- **Cold climate requirements -** Small hydroelectric design must provide for control of ice and pipeline freezing – factors that add to capital expenses and operating costs

- **Fish protection -** At sites where fish migration is a concern, small hydroelectric developers may have to provide expensive preventative measures such as fish guidance or habitat compensation.

- **Institutional -** Often, small-scale hydroelectric developers sell the output of their plants to regional or provincial grids. Because purchase contracts and interconnection requirements are not standardized, project preparation and design costs are higher.

- **Regulation -** The regulations focus more on large-scale hydroelectric issues than on small-scale hydroelectric issues that sometimes impose disproportionate demands on small hydroelectric developers.

II. Market Trends and Characteristics

Global Situation

Small-scale hydro deployment worldwide is increasing at about 900MW annually and is expected to reach 55,000MW by 2010. Rapid expansion is expected in Asia, Latin America, Central and Eastern Europe and the former Soviet Union. For illustration, in the European Union, in 1995, there were approximately 8,000 MW of operational small-scale hydro projects generating 33TW of power a year. By 2010, there is expected to be 9,500 MW of capacity (an annual increase of over 10%) generating 45 TW of power per year. Spain, Italy, Sweden, Germany and Austria are expected to experience the most growth.

Canadian Situation

There are currently about 300 sites with 2,000MW of installed small hydro capacity in Canada [1], contributing about 3% to the total Canadian installed hydroelectric capacity of 67,000 MW. Ontario Power Generation (previously Ontario Hydro before privatization) has 67 hydroelectric stations throughout the province. About half of these are below 10 MW in capacity and they contribute about 6% of Ontario's power generation. Hydro-Quebec operates fewer smaller stations, relying instead on more large-scale hydroelectric plants. Nova Scotia operates about 40 small hydro plants supplying about 11% of provincial capacity. New Brunswick also operates about 40 small hydro plants, which contribute about 20% to the province.

[1] http://www.small-hydro.com/index.cfm?fuseaction=countries.country&country_ID=13

A recently completed inventory of Canadian small hydro sites identified over 5,500 sites with a technically feasible potential of about 11,000 MW but only about 15 per cent of this total would be economically feasible under currently socio-economic conditions and at the current state-of the – art. If capital cost can be reduced by 10 to 15 per cent, which should be achievable though further technological improvements, a further 2,000 MW of economically exploitable small hydro capacity will be available. A good number of these will be small hydro projects. In a deregulated electrical generation environment, hydro-power offer the prospect of earning longer-term, sustainable return. A comparison of the yield factors of various types of Energy plant suggests that hydro power remains the most valuable form of energy since it provided the highest quantity of energy produced over its lifetime as compared to the energy required for manufacture, operation and disposal including secondary energy.

Alberta Situation

In general, hydro-electricity is not used as extensively in Alberta as it is in other provinces. According to the renewable energy data-base of the Canadian Industrial Energy End Use Data and Analysis Centre at Simon Fraser University [2], as of 2004, Alberta's hydro electric generating capacity was approximately 844MW.

The major players in the Alberta hydro sector are: TransAlta Utilities, Canadian Hydro Developers Inc, Atco, and Irrigation Canal Power Co-op Ltd. The following table provides an overview of the industry within Alberta.

HYDRO – ELECTRIC GENERATION IN ALBERTA IN 2004

Location /Type (Project)	Start Year	Power (kW)	Owner
Run of River			
Raymond (Raymond Reservoir)	2003	11,000	Irrigation Canal Power Co-op Ltd.
Cranford (Chin Chute)	1994	18,000	Irrigation Canal Power Co-0p Ltd.
Sub-total		**29,000**	
Other			
Innisfail (Dickson)	1992	15,000	Algonquin Power Income Fund
Canmore (Three Sisters)	1951	3,000	TransAlta Utilities
Nordegg (Big Horn) Drayton Valley (Brazeau)	1972 1965	120,000 355,000	TransAlta Utlities TransAlta Utlities
Banff (Cascade)	1942	36,000	TransAlta Utlities
Cochrane (Ghost)	1929	54,000	TransAlta Utlities
Seebee (Horshoe)	1911	16,000	TransAlta Utilities
Jasper (Astoria River)	1949	1,400	Atco Electric
Glenwood (Belly River)	1991	3,000	Canadian Hydro Developers Inc
Magrath (St Mary)	1992	2,400	Canadian Hydro Developers Inc
Waterton (Glenwood)	1992	2,800	Canadian Hydro Developers Inc
Magrath (Taylor Coulee Chute)	2000	12,700	Canadian Hydro Developers Inc
Assorted (Tailings - Recycled Water)	1998	1,450	Assorted
Seebee (Barrier)	1947	13,000	TransAlta Utilities
Calgary (Bearspaw)	1954	17,000	TransAlta Utilities
Kananaskis (Interlakes)	1955	5,000	TransAlta Utilities
Kananaskis (Pocaterra)	1955	5,000	TransAlta Utilities
Canmore (Rundle)	1951	50,000	TransAlta Utilities
Canmore (Spray)	1951	103,000	TransAlta Utilities
Subtotal		**815,750**	
Total		**844,750**	

[2] http://www.cieedac.sfu.ca/

In addition, Glacier Power, a subsidiary of Canadian Hydro Developers, has an application before approval bodies for a 100 MW, run of river project on the Peace River near Dunvegan.

Furthermore, upon closer review, of the 844 MW, only nine sites accounting for 102 MW could be considered to be "small scale". These projects are summarized in the following table.[3]

EXISTING SMALL SCALE HYDRO SITES IN ALBERTA (2004)

	River Name	Total Capacity (kW)
JASPER	ASTORIA RIVER	1,400
BEARSPAW	BOW RIVER	15,300
HORSESHOE	BOW RIVER	18,000
KANANASKIS	BOW RIVER	16,360
OUTLET WORKS	BRAZEAU RIVER	19,440
BARRIER	KANANASKIS RIVER	9,560
POCATERRA	KANANASKIS RIVER	13,500
THREE SISTERS	SPRAY RIVER	3,400
INTERLAKES	UPPER KANANASKIS L	5,040
		102,000

Additional Potential

A detailed survey of the small-scale hydro potential in Alberta concludes that there is potential for an additional 185 MW of capacity, although most of it would be in the Southern portions of the province associated with irrigation works. Within the Northern part of the province, only three sites are considered to have potential for a total of 29 MW of capacity: Whitemud Falls and undisclosed rapids along the Clearwater River (totaling 28 MW) and Vermillion Falls along the Peace River (1MW). The following table provides a summary of additional potential small-scale sites in Alberta.

[3] www.small-hydro.com

POTENTIAL SMALL SCALE HYDRO SITES IN ALBERTA

Site Name	River Name	Total Capacity (kW)
ALBION RIDGE LATERAL A		50
BANTRY CANAL INLET		1,600
BARNWELL LATERAL		120
BASSANO DAM		3,000
CHIN CHUTE		19,300
GLEICHEN DROP		2,000
JENSIN RESERVOIR CHUTE		19,600
LAKE NEWELL RES. INLET		2,100
LANGDON DROP		1,300
LATERAL 15		500
MAIN CANAL CHUTE 1A		1,200
MAIN CANAL DROP #3		1,800
MAIN CANAL DROP #5		2,400
MATZHIWIN CREEK		300
MURRAY RES. CHUTE		900
RAYMOND CHUTE		14,100
ROLLING HILLS SPILLWAY		100
SAUDER RES. OUTLET		800
SECONDARY B DROP		1,500
SPRINGHILL TURNOUT		1,350
ST. MARY RIVER TUNNEL		19,300
ATHABASCA FALLS	ATHABASKA RIVER	17,430
CALGARY	BOW RIVER	9,890
CHESTMERE	BOW RIVER	15,530
LAC DES ARCS	BOW RIVER	17,970
RAPIDS	CLEARWATER RIVER	9,670
WHITEMUD FALLS	CLEARWATER RIVER	18,570
CROWSNEST FALLS	CROWSNEST	1,389
VERMILION FALLS	PEACE RIVER	1,000
TOTAL KW		**184,769**

IV. Education and Skills Requirements

Number and Types of Jobs Within the Industry

According to Industry Canada sources [4]:

- The industry is composed of fewer than 50 businesses, approximately a quarter of which are large public providers equipped with small hydroelectric plants.
- The industry involves component manufacturers, developers and consulting firms.
- The industry includes between 750 and 1000 jobs with typical employment in the small hydroelectric plant industry (with the exception of administrative positions) is as follows, in decreasing order of prevalence:
    - Small hydroelectric plant developer
    - Research engineer or design consultant
    - Small hydroelectric plant operator
    - Maintenance engineering technician
    - Manufacturing plant worker

However, It is difficult to assess the number of jobs, because of variation in the definition of the term "small plant."

More detailed descriptions of the type of work and skills and aptitudes required may be found in the relevant section of the report entitled *"Renewable Energy Industry - Situation Analysis of the Knowledge, Competencies, and Skill Requirements of Jobs in Renewable Energy Technologies in Canada"* completed in 2005.

On the basis of the preceding information, and given that hydro development is not a significant component of Alberta's "energy basket" (unlike the case in other provinces), one might assume the Alberta employment base associated with ongoing operation and maintenance for hydro projects to be fewer than 200 individuals. The basis of this calculation is 844 MW (total hydro-electric capacity) multiplied by .22 man years per MW.

Using the logic above, an estimate of the increase in operation and maintenance employment associated with all potential new small-scale hydro projects in Alberta is approximately 63; however, only 28.4 man years of employment would be created in Northern Alberta. The details of the calculations are as follows:

Potential Hydro-Developments	MW	Factor	Man Years of O&M Employment
Total	**285**	**.22**	**62.7**
Southern Alberta	156	.22	34.3
Northern Alberta	**129**	**.22**	**28.4**
"Dunvegan"	100	.22	22.0
Other	29	.22	6.4

[4] http://strategis.ic.gc.ca/epic/internet/inrei-ier.nsf/en/h_nz00010e.html

Skills and Training Requirements

The skills and training requirements associated with small-scale hydro in Northern Alberta are likely minimal due to the limited existing use of the power source. However, the following comments provide perspective regarding the state- of affairs in other parts of Canada: [5]

- At present, there is no impetus in the Micro-hydro industry for certification standards. The bulk of the business is associated with either large-scale commercial developments, where the developer must live with the quality of the installation, or small-scale owner-installed.

- Apart from the need for hydraulics expertise, there is little need for specific Micro-hydro training. Almost all respondents indicated satisfaction with the qualifications that could be found easily in the marketplace. University Engineering programs are considered sufficient for the industry's needs and graduates are considered able to "hit the ground running".

- There is little evidence that there will ever be a unique trade for Micro-hydro designer/installers and in fact, those who do install stand-alone Micro-hydro applications tended to do this as an adjunct to other renewable installations such as wind energy or solar energy. Developers reported that the main difference between traditional trades people and the workers they required is the need to be able to manage a wide variety of tasks. The need for flexibility, resourcefulness, creativity and independence echoes a similar theme cited for wind farms. For this reason, operators and maintenance workers tend to be sourced non-traditionally (i.e. not from a specific training program) and trained on site. The uniqueness of each Micro-hydro site design reinforces this ad hoc type of sourcing, so this will probably continue to be the most probably successful approach of industry.

- Because much of the Micro-hydro development in Canada is commercial in nature, and because the "grid side" of the business does not vary from that of other types of energy generation, there is a good base of training and experience in the utilities of today for electrical maintenance. In fact, more than one developer indicated public utility severance pools as reliable sources for plant operators and maintenance technicians. Other reliable sources cited were ex-fishery operators and farmers. In small sites, the operation and maintenance requirement is not full-time, so this makes these latter types of resources particularly suitable.

A guide developed by BC Hydro [6] provides some insight as to the skill set required for individuals planning micro-scale hydro projects. The key considerations are outlined below.

<u>Plan Development</u>
- Business plan and project pre-feasibility analysis
- Water permitting issues
- Energy sales and interconnect issues

<u>Site Selection</u>
- Desirable characteristics
- Determination of energy potential: stream flow and drop height analysis including use of stream flow data and topographical maps
- Water quality: sedimentation

<u>Equipment and Infrastructure</u>
- Turbine selection
- Electrical systems: battery, alternating current systems, and controllers

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[5] Renewable Energy Industry - Situation Analysis of the Knowledge, Competencies, and Skill Requirements of Jobs in Renewable Energy Technologies in Canada
[6] www.**bchydro**.com/rx_files/ environment/environment1834.pdf

Costs and Financing

- Initial costs: feasibility studies and development permits
- Construction costs: engineering, Balance of plant (such as roads for access), owners' costs, and contingencies
- Annual costs: operating and maintenance, insurance etc
- Project cash flow analysis
- Financing options: debt and equity
- Financing acquisition, requirements and procedures

Permitting Process

- Obtaining permits
- Information submission
- Ongoing reporting and monitoring requirements
- Crown land rental procedures and costs
- First Nations consultation

Grid Interconnection and Energy Sales

- Procedures and types of agreements

Construction

- Contracts and agreements
- Planning
- Emergency plans

Operation, Maintenance and Surveillance

- Design considerations
- Recording and reporting requirements

Existing Training Programs

A review of literature associated with small-scale hydro projects indicated that the training available at community colleges in Canada found one example of a program at the Willis College of Business and Technology in Ottawa. Details are below.

Established in 1896, Willis College is a leading Canadian training institution in Business and Technology. Building upon the extensive RETScreen International curriculum developed by Natural Resources Canada, the institute has developed a series of courses and certificate programs on clean energy project feasibility. Courses are available online, and include certification exams on technologies covered and on the knowledge required to perform a professional feasibility analysis using RETScreen. The courses include guided project feasibility assignment, two real projects on each of the technologies covered. The Small-scale hydro module is 90 hours in length and the next intake of 20 students starts on June 5, 2006.

V. Key Contacts

In addition to the individuals and companies referenced throughout this Chapter, there are a number of organizations and individuals with a wide array of additional resources and contacts that may be of benefit or interest to Clearinghouse planners including:

- Canadian Renewable Energy Network: (613) 947-1598

Chapter 5
Fuel Cell Power

The purpose of this chapter is to provide an analysis of some of the major characteristics, trends and issues associated with fuel cell power that may have a bearing on the need for related training at colleges in Northern Alberta.

I. Technological Aspects

Overview

A fuel cell is a device that generates electricity by a chemical reaction. In most simplistic terms, a fuel cell converts the chemicals hydrogen and oxygen into water, and in the process produces electricity. The reactions that produce electricity take place at the electrodes. The positive electrode is called the cathode and the negative electrode is called the anode. Unlike a battery, which has all of its chemicals stored inside and eventually "goes dead" once the chemicals are used, with a fuel cell, chemicals constantly flow into the cell so it never goes dead -- as long as there is a flow of chemicals into the cell, the electricity flows out of the cell. Most fuel cells in use today use hydrogen and oxygen as the chemicals. One great appeal of fuel cells is that they generate electricity with very little pollution—much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless byproduct, namely water.

There are several different types of fuel cells, each using a different chemistry, and classified by the type of **electrolyte** (the material sandwiched between the two electrodes) utilized. The characteristics of the electrolyte determine the optimal operating temperature and the fuel used to generate electricity. Each comes with its particular set of benefits and shortcomings. Additional details are presented below.

Polymer Electolyte Membrane Fuel Cell (PEMFC) - More commonly known as the proton exchange membrane fuel cell or PEM, this is one of the most promising fuel cell types for widespread use. PEMs are exceptionally responsive to varying loads (such as driving) and are rapidly declining in cost to manufacture. A thin platinum catalyst chemically activates the reactions at the electrodes. In the past, the platinum has made these devices prohibitively expensive, but new application technologies have dramatically thinned the platinum layer, allowing these devices to deliver electricity for less than $3000/kW. The PEM fuel cell uses an advanced plastic electrolyte (typically Nafion) to shuttle protons from the anode to the cathode. The PEM's solid electolyte is much easier to handle and use than a liquid counterpart, and its low operating temperature allow a quick startup. PEM fuel cells are best suited for 1kW to 100kW applications.

Alkaline Fuel Cell (AFC) - Widely used by the space program, this device was developed by NASA to power the Gemini missions and subsequent Space Shuttle operations. AFCs are very efficient, and discharge only pure water. However, these devices require very pure hydrogen and oxygen, and the electrolyte, alkaline potassium hydroxide, is exceptionally expensive. Since most fuel processing produces some carbon dioxide, which poisons the alkaline catalyst, AFCs will find only niche markets.

Phosphoric Acid Fuel Cell (PAFC) - This configuration has been commercially available since

1992. The PAFC has potential for use in small stationary power-generation systems. They are known for their high reliability, quite operation, and high efficiency—over 80 percent conversion efficiency as a co-generation device. They run at a medium temperature range and can run on impure hydrogen.

Molten Carbonate Fuel Cell (MCFC) – MCFCs use a carbonate-salt-impregnated ceramic matrix as an electrolyte. Because MCFCs operate at 800°F, they are best suited to large stationary applications. Yet they potentially have the most to gain, as they operate at 85 percent efficiency with cogeneration. MCFCs may be especially useful in hospitals, hotels, or other industrial applications that require electricity and heating (or cooling) around the clock.

Solid Oxide Fuel Cell (SOFC) - These fuel cells are best suited for large-scale stationary power generators that could provide electricity for factories or towns. SOFCs use a prefabricated ceramic sandwich between electrodes. Like MCFCs, they operate at higher temperatures (about 1000°F) and make excellent co-generation devices for industrial applications where high temperature steam is required.

The following table provides an overview of the characteristics of the fuel cells discussed above.

TYPES OF FUEL CELLS

Fuel Cell Type	Electrolyte	Anode Gas	Cathode Gas	Temperature	Efficiency
Proton Exchange Membrane (PEM)	solid polymer membrane	hydrogen	pure or atmospheric oxygen	75°C (180°F)	35–60%
Alkaline (AFC)	potassium hydroxide	hydrogen	pure oxygen	below 80°C	50–70%
Direct Methanol (DMFC)	solid polymer membrane	methanol solution in water	atmospheric oxygen	75°C (180°F)	35–40%
Phosphoric Acid (PAFC)	Phosphorous	hydrogen	atmospheric oxygen	210°C (400°F)	35–50%
Molten Carbonate (MCFC)	Alkali-Carbonates	hydrogen, methane	atmospheric oxygen	650°C (1200°F)	40–55%
Solid Oxide (SOFC)	Ceramic Oxide	hydrogen, methane	atmospheric oxygen	800–1000°C (1500–1800°F)	45–60%

Development History

The Fuel Cell [1] was first developed by William Grove, a Welsh judge with intense scientific curiosity. In 1839, Grove was experimenting on electrolysis (the process by which water is split into hydrogen and oxygen by an electric current), when he observed that combining the same elements could also produce an electric current. Other scientists paid sporadic attention to fuel cells throughout the 19th century. From the 1930s through 1950s Francis Thomas Bacon, a British scientist, worked on developing alkaline fuel cells. He

[1] http://www.fuelcellscanada.ca/tech.html

demonstrated a working stack in 1958. This technology was licensed to Pratt and Whitney where it was utilized for the Apollo spacecraft fuel cells.

In Canada, early research into the development of fuel cells was carried out at the University of Toronto, the Defense Research Establishment in Ottawa, and at the National Research Council - also in Ottawa. Most of this early work concentrated on alkaline and phosphoric acid fuel cells. In 1983, Ballard Research began the development of a Polymer Electrolyte Membrane fuel cell under a contract with the Defense Research Establishment in Ottawa. Over the past twenty years, Canadian companies, with some government support, have developed a world-leading position in the development and commercialization of fuel cells and related products.

Advantages – Disadvantages [2]

Advantages

- Fuel cells eliminate pollution caused by burning fossil fuels; the only by-product is water.
- If the hydrogen used comes from the electrolysis of water, the use of fuel cells also eliminates greenhouse gases.
- Fuel cells do not need conventional fuels such as oil or gas and can therefore eliminate economic dependence on politically unstable countries.
- Since hydrogen can be produced anywhere where there is water and electricity, production of potential fuel can be distributed.
- Installation of smaller stationary fuel cells leads to a more stabilized and decentralized power grid.
- Fuel cells have a higher efficiency than diesel or gas engines.
- Most fuel cells operate silently compared to internal combustion engines.
- Low temperature fuel cells (PEM, DMFC) have low heat transmission, which makes them ideal for military applications.
- Operating times are much longer than with batteries, since doubling the operating time needs only doubling the amount of fuel and not the doubling of the capacity of the unit. .
- Fuel cells have no “memory effect” when they are getting refuelled.
- The maintenance of fuel cells is simple since there are few moving parts in the system.

Disadvantages

- Fuelling fuel cells is still a major problem since the production, transportation, distribution and storage of hydrogen is difficult.
- Reforming hydrocarbons via reformer to produce hydrogen is technically challenging and not clearly environmentally friendly.
- The refuelling and the starting time of fuel cell vehicles are longer and the driving range is shorter than in a “normal” car.
- Fuel cells are in general slightly bigger than comparable batteries or engines. However, the size of the units is decreasing.
- Fuel cells are currently very expensive to produce, since most units are hand-made.
- Some fuel cells use expensive materials.
- The technology is not yet fully developed and few products are available.

[2] www.fuelcelltoday.com

Cost Issues

To a large extent, as noted above, the fuel cell industry is still in the experimental or research and development phase and, as such, it is difficult to quantify costs. For example, the fuel cell project at NAIT encompasses the purchase of a 5 kW solid oxide fuel cell that will be used for research and educational purposes, and the creation of an interpretative centre to educate the public about fuel cell technology and environmental impacts. Partners investing in this $3.25 million applied research project are the Alberta Energy Research Institute, ATCO Gas, Western Diversification and Climate Change Central. At present, there are only 200 such fuel cells in the world.

II. Market Trends and Characteristics

Global Market Indicators

According to a May 2005 report (World Fuel Cells) completed by The Freedonia Group, a Cleveland-based industrial market research firm [3]:

- Commercial demand for fuel cell products and services, including revenues associated with prototyping and test marketing activities, will increase nearly sevenfold to $2.6 billion in 2009. By 2014, those revenues are expected to reach $13.6 billion as a number of viable markets for fuel cells are projected to develop during this time period, while advances and economies of scale help drive costs down to competitive levels.

- World fuel cell spending (including research and development funding and investment in fuel cell enterprises, in addition to commercial sales) will more than double to $10.8 billion in 2009.

- Electric power generation is emerging as the first large-scale commercial application for fuel cells and will account for more than half of global product and service demand through 2014. However, portable electronics applications are projected to register the strongest gains over the next 10 years, rising from what are now extremely low levels of demand to become the second largest fuel cell market. Fuel cell-powered industrial stationary and motive power equipment will achieve some commercial success as well.

- Motor vehicle-related fuel cell demand is potentially huge but has not yet lived up to its potential, constrained by technical and infrastructure-related issues, as well as by high cost barriers. Nevertheless, the use of fuel cell vehicles in government and commercial fleets will provide some impetus to market growth through 2014, as automakers continue to invest in demonstration and test marketing programs. Proton-exchange membrane (PEM) fuel cells, which currently account for more than half of world commercial demand, will maintain their dominant position through 2009 and beyond. Projected sales could generate nearly $35 billion if market conditions improved for automotive fuel cells.[4]

- With a few notable exceptions (such as China), future demand for fuel cell products and services will largely be concentrated in geographic areas where pre-commercialization

[3] http://powerelectronics.com/news/fuel-cell-market/
[4] http://biz.yahoo.com/bw/060404/20060404005060.html?.v=1

activity has been concentrated—the United States, Canada, parts of Western Europe and Japan. Applications that are the most amenable to the use of fuel cells tend to be highly evolved in economically advanced countries such as these, and sufficient amounts of wealth exist in these nations to allow them to invest in fuel cells, as costs are likely to remain high for at least the initial generations of commercially viable systems. Fuel cells also are expected to find some use as a source of electricity in developing countries with inadequate central power grids.

Select example of some of the activities and priorities of other countries, with amounts expressed in $US, are summarized below:

- **United States** - The US government proposes spending $2.7 billion over the next five years for hydrogen and fuel cell research and development and advanced automotive technologies including.

  - Freedom Fuel Initiative will develop technologies for hydrogen production and the distribution infrastructure needed to power fuel cell vehicles and stationary fuel cell power sources.
  - FreedomCAR Initiative is a partnership with automakers to develop technologies for mass production of safe and affordable hydrogen-powered fuel cell vehicles.
  - In addition, individual states have established their own incentive programs to promote alternate energy sources:

    - California: Incentives, emission targets and demonstration activities
    - Michigan: NextEnergy program will provide funding of $79 million over next three years, plus a 700-acre tax-free research zone
    - Ohio: Fuel cell initiatives totalling $162 million over three years

- **Japan -** The government provided over $275 million in 2002 to support fuel cell research, development and commercialization. This spending is expected to exceed $380 million per year beginning in 2003.

- **European Community** - EC will spend $3.3 billion from 2003–2006 on renewable energy, mostly hydrogen and fuel cells. This is a significant increase from the 1999–2002 period, when the average annual spending on fuel cell research, development and demonstration was $140 million. The European Economic Union's 6th Framework Program (2002–2006) identifies the following research, technological development and demonstration activities pertaining to sustainable development:

  - Estimated $2.5 billion will be dedicated to fuel cells and hydrogen initiatives.
  - Target of five percent of EC road transport to be hydrogen-powered by 2020.
  - Targets for fuel cell cost reductions in stationary power of less than $1,650/kW.
  - Focus on identifying actions necessary for vibrant fuel cell industry and sustainable hydrogen economy, with ability to target additional expenditures of up to $4.3 billion.

- **Singapore** - The government has established the Singapore Initiative in Energy Technology Program (SINERGY), which aims to make Singapore a leading player in the development of alternative energy technology. SINERGY is part of the government's effort to promote more clean energy R&D and test-bedding activities for automotive and stationary power applications.

Canadian Industry

Revenues of Canadian companies in 2004 were approximately $244 million, up 151% from 2001 revenues of $96.9 million. In 2001, 82% of revenues were based on exports, with sales of equipment (77 percent) being the mainstay of the growing industry. Western Canada was responsible for 70 percent of all revenues.

As of October 2001, an estimated 1,800 people were directly employed by the Canadian fuel cell industry, with 76 percent of the total in Western Canada. Approximately 78 percent of the 2001 workforce had a post-secondary education. Of that total, 55 percent held a university degree and 22 percent held a community college education

The sector is a significant player in the Canadian innovation scene. In 2001, research and development expenditures in the fuel cell and hydrogen sector were similar to that in the Canadian auto industry despite the latter's $92 billion in sales and 132,000 employees. Western Canada was responsible for 87 percent of research and development expenditures in 2001.

In Canada and elsewhere, the industry is characterized by a relatively low number of small (mostly under 500 employees) companies engaged exclusively (over 50 percent of revenues derived from the fuel cell and hydrogen related activities) in the sector, with a much larger range of companies involved to a much smaller degree in the supply of parts, systems and services. As summarized in the following table, in 2004 there are 17 companies in Canada whose primary market focus or goal is fuel cell production and/or system integration.

FUEL CELL PRODUCERS AND SYSTEMS INTEGRATORS

Company	City	Province	Applications
Alumin um Power	Toronto	ON	Mobile
Angstrom Power	North Vancouver	BC	Portable
Astris Energi	Mississauga	ON	Mobile
Ballard Power Systems	Burnaby	BC	Stationary; Portable; Mobile
Cellex Power Products	Richmond	BC	Stationary
DuPont Canada	Kingston	ON	Stationary; Portable; Mobile
Energy Visions	Mississauga/Calgary	ON/AB	Stationary; Portable; Mobile
Fuel Cell Technologies	Kingston	ON	Stationary
Global Thermoelectric	Calgary	AB	Stationary; Mobile
GreenVOLT Power	Orillia	ON	Stationary
Hydrogenics	Mississauga	ON	Stationary; Portable; Mobile
Kinectrics	Toronto	ON	Stationary
MagPower Systems	Delta	BC	Stationary; Portable
Palcan Fuel Cells	Burnaby	BC	Portable; Mobile
PEM Technologies	Vancouver	BC	Portable; Mobile
PowerDisc Development	Chilliwack	BC	Mobile
Siemens Canada	Mississauga	ON	Stationary; Portable

III. Canadian Public Policy and Strategy

A range of strategic federal programs and activities are helping Canada's hydrogen and fuel cell industry overcome technical challenges and develop infrastructure that will accelerate the commercialization of hydrogen and fuel cell technologies. These programs span the innovation spectrum, from basic research and development through to the policy development needed for mass commercialization of hydrogen and related technologies and are summarized below. [5]

Basic R&D - Fuel Cell and Hydrogen Program, NRC; Fuel Cell Network and Targeted Research Program, NRC/NSERC; Hydrogen and Fuel Cell R&D Program, NRCan; NRC Institute for Fuel Cell Innovation, NRC; Process and Environmental Catalyst Program, NRCan; Strategic Project Grants, NSERC; and The Initiative on the New Economy, SSHRC.

Applied R&D and Product Development - Buildings Energy Technology Advancement Plan, NRCan; Canadian Transportation Fuel Cell Alliance, NRCan; CANMET Materials Technology Laboratory, NRCan; Collaborative Research and Development Program, NSERC; Defense Industrial Research Program, DND; Defense R&D Canada, DND; Fuel Cell and Hydrogen Program, NRC; Hydrogen and Fuel Cell R&D Program, NRCan; Ideas to Innovation Program, NSERC; Industrial Research Assistance Program, (NRC-IRAP) NRC; Industrial Research Assistance Program, (IRAP-TPC) NRC; Industrial Research Chairs, NSERC; Industry Energy Research and Development, NRCan; NRC Institute for Fuel Cell Innovation, NRC; Process and Environmental Catalyst Program, NRCan; Research and Development Program, TPC ; Research Partnership Program, DND/NSERC; Sustainable Development Technology Canada; Technology Demonstration Program, DND; and The Initiative on the New Economy, SSHERC.

Engineering, Testing, Codes and Standards - Canadian Transportation Fuel Cell Alliance, NRCan; Hydrogen and Fuel Cell R&D Program, NRCan; NRC Institute for Fuel Cell Innovation, NRC; and Sustainable Development Technology Canada

Market Demonstration - Canadian Transportation Fuel Cell Alliance, NRCan; Defense R&D Canada, DND; Hydrogen Early Adopters Program, TPC; NRC Institute for Fuel Cell Innovation, NRC; Technology Early Action Measures, NRCan, IC, EC; The Initiative on the New Economy, SSHERC; and Western Economic Partnership Agreement, WD

Production and Sales - Canadian Commercial Corporation; Energy and Marine Branch (EMB), IC; Export Development Canada; Regional Offices, ITCan; Science Research and Experimental Development Program, CRA; and Team Canada Inc.

The Canadian Transportation Fuel Cell Alliance is a $33 million federal government initiative that will demonstrate and evaluate fuelling options for fuel cell vehicles in Canada. Different combinations of fuels and fuelling systems will be demonstrated by 2008 - for light, medium and heavy-duty vehicles. The initiative will also develop standards and training and testing procedures as related to fuel cell and hydrogen technologies.

[5] http://strategis.ic.gc.ca/epic/internet/inhfc-hpc.nsf/en/mc00051e.html

IV. Education and Skills Requirements

According to those contacted as part of this study (Chris Curtis, Vice President of Fuel Cells Canada in Vancouver, and Denis Cote, Manager of the Fuel Cell Project at NAIT), it will still be several years before the Canadian fuel cell industry is sufficiently developed to warrant more general consideration of courses at the Community College level, even at the most advanced institutions such as NAIT. As noted in the preceding "advantages and disadvantages" discussion, there is an extensive array of issues that need to be addressed.

Over the course of this project, there were only four examples found of the integration of fuel cells into the curriculums at community colleges:

Canada

- **NAIT's** Power Engineering program currently includes a fuel cells component and plans are being developed to integrate fuel cell technology into other programs such as Building Environmental Systems, Electrical and Instrumentation and some consideration has been given to development of a short continuing education program dealing with fuel cells.

- **BCIT** covers fuel cells to a very limited extent in its automotives program.

United States

- **Kettering University/Mott Community College -** Kettering University will partner will Mott Community College and private training firm to establish a training facility within the Kettering University Research Park for the purpose of training technicians in the repair and maintenance of fuel cell systems. Kettering University fuel cell laboratories will be used by this training firm and Kettering University faculty will assist in the development of training courses offered by Mott Community College faculty.

- **Texas State Technical College -** A curriculum has been developed and presented for approval by the Texas Higher Education Coordinating Board (THECB). The objective of the two-year Fuel Cell Maintenance and Repair Technician program is to provide the graduate with hands-on training and education in fuel system theory, operation, installation, maintenance, troubleshooting and repair. The program includes 72 credit hours of extensive classroom and "hands on" laboratory experience with stationary fuel cells designed for residential, commercial, and industrial applications. Successful graduates will receive an Associate of Applied Science (A.A.S.) degree, and will be prepared to enter the workforce with working background in a wide range of fuel cell types and applications.

Some Potential Insights to Future Directions Based Upon Developments at US Universities

In the United States, universities are fast becoming the focal point of fuel cell and hydrogen research, and some recent developments and partnerships may provide some indication of future directions in Canada, and in particular, the organizations and types of jobs that may employ community college graduates:

- The National Fuel Cell Research Center (NFCRC), located at the University of California, Irvine, is the oldest and perhaps the most well-known of the dedicated research centers.

NFCRC conducts research in the area of fuel cell systems and components, as well as analysis and market research. Through NFCRC, Toyota leases two of its FCHVs and the center researches product performance, reliability and usability of the vehicles.

- At the University of Connecticut, the Connecticut Global Fuel Cell Center, which came about through a partnership between the university's School of Engineering, industry companies, and Connecticut Innovations.

- In Michigan, Kettering University received a $1.8 million grant from the Department of Commerce's Economic Development Administration (EDA) for the construction of a new Center for Fuel Systems and Power Integration. The 10,000-square-foot facility opened in June 2005 and accommodates the evaluation and testing of prototype fuel cell systems and validation for fuel cell codes and standards. Kettering also collaborates with local community colleges to offer training programs for fuel cell testing, repair and maintenance. One of its more recent collaborations, Kettering is working with the Mass Transit Authority (MTA) of Flint, Michigan, on a 40-foot hybrid electric fuel cell passenger bus and a hydrogen refueling station.

- Case Western Reserve University (CWRU) is involved in many of the activities underway in Ohio, participating in the Ohio Fuel Cell Coalition and serving as the home base for the Wright Fuel Cell Group, both industry/academic partnerships aimed at developing the fuel cell industry in Ohio. At the Case Advanced Power Institute, research areas include portable fuel cell systems, instrumented bipolar plates, science-based durability studies of fuel cells, modeling of fuel cell systems, and advanced catalysts for fuel cells and fuel processors.

- Stark State College, also in Ohio, broke ground on a $4.4 million, 23,000 square foot Fuel Cell Prototyping Center that will enable manufacturers to evaluate new designs with state-of-the-art commercial equipment. The Center, which will be completed by Spring 2006, will enable companies to conduct research and development in solid oxide fuel cells in order to reduce the cost and develop commercial products.

- The University of South Carolina is home to the Center for Fuel Cell Research, the nation's only fuel cell center sponsored by the National Science Foundation (NSF), USC researchers are focusing on the design and performance of fuel cells, as well as hydrogen storage, production and distribution, and component and balance of plant issues. USC has numerous industry partners working together, including DuPont, BASF AG, DANA Corporation, General Motors Corporation, John Deere ePower Technologies, Plug Power Inc., Westinghouse Savannah River Company LLC, and W.L. Gore & Associates Inc., among others. USC is also reaching out globally, working with the Fraunhofer Institute for Solar Energy Systems in Germany and the Korea Institute of Energy Research (KIER).

- Rensselaer Polytechnic Institute (RPI) has formed the new Center for Fuel Cell and Hydrogen Research, led by former Plug Power executive Glenn Eisman. The new center will focus on fuel cell development, hydrogen generation and storage, electrochemistry, solid state and polymer science, and the application of nano-materials in fuel cell and hydrogen research.

Other Potential Private Sector Training

Heliocentris Energy Systems - Website: www.heliocentris.com

The company is a world leader in providing fuel cell and hydrogen technology systems for education, outreach and demonstration. The parent company, Heliocentris GmbH is located in Berlin, Germany. In November 2002, Heliocentris Energy Systems Inc. was established in Vancouver, Canada. This company has been set-up to develop fuel cell course material, provide fuel cell education and training, and promote Heliocentris fuel cell products throughout North America. Products include fuel cells and hydrogen technology equipment for education, ranging in power from 1-watt single fuel cells through to a 300-watt cogeneration system.

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V. Potential Key Contacts and Advisors

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- Denis Cote, Fuel Cell Demonstration Project Coordinator, NAIT, Edmonton (780) 471-7027
- Paul Brennan, Director, Canadian Association of Community Colleges, Ottawa
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Chapter 6
Earth Energy (Geothermal or Ground Source Heat Pumps)

The purpose of this chapter is to provide an analysis of some of the major characteristics, trends and issues associated with earth energy systems, sometimes referred to as ground source heat pumps, which may have a bearing on the need for related training at colleges in Northern Alberta.

I. Technological Aspects

Overview

Earth energy uses temperatures found in the earth or below water to cool or heat air and water for buildings. For example, a heat pump can extract heat from underneath the ground to heat a building. In the summer, the pump can be reversed to provide air conditioning by moving hot air out of the building and down into the ground. It is more efficient to use earth energy than a combustion furnace (earth energy systems typically generate three to four units of energy output per unit of input) because less energy is required to move heat from one place to another than to convert one kind of energy into another, as is the case with a furnace.

Natural/solar heat from the earth or water source is absorbed into a liquid, heat transfer medium circulating in exterior buried pipes and carried to a building. It is then upgraded to a comfortable room temperature through a heat pump unit. When cooling is required, the system is reversed. Heat is returned to the cooler ground and/or water source and is again transferred back to the building where it is distributed at cooler temperatures. Ground source heat pumps use the earth or ground water as a source of heat in winter and as a "sink" for heat removed from indoor air in summer. For this reason, ground-source heat pumps have come to be known as "earth-energy systems (EES)".

History

Earth energy systems have been used extensively in parts of the United States and Northern Europe; however, have only more recently attracted greater attention in Canada due to rising energy costs and environmental concerns.

Advantages and Disadvantages

Advantages

- Operating costs are considerably lower than traditional combustion furnaces and air conditioning units
- Systems provide constant low-level heat, which eliminates the need to change thermostats at night. Another benefit is the absence of draughts that are common with conventional forced-air heating systems.
- Because there is no combustion, earth energy systems cannot explode and there is no need to store fuel. Insurance companies often provide a discount on policies that use earth energy.

- In commercial or industrial buildings, earth energy systems reduce the need for mechanical space. That allows space to be used for more productive purposes. In many cases, the cost savings from reduced overhead space in the ceiling and the mechanical room can offset any increased cost for the installation of the system.

Disadvantages

- Initial installation costs are high.
- Retrofitting an existing "traditional/combustion" system can be inconvenient due to the need to install and bury exterior piping network.

Costs

While no specific data could be obtained and upfront costs are directly related to the scope of the system, from a "life-cycle" basis, an argument can be made that earth energy is less expensive.

II. Market Trends and Characteristics

Global Indicators

In 2004, there were an estimated 2 million ground source heat pumps throughout the world that generate an estimated 15 GW of power. [1]

Canadian Market

Sales of EES in Canada represent less than one percent of the total heating, ventilation and air conditioning (HVAC) market. According to a recent market development study carried out for the industry, there are 1,500 to 2,200 units sold and installed per year. About two-thirds are in the residential sector, mainly in more expensive new homes with the remainder in the commercial/ institutional sectors. Total installed value of these units is about $10 million. Most of this market is in the provinces of British Columbia, Ontario, Nova-Scotia, Manitoba and Quebec. Nation-wide, Natural Resources Canada estimates are that there may be up to 30,000 units installed.

In a personal discussion with Larry Peters, Vice President of React Energy and a Director of the Earth Energy Society of Canada, the current (2005-2006) Alberta market was estimated to be in the order of 200 residential installations per year, primarily in "luxury" homes. There are less than 10 major "players" in Alberta at present. Each installation can cost in the range of $20,000 to $200,000. The market is growing by an estimated 20% to 25% per year. There is also a strong commercial market, with less than five major players; however, firms are reluctant to divulge details of this component. Typical installations costs are in the range of $200,000 to $1 million or more per project.

The main barriers to the rapid commercialization of EES are economic. As noted above, EES often have a higher capital cost than competing systems due to the installation of the underground loop. This may discourage potential buyers. However, operating and maintenance costs are greatly reduced and EES can be quite appealing when considered on a life-cycle basis.

[1] Renewables 2005: Global Status Report

The economics of EES must be compared to alternatives for both heating and cooling. It is particularly attractive in areas where the costs of heating fuels and electricity for conventional cooling are high. In the past, there have also been problems with the design of systems by engineers who are unfamiliar with the technology.

Other barriers include a general lack of familiarity with the technology, higher transactional costs due to inefficiencies in the marketing infrastructure, as well as a need for streamlining and harmonization of standards and procedures.

Annual sales of EES peaked in the early 1990s, primarily as a result of an Ontario Hydro incentive program. During that period, Ontario Hydro provided cash incentives for the residential installation of GSHP in areas not serviced with natural gas.

At present, there are two organizations in Canada involved in Ground Source Heat Pumps:

- The Earth Energy Society of Canada; and
  http://www.earthenergy.ca/

- The Canadian Geoexchange Coalition
  http://www.geo-exchange.ca/en/home/index.htm.

The relationship is somewhat acrimonious due to issues associated with the disposition of funds provided by the federal government to develop course materials.

III. Canadian Public Policy and Strategy

The federal government has expressed some interest in the "sector" by virtue of providing some funding for the development of training programs. In addition, at one time Natural Resources Canada set a nation-wide objective of installing an additional 25,000 new earth energy systems by 2008 [2], which would bring the total number of installations to approximately 55,000. It is not know if the objective is still current given recent changes in energy policies.

VI. Education and Skills Requirements

During the past 15 years, the earth energy sector in Canada has relied on training from four identifiable sources:

- Manufacturers
- Professional training organizations
- 'Ad hoc' programs and courses
- The Canadian Earth Energy Association.

Each has had strengths and weaknesses, and further review has concluded that there are at least seven distinct issues that will be required to be addressed in order to ensure an adequately-trained workforce in Canada:

[2] NRC 2004 Sustainable Development Strategy

- **System Design** - Key skills will include assessing whether a site is suitable for the technology and understanding building dynamics. It is expected that individuals have some previous experience in plumbing an HVAC systems.

- **System Installation** - There are three components to an installation: the loop, the box and the distribution network. Proper installation of the loop bed is crucial, regardless of the configuration of the pipes and the source of ground heat. The installation of the box is relatively easy with a basic knowledge of plumbing, refrigeration and conventional HVAC systems, but, there are unique aspects of a ground-source unit that would require specialized training to ensure adequacy. Installation of a heating distribution network reflects conventional techniques for other HVAC systems, subject to specific modifications for a GeoExchange unit.

- **Third Party Inspectors** - There is also a need to determine what factors are crucial, important or peripheral to a good installation, so the inspector can make a correct determination based both on regulation and industry practice. Inspections may become an important issue in future if GeoExchange units were to be qualified for any incentives, for verification of greenhouse gas emission credits, or for coverage under an insurance warranty.

- **"Specifiers"** - It will be important to acquaint architects, engineers, building owners and other key "specifiers" with the financial, environmental and aesthetic advantages of ground-coupled heat pumps.

- **Trainers** - To minimize travel and downtime costs for participants, and to increase the frequency of courses that are offered across the country, it would be beneficial to have trained trainers in many locations. This network of trainers would provide regional perspective and allow more-frequent training courses to be offered. One ancillary use of regional trainers would be to allow an honest effort at continuing education and re-certification.

- **Customer Relations** - Much of Canada's HVAC industry is not well trained to market units to affluent customers in a strategic manner; many dealers lack public relations; and the industry needs to be able to take advantage of the evolving market for green power and climate change issues.

- **Post-Training Support** - Components of this need include some form of continuing education or "re-certification" requirement and a format of high level technical assistance to solve problems in a timely manner and project a professional image for the industry. Another valuable training tool would be the compilation and timely update of all relevant regulations and standards (down to the municipal level) and interpretative documents that will facilitate compliance by installing contractors.

Status of Training Programs

At present, the Oklahoma International Ground Source Heat Pump Association [3] (affiliated with Oklahoma State University at Stillwater) has developed a three day course for "certified installers" and other "train the trainer" and "design" courses". Furthermore, the Earth Energy Society is currently working with the Canadian Association of Community Colleges to develop a course for installers adapted to the unique needs of the Canadian climate.

[3] http://www.igshpa.okstate.edu/about/about_us.htm

V. Key Contacts and Advisors

The potential key contacts for this sector include:

- **Mr. Larry Peters**, Vice President of React Energy and a Director of the Earth Energy Society of Canada, Calgary
  Tel: (403) 873-0109

- **Mr. Denis Tanguay**, President of the Canadian Geoexchange Coalition, Montreal
  Tel: (514) 807-7559

- **Ms. Lise Robitaille**, Canadian Association of Community Colleges, Ottawa
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Chapter 7
Cogeneration and Use of Wood Waste Products

The purpose of this chapter is to provide an analysis of some of the major characteristics, trends and issues associated with cogeneration and the use of wood waste products, which may have a bearing on the need for related training at colleges in Northern Alberta. Interest in the subject matter appears to be attributable, at least in part, to the new Grande Prairie Eco Power plant developed by a subsidiary of Canadian Hydro Developers Ltd as well as rising interest in cogeneration.

I. Technological Aspects

Overview

Cogeneration

Cogeneration, also known as “combined heat and power generation” encompasses a range of technologies. Cogeneration power plants can be “designed” according to unique circumstances and a range of fuel sources that may be available ranging from wood waste and biogas from anaerobic digestion to highly efficient use of natural gas with turbines as well as emerging technologies such as fuel cells. However, cogeneration always includes an electricity generator subject to the unique situations and power supplies of the location) and a heat recovery system. It is a highly efficient means of generating heat and electric power at the same time from the same energy source. The principle behind cogeneration is simple. Conventional power generation, on average, is only 35% efficient with up to up to 65% of the energy potential released as waste heat and up to an additional 10% of energy can be lost in the transmission from more remote power stations to locations where the energy is required. More recent combined cycle generation can improve this to 55%, excluding losses for the transmission and distribution of electricity. Cogeneration reduces this loss by using the heat for industry, commerce and home heating/cooling. Because transporting electricity over long distances is easier and cheaper than transporting heat, cogeneration installations are usually sited as near as possible to the place where the heat is consumed and, ideally, are built to a size to meet the heat demand.

At present, the most common systems for cogeneration include:

- **Steam Turbines** - have been used for industrial cogeneration systems for many years. High-pressure steam raised in a conventional boiler is expanded within the turbine to produce mechanical energy, which may then be used to drive an electric generator. The power produced depends on how much the steam pressure can be reduced through the turbine before being required to meet site heat energy needs. This system generates less electrical energy per unit of fuel than a gas turbine or reciprocating engine-driven cogeneration system. However, the major advantage of steam turbine systems is that they can be based upon almost any fuel supply including gas, heavy fuel oil (HFO), coal, residues and municipal or other wastes, and are often capable of operating on a range of fuels. The plant is capital intensive because a high-pressure boiler is required to produce the motive steam.

  Steam turbines fall into two types, according to exit pressure of the steam from the turbine:

- back-pressure turbines, in which exit pressure is greater than atmospheric;
- condensing turbines, in which exit pressure is lower than atmospheric and a condenser is required. The simplest arrangement is the back-pressure turbine in which all the steam flows through the machine and is exhausted from the turbine at a single, relatively low pressure suitable for on-site.

- **Reciprocating engines** - are internal combustion engines operating on the same familiar principles as their petrol and diesel engine automotive counterparts. Although conceptually the system differs very little from that of gas turbines, there are important differences. Reciprocating engines give a higher electrical efficiency, but it is more difficult to use the thermal energy they produce, since it is generally at lower temperatures and is dispersed between exhaust gases and engine cooling systems. There are two types of engine, classified by their method of ignition:

  - Compression-ignition ('diesel') engines for large-scale cogeneration are predominantly four-stroke direct-injection machines fitted with turbochargers and intercoolers. Diesel engines will accept gas oil, HFO and natural gas.

  - Spark-ignition engines are derivatives of their diesel engine equivalents and have their same parameter equivalents. They are suited to smaller, simpler cogeneration installations, often with cooling and exhaust heat recovery cascaded together with a waste heat boiler providing medium or low temperature hot water to site. Spark-ignition engines operate on clean gaseous fuels, natural gas being the most popular. Biogas and similar recovered gases are also used but, because of their lower calorific value, output is reduced for a given engine size.

- **Gas turbines** - have become the most widely used prime mover for large-scale cogeneration in recent years, typically generating 1-100 MW. A gas turbine based system is much easier to install on an existing site than high-pressure boiler plant and a steam turbine. On many sites plot space is at a premium, a factor weighing heavily in favour of gas turbines. This, together with reduced capital cost and the improved reliability of modern machines, often makes gas turbines the optimum choice. Gas turbine operates under exacting conditions of high speed and high temperature. As such, the hot gases supplied to it must therefore be clean (i.e. free of particulates which would erode the blades) and must contain not more than minimal amounts of contaminants, which would cause corrosion under operating conditions. High-premium fuels are therefore most often used, particularly natural gas.

- **Combined cycle** - Some large systems (power output generally greater than 3 MW) utilize a combination of gas turbine and steam turbine, with the hot exhaust gases from the gas turbine being used to produce the steam for the steam turbine. This is called a combined cycle. Gas turbine combined cycle (CCGT) systems have been adopted by public utility companies where supplies of natural gas are plentiful: power stations of up to 1,800 MW have been constructed. In cogeneration applications of the CCGT, exhaust or pass-out steam from the steam turbine is used for process or other heating duties. The main advantage of CCGT cogeneration is its greater overall efficiency in the production of electricity, compared with the alternatives described above. Combined cycles with gas turbines are the most common case, but they can also be designed with diesel engines.

In addition, the following technologies are emerging:

- **Fuel cells** - convert the chemical energy of hydrogen and oxygen directly into electricity without combustion and mechanical work such as in turbines or engines. In fuel cells, the fuel and oxidant (air) are continuously fed to the cell. All fuel cells are based on the oxidation of hydrogen. The hydrogen used as fuel can be derived from a variety of sources, including natural gas, propane, coal and renewables such as biomass, or, through electrolysis, wind and solar energy. A typical single cell delivers up to 1 volt. In order to get sufficient power; a fuel cell stack is made of several single cells connected in series. The advantages of fuel cells include: their relatively small size; and increased reliability due to very few moving parts. However, costs are still high and some other problems include corrosion.

- **Stirling engines** - external combustion device and therefore differs substantially from conventional combustion plant where the fuel burns inside the machine. Heat is supplied to the Stirling engine by an external source, such as burning gas, and this makes a working fluid, e.g. helium, expand and cause one of the two pistons to move inside a cylinder. This is known as the working piston. A second piston, known as a displacer, then transfers the gas to a cool zone where it is recompressed by the working piston. The displacer then transfers the compressed gas or air to the hot region and the cycle continues. The Stirling engine has fewer moving parts than conventional engines, and no valves, tappets, fuel injectors or spark ignition systems. It is therefore quieter than normal engines, a feature also resulting from the continuous, rather than pulsed, combustion of the fuel. Stirling engines also require little maintenance and emissions of particulates, nitrogen oxides, and unburned hydrocarbons are low. The efficiency of these machines is potentially greater than that of internal combustion or gas turbine devices. There is a more that 60 years experience with this technology, what is newer is its use for micro-cogeneration boilers. For this type of boilers, there is a need for small engines with a capacity between 0.2 and 4 kW. Gas turbines and even gas engines are unsuited for this kind of size (although the current smallest spark-ignition engine is 3 kW), while the Stirling engine offers a good alternative. The advantages of the Stirling engine are: less moving parts with low friction, no need for an extra boiler, no internal burner chamber, high theoretical efficiency and very suited for mass production. The external burner allows a very clean exhaust and gives the possibility of controlling the electrical output of the engine by reducing the temperature of the hot side. So there is the possibility of varying the electricity production regardless the need of thermal heat demand. The electrical efficiency is still not very high and in the range of 10% (350 We engine); 12.5% (800 We engine) up to 25% (3,000 We engine), but it should be possible to design then with at least 25% electrical efficiency and total efficiency of 90%.

- **Micro-turbines** - systems smaller than 1 MW have so far been uneconomic, but this is starting to change. Manufacturers are developing smaller and smaller systems and nowadays there are micro-turbines as small as 25 kW. In general, micro-turbines can generate anywhere from 25 kW to 200 kW of electricity. Micro-turbines are small high-speed generator power plants that include the turbine, compressor, generator, all of which are on a single shaft to deliver the power to the grid. Micro-turbines have only one moving part, use air bearings and do not need lubricating oil. They are primarily fuelled with natural gas, but they can also operate with diesel, gasoline or other similar high-energy fossil fuels. Research is ongoing on using biogas. Micro-turbines are smaller are smaller than conventional reciprocating engines, and capital and maintenance costs are lower.

For a more detailed discussion of the technologies, efficiencies and advantages and disadvantages, please referenc e:

http://72.14.203.104/search?q=cache:Ms0jNp5qvYYJ:www.cogen.org/Downloadables/Projects/EDUCOGEN_Cogen_Guide.pdf+cogeneration&hl=en&gl=ca&ct=clnk&cd=9

Wood Waste

Wood waste is one of the simplest forms of biomass. There are no specific technological aspects beyond those that may be unique to the individual power- generating situation. The Grande Prairie Eco Centre project will be closely aligned with the local forest industry.

Advantages and Disadvantages

Cogeneration

While there are very specific advantages and disadvantages in relation to the power source used in cogeneration situations (for example, a gas turbine might require less space and generate more energy than a reciprocating engine, it's disadvantage would be the requirement to be in close proximity to a source of a clean fuel such as natural gas so as not to contaminate components), the principal advantages and disadvantages are outlined below.

Advantages

- Results in more efficient use of energy in general.
- Fewer pollutants and greenhouse gas emissions per unit of energy consumed.

Disadvantages

- The need to utilize "surplus" energy close to where it is produced places some restrictions on the location and design of cogeneration facilities and infrastructure.

Wood Waste

Advantages

- Makes use of a readily available by-product in a manner that is more cost effective than others.

Disadvantages

- Potential concern over release of greenhouse gases and other pollutants if appropriate measures are not taken.
- Changes to the local supply of feedstock may negate any operating and cost advantages.

History

While early use of cogeneration systems can be traced back to industries such as pulp and paper (to exploit wood wastes) and countries in Northern Europe in the earlier part of the 20^{th} century, Cogeneration is now an established technology. In the last 10-15 years, significant technological progress has been made to enable engine and turbine technology to be widely implemented and promote more decentralized and more efficient forms of heat and power generation.

Wood waste products have been associated with the pulp and paper and forest industries for many years.

Costs

Costs of cogeneration and wood waste are specific to individual sites and situations and as such it is difficult to make generalizations. Cogeneration's more efficient use of fuels supports lower costs over the life-cycle of a project; however, up-front design and construction costs may be higher than for other power generation systems/plants.

II. Market Trends and Characteristics

Global and Canadian Indicators

Cogeneration

Over the course of this project, it proved to be difficult to determine the incidence of cogeneration projects throughout the world. As one indicator, it is estimated that cogeneration systems now accounts for approximately 10% of power production in the European Union.[1]

Across Canada, cogeneration power plants accounted for approximately 7,700 MW in 2000, and depending upon the cost of electricity, this figure could increase to 21,000 MW by 2015. [2]

Wood Waste

Biomass, one oft he simplest and easy to produce and use forms of renewable energy, accounted for approximately 9% of the global primary energy supply in 2004. [3] However, more detailed indicators of the global and Canadian "situation" were not readily obtainable.

Alberta Situation

Cogeneration Current Situation

The following comments are based upon the "Cogeneration Data Base" at the Canadian Industrial Energy End-Use Data and Analysis Centre [4] at Simon Fraser University:

[1] A Guide to Cogeneration, March 2001, The European Association for the Promotion of Cogeneration
[2] Cogeneration Potential in Canada, Natural Resources Canada, March 2002
[3] Renewables 2004 Global Status Report
[4] http://www.cieedac.sfu.ca/CIEEDACweb/mod.php?mod=cogeneration&what=facilitylisting&subwhat=facilitysearch&region=western&sector=all&fuel=all&systemtype=all&startyear=all&name=

- In Alberta, cogeneration power plants accounted for approximately 2,700 MW of electrical generating capacity as of 2003.
- Most of the plants were based upon natural gas; however, other fuel sources such as “hog fuel” (a combination of wood waste products) and Spent pot liner or “SPL”, a by-product of certain manufacturing processes as well as hydrogen were also used.
- There was also a range of equipment configurations to generate and recover heat. Many of the processes and equipment types are discussed in earlier parts of this chapter.
- Approximately 46% of the cogeneration capacity (approximately 1,256 MW) was located within the NADC region.
- The largest operations were associated with oil and gas extraction or processing.
- The earliest plant in Alberta was built in 1957.

Table 1 provides a summary of cogeneration plants in Alberta as of 2003.

Future Cogeneration Projects

The cogeneration power production in Alberta is expected to increase significantly in the near future. Between 2005 and 2009, approximately 1,583 MW of new cogeneration capacity is planned. Approximately 94% of the expanded capacity (1,498 MW) will be in the NADC region. The following table provides a summary of new cogeneration projects planned for Alberta.

NEW COGENERATION PROJECTS

Proponent	Location	Capacity (MW)	Expected Completion
Syncrude	Fort McMurray	185	4Q 2005
Petro Canada	Meadow Creek	330	2006
CNRL	Fort McMurray	187	2007+
CNRL	Primrose East	86	2007+
EnCana	Medicine Hat	85	2007+
Shell Canada	Jackpine	170	2007+
Shell Canada	Jackpine	170	2007+
Shell Canada	Carmon Creek	185	2009+
Suncor Firebag	Fort McMurray	85	2007+

Wood Waste - Current Situation

As of early 2006, biomass sources accounted for 178 MW, or 1.6% of Alberta’s electrical generating capacity of 11,477 MW. Approximately 122 MW of the 178 MW, or 68% (which includes the new project in Grande Prairie) was added in the period after 1998 as follows:

- Alberta Pacific Forest Ind. (Boyle): 80 MW
- Canadian Hydro Developers (Grande Prairie): 25 MW
- Drayton Valley Power -Small Power R&D Program (Drayton Valley): 17 MW

TABLE 1 - COGENERATION IN ALBERTA IN 2003

Year Started	Electrical Cap (MW)	Sold to Grid?	Equipment	Location	Fuel Input	Owner/Site
1983	20	N	Gas Turbine	Joffre		**AG Ethyl**
2000	84	N	Gas Turbine	Scotford		**Air Liquide**
1969	3	N	Steam Turbine	Edmonton		**Alberta Hospital**
1960	1.2	N	Back Pressure Steam (BPS)	Ponoka	NG (100%)	**Alberta Hospital Ponoka**
1980	1.2	N	Back Pressure Steam (BPS)	Ponoka	NG (100%)	**Alberta Hospital Ponoka**
1992	92	N	Steam Turbine	Boyle	SPL, HOG, NG	**Alberta Pacific Forest Industries**
2001	45	All	Steam Turbine	Rainbow Lake	NG (100%)	**ATCO Power**
1998	84	Some	Gas Turbine	Primrose	NG (100%)	**ATCO/Canadian Natural Resources Ltd.**
1996	.45	N	Internal Combustion	Lethbridge		**Black Velvet Distillers**
1964	18	N	Steam Turbine	Calgary		**Calgary Health Region**
2004	25	N	Back Pressure Steam	Grande Prairie		**Canadian Gas and Electric, Inc.**
1958	13.9	N	Extraction BPST	Lindbergh		**Canadian Salt Co. Ltd.**
1954	21	N	Extraction Condensing ST, Extraction BPST, Regenerative Feedwater Heating	Edmonton	NG (100%)	**Celanese Canada Inc.**
1992	2.7	N	Spark Ignition BPS Turbine	Lethbridge	NG (100%)	**Chinook Health Region**
1994	.45	N	Spark Ignition, BPS Turbine	Lethbridge	NG (100%)	**Chinook Health Region**
1989	40	Some	Extraction BPST, Regenerative Feedwater Heating	Peace River	SPL (71%), Hog (26%), NG (3%)	**Daishowa - Marubeni International Ltd.**
1996	.02	N	Spark Ignition BPS Turbine	Red Deer	NG (100%)	**David Thompson Health Region**
1977	20	N	Gas Turbine	Red Deer		**Dow Chemical Canada Inc.**
1979	180	Some	Combine Cycle Gas Turbine	Fort Sask	NG (90%), Hydrogen (10%)	**Dow Chemical Canada Inc.**
1999	124	Some	Gas Turbine, Extraction Condensing ST, Duct Burners	Fort Sask	NG (85%), Hydrogen (15%)	**Fort Saskatchewan Cogeneration Project**
1999	25	All	Gas Turbine	Rainbow Lake	NG (100%)	**Husky Oil**
2002	165.1	Some	Gas Turbine Duct Burners	Bonnyville	NG (100%)	**Imperial Oil Ltd.**
2000	400	All	Gas Turbine Condensing ST	Joffre	NG (100%)	**Joffre Cogeneration**
1961	.04	N	Steam Turbine	Rimby		**Keyspan Energy Canada Inc.**
2001	.03	Some	Microturbine	Calgary	NG (100%)	**Mariah Energy Corp.**
2003	.09	All	Microturbine	Medicine Hat	NG (100%)	**Mariah Energy Corp.**
2003	60	N	Nicroturbine	Calgary	NG	**Mariah Energy Corp.**
2003	.12	Some	Microturbine	Medicine Hat	NG (100%)	**Medicine Hat Family Leisure Centre**
2002	170	Some	Gas Turbine	Fort Mc/Muskeg	NG (100%)	**Muskeg River Cogeneration**
1949	2	N	Back Pressure Steam	Taber	NG (100%)	**Rogers Sugar Ltd.**
1967	4	N	Back Pressure Steam	Taber	NG (100%)	**Rogers Sugar Ltd.**
2003	170	Some	Gas Turbine, BPS, Duct Burners	Scotford	NG (100%)	**Scotford Cogeneration**
	7.8	N	Gas Turbine, Steam Turbine	Fort Sask		**Sheritt International Corp.**
1998	.30	Y	Back Pressure, Steam Turbine	Calgary	NG (100%)	**Southern Alberta Institute of Technology**
1975	45	N	Gas Turbine	Mildred Lake		**Syncrude**
2001	365	Some	Gas Turbine, Extraction Condensing ST, Duct Burners	Fort Mc/Muskeg	NG (100%)	**TransAlta Energy Corp.**
2001	40	N	Extraction Condensing ST, Duct Burners	Medicine Hat	NG (100%)	**TransCanada Energy Ltd.**
2001	80	Some	Gas Turbine Duct Burners	Carseland	NG (100%)	**TransCanada Energy Ltd.**
2003	165	Some	Gas Turbine Duct Burners	McKay River	NG (95%)	**TransCanada Energy Ltd.**
2002	93	Some	Gas Turbine Extracting Condensing ST Burners	Grande Prairie	NG (75%), Hog (25%)	**TransCanada Energy Ltd., Bear Creek Cogeneration Plant**
	13.3	N	Gas Turbine	Edmonton		**University of Alberta**
1957	23	Some	Extracting Condensing ST, Regenerative Feedwater Heating	Hinton	SPL (65%), NG (21%), Hog (13%)	**Weldwood Of Canada Ltd.**
1989	28	Some	BPS Turbine, Regenerative Feedwater heating	Hinton	SPL (65%), NG (21%), Hog (13%)	**Weldwood Of Canada Ltd.**
	.8	N	Steam Turbine	Medicine hat		**Western Coop Fertilizer**
1973	34.5	N	Steam Turbine	Grande Prairie		**Weyerhaeuser Canada Ltd.**
Total	**2,710.8**					

Wood Waste - Future Projects

The Alberta Energy Department and the Energy and Utilities Board are only aware of two very small biomass power projects planned between now and the 2009 period. The total capacity is 15 MW and both are beyond the boundaries of the NADC region.

III. Canadian Public Policy and Strategy

No explicit Government of Canada or Alberta policy could be identified over the course of this project regarding cogeneration or the use of wood waste products for electricity generation. The relatively significant increase in cogeneration power in Alberta must; however, be viewed at least as tacit approval.

IV. Education and Skills Requirements

While larger cogeneration systems require relatively complex design at the pre-construction stage (and requires skill sets beyond those covered in community college programs), the types of occupations most likely for community college graduates are associated with the operation of the cogeneration and wood waste power plants. General training is covered in the curriculum of Power Engineering programs, according to Gilbert Requena, Head of the Power Engineering Program at NAIT. However, supplemental training may be required from time to time depending upon the unique configuration of equipment and the introduction of new technologies used at a cogeneration plant. In addition, the shift toward cogeneration may create needs for training for others such as regulatory officials, municipal planners, contractors and electrical utilities. The exact nature and need for such training is not easily determined without greater detailed effort.

The Alberta Regional Issues Working Group, in Fort McMurray, is undertaking a study of the demand for Power Engineer training associated with oilsands developments. At the time of writing this report, the results were not available. While the increased staffing requirements associated with wood waste power plants are likely to be small, the requirements for the new cogeneration plants could be more significant. The demand might be met in part by increasing the training capacity of institutions or by providing upgrading or specialized ad hoc training to more experienced staff depending upon the specific requirements of individual power plants and their owners.

There are no specific and unique standards or formal accreditation for the operation of cogeneration or wood waste power plants; however, management of the new facility in Grande Prairie indicated a requirement for different levels of Power Engineering training according to the type of job:

- Employees operating the control panel are required to have Second Class Power Engineering credentials;
- Employees working on the “floor” are required to have Third Class Power Engineering credentials; and
- All other employees working in the yard are required to have Fourth Class Power Engineering Credentials.

Existing Training Programs

At the present time, cogeneration is covered in the more advanced Power Engineering programs at technical institutions at a range of technical institutions in Alberta. In addition, more specialized and upgrading training is sometimes provided by organizations such as Cogen Canada:

COGENCanada
1855 Beattie Ave. Ottawa, ON, Canada; K1H 5R7
Tel: (613) 731 6783 *Fax:* (613 523 7249)

V. Key Contacts and Advisors

In addition to those individuals and organizations referenced in this chapter, the following may be helpful for additional information:

- Doug Hazelton, Area Manager, Canadian Hydro Developers (Grande Prairie Eco Power Plant) Grande Prairie: (780) 539-0804; Calgary: (403) 269-9379

- Manfred Klein, Senior Program Engineer in the Oil, Gas & Energy Branch and the Electricity & Industrial Combustion Branches of Environment Canada, Ottawa
  manfred.klein@ec.gc.ca

Chapter 8
Renewable Liquid Fuels (Ethanol and Biodiesel)

The purpose of this chapter is to provide an analysis of some of the major characteristics, trends and issues associated with Ethanol and Biodiesel that may have a bearing on the need for related training at colleges in Northern Alberta. Interest in the subject matter appears to be attributable, at least in part, to a new facility being considered in High Level that will have an ethanol plant integrated in to the overall operation.

ETHANOL

I. Technological Aspects

Overview

Ethanol [1], also known as ethyl or grain alcohol, is a high-octane fuel produced from the fermentation of plant sugars. There are several ways to make ethanol. The most commonly used processes today use yeast to ferment the sugars and starch in corn. The starch in the corn is fermented into sugar, which is then fermented into alcohol. Other crops such as, barley, wheat, rice, sorghum, sunflower, potatoes, cassava, molasses, sugar cane and sugar beets can also be used to produce ethanol. Sugar cane and sugar beets are the most common ingredients for ethanol in other parts of the world. Since alcohol is created by fermenting sugar, sugar crops are the easiest to convert into alcohol. Brazil, the world's largest ethanol producer, makes its ethanol this way. A new experimental process breaks down cellulose in woody fibers (lignin). This process, known as cellulosic ethanol, has seen increasing support and research in recent years, and a Canadian company called Iogen Corporation is an industry leader. With this process ethanol can be made from trees, grasses, and crop wastes. For more information pertaining to ethanol, please reference:

http://en.wikipedia.org/wiki/Ethanol

Advantages and Disadvantages

Advantages

- As an alternative and supplementary market for certain crops and forest products, Ethanol can contribute to regional economic growth and job creation, particularly in rural communities that have been disadvantaged in recent years.

  Canadian farmers, notably in Saskatchewan, are becoming increasingly aware of this new market opportunity. Some have formed cooperatives to grow crops intended specifically as a feedstock for ethanol production. A 100-million-litres-per-year wheat-based ethanol production plant requires 300 000 tonnes of feed grain per year and an estimated 250 000 acres to produce the feedstock. A plant this size would consume about 800 acres worth of production per day.

[1] http://www.ethanolmarketplace.com/page/view/ethanolinfo

- Ethanol production also offers opportunities to expand cattle feedlot operations. Large volumes of distiller's grain, a high-protein feed ingredient, are generated as a by-product of ethanol production. The current value of this production is about $200 million annually in Canada.

- Ethanol is a renewable fuel because it is produced from plants.

- Ethanol also burns more cleanly and completely than gasoline or diesel fuel. Some studies show that on a full life cycle, it can produce lower levels of carbon monoxide emissions.

- Ethanol reduces greenhouse gas (GHG) emissions because the grain or other biomass used to make the ethanol absorbs carbon dioxide as it grows. E-10 (10% ethanol) from corn produces about 3 to 4 percent fewer greenhouse gas emissions than gasoline and costs the same as gasoline with an equivalent octane rating. E-10 made from wood or agricultural cellulosic materials would produce 6 to 8 percent fewer emissions compared with gasoline, and E-85 (85% ethanol) from cellulose would produce 75 percent fewer emissions.

Disadvantages

- There are no significant disadvantages; however, significant investment and “will”, cooperation and patience is required to establish a large-scale industry.

- The Iogen Corporation process is complex; however, it offers the greatest overall benefits on a life-cycle basis.

History

Ethanol has been used by humans since prehistory as the intoxicating ingredient in alcoholic beverages. Ethanol was first prepared synthetically in 1826, through the independent efforts of Henry Hennel in Britain and S.G. Sérullas in France. The “modern era” of ethanol use and awareness began in Brazil more than 20 years ago using sugar cane. At the time, Brazil had a military government, which wanted to reduce the country's dependence on imported Middle Eastern petroleum after the 1970s oil shocks. Since then, its use has expanded and it is now the major fuel in other counties such as Sweden and India. Interest has increased in Canada and the United States as a result environmental concerns and rising energy costs.

Costs

The cost of producing ethanol varies with the cost of the feedstock used and the scale of production. In the United States, approximately 85 percent of ethanol production capacity in the on corn feedstock and the cost of producing ethanol from corn is estimated to be about $1.10 per US gallon. The estimated production cost using wood and agricultural waste feedstocks is $1.15 to $1.43 per gallon. Because a gallon of ethanol contains less energy than a gallon of gasoline, the production cost of ethanol must be multiplied by a factor of 1.5 to make an energy-cost comparison with gasoline. [2]

[2] http://www.oregon.gov/ENERGY/RENEW/Biomass/Cost.shtml

II. Market Trends and Characteristics

Global and Canadian Indicators

Globally, the leading ethanol production nations and their capacities as of 2004, are summarized in the following table.

LEADING ETHANOL PRODUCTION NATIONS IN 2004

Nation	Annual Production Capacity (billions of litres)
Brazil	14
USA	10
China	3
Russian Federation	2.5
India	2
Western Europe	2
Sub-total	**33.5**

Source: Renewable Fuels Global Outlook 2004

By comparison, Canada's ethanol production capacity as of February 2004 was approximately 240 million litres per year, with the single largest facility (150 million litres per year) in Chatham, Ontario. Approximately 65% of production was fuel ethanol. Following the expansion of capacity financed via the first round of the Ethanol Expansion Program, the capacity is expected to rise to over 900 million litres per year and consist of approximately 87% fuel ethanol. Significant components of the expansion are expected to be located in: Sarnia (208 million litres); Lloydminster (130 million litres) and Kelowna (114 million litres). The objective is to have a national capacity of 1.33 billion litres by 2010.

The major players in the Canadian ethanol industry and their estimated market shares are summarized in the following table.

Company	Market Share
Commercial Alcohols	31%
Husky Energy	21%
Suncor Energy	21%
Okanagan Biofuels	12%
Others	15%
Total	**100.00%**

Husky Energy, Sunoco and Sonic each have limited retail distribution of ethanol at present.

Canada is a net corn and wheat feed importer and an expanded ethanol industry would require increasing such imports from the United States. It will be necessary to increase domestic feedstocks of corn and wheat if the production targets are to be met by 2010. Other barriers have included: the lack of a minimum “blend mandate” as a constituent of gasoline; and the relatively higher cost of ethanol production vs. gasoline, as discussed above.

Alberta Situation

In addition to the ethanol plant being considered in High Level (production capacity of 20 million litres per year), Alberta’s other ethanol production facility is the API/Permolex plant in Red Deer, with a capacity of 26 million litres per year but to be expanded to 40 million litres per year.

III. Canadian Public Policy and Strategy

The Ethanol Expansion Program (EEP), with an initial $118-million investment, is one part of the Government of Canada's renewable fuels strategy that also includes support for research and development, exemptions from federal fuel excise taxes and consumer awareness activities. The program supports the Government of Canada's target of increasing the proportion of our gasoline that is blended with ethanol, a renewable fuel, from approximately 7 percent today to 35 percent by 2010. The EEP was announced on August 12, 2003, as part of Canada's climate change plan. Round 2 of the EEP was launched on December 6, 2004, and the deadline for proposals was February 22, 2005. Sixteen proposals from across Canada were received, and results were announced on July 6, 2005 with $42 million being allocated to five proposals.

To stimulate ethanol use and production, each of the Canadian provi nces has an ethanol fuel tax exemption ranging from 9 cents per litre in Alberta to 20 cents per litre in Manitoba. [3] However, the difference in the incentive has a negative impact on the Canadian industry.

IV. Education and Skills Requirements

Industry Size

The direct employment potential of a fully developed ethanol industry (1.33 billion litres per year by 2010) might be estimated in the order of 1,500 nation-wide and 80 for Alberta. These figures are based upon a study of the potential for an ethanol industry in Saskatchewan [4], which projected employment of 450 associated with a fully-developed industry in Saskatchewan (assuming a “blend mandate”) having a production of 400 million litres per year. Using such logic and figures, the employment potential of the 20 million litre per year ethanol plant in High Level would be in the order of 40; this is consistent with the 40 existing employees at the API/Permolex ethanol plant in Red Deer. It is difficult to estimate the multiplier effect of job creation in other supporting aspects of the industry.

Training Requirements

The forecast growth of the industry in Canada (almost four-fold in Canada) suggests that there will be a need for specialized training and greater attention.

[3] Presentation “Ethanol Industry in Canada” AIEA2 Conference, Laval University, August 24, 2004
[4] http://www.ir.gov.sk.ca/Default.aspx?DN=3288,3286,2937,2936,Documents

The potential training requirements of the ethanol industry are broad and may encompass aspects of supporting industries such as the provision of feedstock (mostly wheat in western Canada), through to the marketing and handling of byproducts such as animal feed and care of livestock. In addition, for the industry to thrive, it will be necessary to provide "informational" training for younger individuals who will be future consumers as well as investors and policy makers. From a broader industry perspective, there will be a need for those employed in the industry to be familiar with unique business, quality control, environmental and regulatory aspects of the industry. Cost pressures will require those at more senior levels to be well-versed with respect to chemistry and production innovations such as those that may be required to utilize less expensive feedstocks.

While there is no clearly defined curricula of skills required for the Canadian ethanol industry at this time, there are a number of developments in the United States that may be useful for Clearinghouse planners:

- Northeast Community College in Norfolk, Neb., is considering the addition of an ethanol-training program at the request of area ethanol producers and others. The two-year program would likely cover chemistry, operations, technology, marketing and maintenance for ethanol plants.

- Minnesota West Community and Technical College has various ethanol training programs including the college's new ethanol plant simulator, developed by Novatech Process Solutions, which will be available for students soon. The online simulator will take students through start up, a steady operation state and onto shut down. The simulator replicates the control screens the students would use at an operating ethanol plant. The Program Head, Dwayne Carroll, may be contacted at (320) 564-4511.

- Pratt Community College of Pratt, Kan., could be offering training programs and screening for potential employees of Wildcat Bioenergy LLC, a local proposed 50 million gallon (US) per year ethanol plant.

- In contrast to most bioprocess training programs that are either strictly classroom based (i.e., a two- or four-year degree) or on-the-job and provided by ethanol plant builders for new employees [5], the National Corn-to-Ethanol Research Center (NCERC) at Southern Illinois University provides hands-on workforce training to student interns while conducting commercial testing trials. NCERC interns work side by side with industry and NCERC plant and/or lab professionals trained in ethanol production and analytical methodologies. Envisioned by Illinois economic and agricultural leaders over a decade ago, today NCERC is the nation's only stand-alone, not-for-profit pilot commercial testing plant for validating new renewable fuel technology. Since late 2003, nearly 35 interns from several midwestern universities have helped with the successful operation of the NCERC.

- Building upon past experiences and recommendations made within a white paper edited by Dr. Mark Worden of Michigan State University, the NCERC plans to design and implement a National Resource Center for Biofuels Training. For example, this resource would work to identify educational and training needs of the biobased industry and to identify and

[5] http://farmweek.ilfb.org/viewdocument.asp?did=8827&drvid=108&r=7.317752E-02

collaborate with academic and industry experts to develop these materials and/or courses, including distance learning, linked to the plant and labs in key areas. Additionally, the NCERC is requesting input on how other groups might like to use the NCERC for customized training programs/coursework/workshops for future ethanol plant investors, the general public, classroom teachers of elementary, junior high, and high school students, and college professors.

- Finally, ICM, Inc a Colwich Kansas training company gas developed a six- week long, training program for new ethanol plant employees. As extracted from the company's web-site [6], the details of the program are summarized below, and provide some insight to the considerations and skills required to operate an ethanol plant.

  - ***Week 1 – Classroom Training***
    Each day of this week begins with a two-hour safety topic, for example: confined space entry; lock-out tag-out; hazard communication; etc. This exposes the employees to the safety precautions applicable to the process. The remaining class time is dedicated to the chemistry and unit operations used for converting grain to ethanol:

♦ *Cook (Liquefaction of starch to dextrins)* ♦ *Fermentation (Conversion of sugar to ethanol and carbon dioxide)*	♦ *Distillation/Evaporation (Separation of ethanol from water and corn solids)* ♦ *Dried Distiller's Grain Dryer System*

  - ***Week 2 – Off-site Training at an Operational Ethanol Facility***
    New employees are sent to the U.S. Energy Partners ethanol facility in Russell, Kansas for hands-on training in an operational ethanol plant. Each day they receive four hours of classroom training, expanding on the same topics covered in week one. They also experience four hours of actual side-by-side training with the Russell plant operators. This exposes them to the duties required of operators, including:

♦ *Sampling* ♦ *Computer Operations* ♦ *Key Operating Parameters*	♦ *Safety Concerns* ♦ *Overall Plant Operations "Culture"*

  - ***Weeks 3 and 4 – Vendor Training***
    Employees are given specific vendor training involving the equipment they will be operating in the new ethanol plant. These topics include, but are not limited to:

♦ *Enzymes* ♦ *Yeast* ♦ *Boiler Operations* ♦ *Water Treatment* ♦ *Centrifuge Operation* ♦ *Pump Operation*	♦ *Instrumentation* ♦ *Heat Exchangers* ♦ *Truck and Rail Loadout* ♦ *Cooling Tower* ♦ *Grain Handling* ♦ *Bio-Methanator Water Treatment*

    ICM also provides a Process Hazard Analysis review with the plant management team and several operators. This is led by one of ICM's professional engineers. During the times when no presentations are scheduled, employees are assigned the task of labeling tanks, piping, and equipment to increase their familiarity with equipment location and piping contents.

[6] http://www.icminc.com/operatortraining.aspx

- ***Week 5 - Return to U.S. Energy Partners Ethanol Facility***
  During this visit, the new employees actually run the ethanol process under the supervision of a U.S. Energy Partners operator.

- ***Week 6 - Water Trials***
  ICM's start-up team, consisting of professionals focused on plant operations, laboratory operations, dryer system operations, and electrical and digital control system (DCS) operations, comes on site to start the water trials. (This may begin in week five.) The boiler is started up under supervision of the manufacturer and boiler inspector. Water is introduced into the first tank in the process and transferred through the piping system in order to test the following:

♦ *Vessel Integrity* ♦ *Welding Quality* ♦ *Valve and Instrument Performance and Tuning*	♦ *Pump Performance* ♦ *Vacuum Leaks in the Distillation System* ♦ *Heat Exchanger Integrity*

Steam is introduced into the cook system and evaporator system to test for leaks and expansion joint performance. The cooling tower is filled and circulated as well. Thus, prior to the introduction of grain into the hammer mills, the entire process is brought up to flow, pressure, and temperature using water and steam. This not only tests the mechanical integrity of the workmanship, but also provides the new employees with additional experience operating the control systems

In the period following start-up, ICM runs its 7-10 day performance guarantee test. All corn consumed and ethanol produced is closely monitored during this time period to ensure the facility produces at or above nameplate capacity, and meets yield and energy guarantee specifications. ICM remains on site until this guarantee is met.

V. Potential Key Contacts and Advisors

In addition to the individuals and organizations referenced above, the following may also be of benefit:

- Kory Teneycke - Executive Director
  Canadian Renewable Fuels Association
  (416) 304.1324 / Office
  (416) 304.1335 / Fax
  E-mail: **KTeneycke@greenfuels.org**

- Mike Bryan
  CEO, BBI International [7]
  President, BBI Biofuels Canada
  Salida, Colorado (719) 539-0300 Phone; (719) 539-0301 Fax
  Kitchener, Ontario (519) 576-4500 Phone; (519) 576-7620 Fax
  http://www.bbibiofuels.com/

[7] BBI International is emerging as a North American leader in the biofuels industry and has a wealth of information and contacts that can be referenced from the company's web-site.

BIODIESEL

I. Technological Aspects

Overview

Biodiesel [8] is a renewable fuel produced from vegetable oils or animal fats. Renewable feedstocks include soybeans, canola, cotton seed, mustard seed, tallow, rape seed, sunflower seed, and restaurant grease. Biodiesel is used in place of petroleum based-diesel fuel. Most diesel cars require no modifications to the fuel system to run on biodiesel. Biodiesel begins as a vegetable based oil. The oil is chemically transformed into methyl esters (biodiesel) and glycerin (a byproduct). The chemical process is known as transesterfication.[9] Biodiesel can be made from new oil, but the biodiesel is usually made from used oil from a local restaurant. Biodiesel can be blended in any amount with petroleum based diesel fuel. B100 is the name for pure biodiesel, whereas B20 contains only 20% biodiesel and B10 only 10% biodiesel. Like petroleum based diesel fuel, biodiesel will need additives to keep it from "gelling" in extreme cold weather.

According to the British Columbia Sustainable Energy Association, [10] biodiesel is a safe, non-toxic, biodegradable and renewable fuel that can be easily used in unmodified diesel engines. Fuel markets that can benefit from biodiesel include bus and truck fleets, heavy equipment, diesel cars and boats, oil heating furnaces and electric generators.

Biodiesel is produced by chemically re-acting an alcohol (usually methanol, occasionally ethanol) with vegetable based oils, animal fats, or waste cooking oils, using either sodium or potassium hydroxide as a catalyst. The conversion process will result in approximately 90% B100 biodiesel (neat/pure) and 10% glycerin (crude) as a co-product. The most common process for producing biodiesel is the transesterification of fatty acid glycerol esters to methyl esters.

For more information pertaining to biodiesel, please reference:

http://en.wikipedia.org/wiki/Biodiesel

Biodisel is relatively easy to make in "small batches". A web site that provides an overview of a "do it yourself" process that might form the basis of such a course can be found at:

http://www.biodieselcommunity.org/

Advantages and Disadvantages

Advantages

- Biodiesel's performance is similar to diesel. While biodiesel has slightly less energy per gallon than number 2 diesel, it has slightly more energy than number 1 diesel. Tests have shown its performance when used in vehicles to be virtually the same as diesel.

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[8] http://www.ethanolmarketplace.com/page/view/biodiesel_info
[9] http://en.wikipedia.org/wiki/Transesterification
[10] http://www.bcsea.org/sustainableenergy/biodiesel.asp

- B100 is a very clean burning, non-toxic fuel, offering significant benefits over fossil fuels. Biodiesel can also be splash blended with any percentage of petro-diesel to meet a variety of purposes. A B20 (20% B100 biodiesel + 80% petro-diesel) blend is the most commonly used in North America, as it provides a large number of benefits while easily maintaining current biodiesel standards. B2 and B5 on the other hand, are popular as a lubricant due to biodiesel's high lubricity rating.

- The "life-cycle/carbon sink" benefits as discussed above with ethanol.

- Increased demand for domestic agricultural products with resulting benefits to producers.

- Better use of feed-stocks that are considered waste, such as cooking oil and trap grease.

Disadvantages

- Biodiesel is currently more expensive than petroleum diesel fuel; however, the cost can be reduced by using recycled cooking oils.

- Biodiesel fuel can damage rubber hoses in some engines, particularly in cars built before 1994.

- Biodiesel cleans the dirt from the engine. This dirt then collects in the fuel filter, which can clog it. Clogging occurs most often when biodiesel is first used after a period of operation with petroleum diesel, so filters should be changed after the first several hours of biodiesel use.

- Biodiesel is not distributed as widely as traditional, petroleum diesel, but distribution infrastructure is improving.

<u>History</u>

Vegetable oil was used as a diesel fuel as early as 1900, when Rudolf Diesel demonstrated that a diesel engine could run on peanut oil. (It should be pointed out, however, that today's diesel engines are not designed to run on fuels with such a high viscosity as vegetable oil. Biodiesel is similar in viscosity and other properties to petroleum diesel, which makes its use in today's diesel engines usable without any engine modifications. Biodiesel can either be used in its pure state or can be blended with conventional diesel fuel derived from petroleum.)

In Europe, increasing environmental concerns, expensive overproduction in European agriculture and changes in government policies have resulted in expanded testing and usage of biodiesel. The revival of biodiesel production started with Austrian farm co-operatives in the 1980s. Biodiesel was first produced as a fuel on a commercial scale in Germany in 1991. In the United States, depleting oil reserves and a desire to reduce current distillate imports are the main drivers for increased biodiesel usage and research. The name "biodiesel" was introduced in the United States in 1992 by the National SoyDiesel Development Board (now the **National Biodiesel Board**), which has pioneered the commercialization of biodiesel in the U.S.

Costs

As of March 2006, tests and market prices for inputs such as soy oil in the United States indicate that production costs for biodiesel are up to 2.5 times that of petroleum diesel. [11]

II. Market Trends and Characteristics

Global and Canadian Indicators

In 2003, Europe doubled its production to 2 billion liters., and in 2004, Germany's production alone exceeded 1.1 billion liters . Similar rates of growth are occurring in many other European countries, with significant numbers of new biodiesel plants being built. There are now over 1700 filling stations in Germany and Austria. Many European car manufactures, including VW and Mercedes Benz, have approved biodiesel use for their engines. In France most refineries add biodiesel to motor fuels for sale in proportions ranging from 2% to 5%. It can be used up to 30% in vehicle fleets without any technical constraints. Over 19,000 jobs have been generated in Germany growing the feedstock crops, processing the raw materials, and marketing the biodiesel.

Awareness is growing quickly in Canada due to biodiesel's proven success in other countries and the current and projected prices of petroleum diesel. The potential for biodiesel in Canada is considerable with its abundance of feedstock resources, and by the fact that the federal government has stated a commitment that Canada will produce 500 million litres/year by 2010. The federal fuel tax exemption for biodiesel in 2003 helps provide the industry with an incentive for biodiesel to be priced competitively with diesel fuel.

At present, there are only two major Canadian biodiesel plants in operation. The new Biox Corp. operation at Hamilton Harbour, on the western edge of Lake Ontario, will be able to produce 60 million litres annually when it comes online at the end of May. The other plant is in Montreal and has a capacity of about 30 million litres per annum. Suncor is also set to roll out a micro blending operation in southern Ontario to supply the fuel to municipal and fleet customers with first delivery by the end of May.

The cities of Toronto and Calgary have experimented with using biodiesel as a fuel for their bus fleets and other notable examples of experimental use within the western private sector include Rempel Bros Concrete in Vancouver.

The report "Economic, Financial, Social Analysis and Public Policies for Biodiesel, Phase 1", may be of interest for additional Canadian detail. It can be found at:

http://www.greenfuels.org/biodiesel/pdf/OConnor-Report-Biodiesel2004.pdf

Alberta Situation

In Alberta, the Alberta Biodiesel Association has recently been formed. According to Reinhard Schutz, one of 10 directors, there are up to eight biodisel plants under consideration with an estimated total production capacity of 150 to 200 million litres per year.

[11] http://www.greenfuels.org/biodiesel/world.htm

The Alberta Biodisel Association has also recently created more formal linkages with:

- The Canola Council of Canada;
- The Canadian Renewable Fuels Association; and
- The Alberta Motor Transport Association.

III. Canadian Public Policy and Strategy

In support of the Government of Canada's Biodiesel Initiative, the Alberta Research Council Inc. (ARC) has teamed up with Natural Resources Canada (NRCan) to create an on-line Biofuels Quality Registry. Biodiesel producers and end-users can now register on the Biofuels Quality Registry Web site, an extranet site hosted by ARC, to have their products tested for quality. The site is established as the national database into which analysis results of candidate biofuels are entered. This registry will help ensure that end-users have a quality product and producers have an option for quality control. More information is available at: **http://www.biofuels.arc.ab.ca/**

IV. Education and Skills Requirements

Industry Size

The Canadian biodisel industry is still in the very early stages of formation and it is difficult to estimate, within the scope of this project, the size and growth of the industry.

Skills and Training Requirements

The longer-term skills and training needs of a larger-scale biodiesel industry may be somewhat similar to those outlined in the ethanol section. Ongoing consultation with industry and other institutions, perhaps under the umbrella of the Association of Canadian Community Colleges may be beneficial.

According to Reinhard Schultz of the Alberta Biodiesel Association, the biodiesel plants to be established in Alberta are, to some extent, “kits” that are easy to set up and do not require complex training to operate. In this regard, the potential role for community colleges in the early stages of the industry is minimal.

Given the rising cost of fuel, and ease of manufacture as noted in earlier sections, further steps to explore whether there would be demand for “make your own” training may be warranted. It is likely that the course length would be very short (say in the order of 1 day) and on-line delivery could also be explored.

One additional area for which there may be a role for colleges is in relation to training in the production of the feedstocks that will result in the optimal volume and quality at the plants to be established.

V. Potential Key Contacts and Advisors

In addition to the individuals and organizations mentioned above (as well as those in the Ethanol section), other contacts include:

- Reinhard Schutz
  Alberta Biodiesel Association
  (403) 291-3937

- Dan Wispinski,
  Head, Fuels and Lubricants Group, Alberta Research Council
  (780) 450-5108

- Potential new plant operators and major investors include:

  - Patrick Luft
    Veggie Velocity
    (403) 863-9130

  - Dale Ness
    (780) 888-1162

  - Kelsey Prendervost
    Kyoto Fuels
    (403) 795-7070

- Canola Council of Canada

  http://www.canola.ab.ca/lnk/biodiesel.shtml

Chapter 9
Biogas (Anaerobic Digestion)

The purpose of this chapter is to provide an analysis of some of the major characteristics, trends and issues associated with Biogas (Anaerobic Digestion) that may have a bearing on the need for related training at colleges in Northern Alberta. As in Chapter 8, interest in the subject matter appears to be attributable, at least in part, to a new facility being considered in High Level that will have an ethanol plant integrated in to the overall operation. There are also potential relationships with cogeneration applications and technologies as operators attempt to obtain maximum energy efficiencies.

I. Technological Aspects

Overview

Anaerobic digestion (AD) is the process of microorganisms breaking down organic materials in the absence of oxygen in an enclosed vessel. Anaerobic digestion produces biogas (consisting primarily of methane and carbon dioxide). Depending on the system design, biogas can be combusted to run a generator producing electricity and heat, or it can be burned as a fuel in a boiler or other burner.

Anaerobic digesters need to be designed according to the feedstocks to be used, climate conditions, throughput time desired and quality and amount of gas produced as well as "sanitation levels required and other potential by-products to be used.

They can be designed to be suitable for a single operation or for use as a centralized facility serving multiple farms. Experience has shown that an AD project is most likely to be financially viable if it is treated as part of an integrated farm waste management system in which the feedstocks and the products from AD all play a part. Cogeneration is becoming and increasingly important priority and the type of gas produced is an important consideration in designing and equipping such operations.

For perspective of "inputs and outputs", beef cattle produce more than four times their weight in manure in a year, about three tonnes each. A tonne of manure yields about three cubic metres of methane. The manure from six cows can be converted into enough gas to generate the typical electricity needs of one Alberta household. [1]

A good overview of the technology options, advantages and disadvantages and other issues and challenges that may affect the skills and training required in the Canadian context can be found at:

http://www.omafra.gov.on.ca/english/engineer/facts/04-097.htm - 13

[1] http://www.highmark.ca/index.php?area_id=1003&page_id=1003&article_id=1&LIMIT=

Advantages and Disadvantages

Advantages

- Digester technology can be part of an integrated facility that produces electricity and heat, eliminates waste disposal and odor problems, reduces costs and helps to protect the environment.

Disadvantages

- At this time, there is not a "proven technology" for Alberta (please reference discussion in "Alberta Situation".
- Knowledge and awareness of the technology within the business and support service sectors is minimal resulting in a need for a concerted educational effort.
- The upfront cost of a digester can be high and a barrier to acceptance of the technology.

History

Methane from biomass, including manure, has historically been used in Asia as a fuel for energy. Denmark and Germany have many modern digesters operating on farms and in central locations. Initial interest in biogas technologies was created in North America following the "energy shock" of the 1970s. Unfortunately, earlier systems based upon European specifications were not suitable for colder climate operations. More recently, two trends: a greater number of concentrated feedlot operations and rising energy costs have created resurgence in interest. In addition, the Kyoto protocol has helped to draw greater attention to energy and sustainability issues.

Costs

Based upon experiences in Oregon:[2]

- The estimated cost of producing electric power from anaerobic digestion of animal manure is 3.7 to 5.4 cents per kilowatt-hour.
- The cost of a farm-site manure digester depends on local site conditions and the number of animals on the farm. A plug-flow digester designed to process the manure of 500 dairy cows will have capital costs in the range of US$230,000 to US$260,000.

II. Market Trends and Characteristics

Global and Canadian Indicators

Worldwide, there were an estimated 16 million biogas digesters in 2004, [3] with many "home sized" units of very simple design and operation, located in lesser- developed countries such as India. It is difficult to estimate the power generated from such units.

[2] http://www.oregon.gov/ENERGY/RENEW/Biomass/Cost.shtml

In Europe, as of April 2005, there were over 2,400 anaerobic digesters on farms. Of these, 1,900 were in Germany. The power generating capacity of European anaerobic digesters was approximately 570 MW. The countries with the largest capacities were: Germany (250 MW); United Kingdom (101 MW); Denmark (85 MW); and Italy 62 MW).

In the United States, methane production from anaerobic digesters on farms was approximately 4,500 MT in the year 2000. By 2002, it had increased to approximately 9,500 MT. As of 2003, there were 45 digester projects in operation or under construction with an additional 30 being planned. The total methane production capacity of all 75 is in excess of 22,000 MT of methane. [4]

One estimate of the potential of the Canadian market is 2,100 systems generating 500 MW of power. [5]

Alberta Situation

The Alberta biogas sector is only beginning to emerge and is at least seven to 10 years behind Europe, where it is well-developed. [6] However, the industry has the potential to thrive because the province's agriculture industry has the necessary materials to create biogas from waste management opportunities. These materials include: animal manure; processing wastes; animal wastes; and plant residues.

In addition to the larger municipalities exploring the possibilities of biogas, at one point, five biogas plants had been planned or constructed in Alberta as below:

- Iron Creek Hutterite Colony in Bruce
- Peace County Pork in Fahler
- Cargill Foods in High River
- Highmark Renewables in Vegreville
- Lamb Weston in Taber

An update as to the status of developments at some of the locations is below:

- The Iron Creek Hutterite Colony plant has experienced problems with management and maintenance, which have reinforced the need for appropriate management and operator training, 24 hour on-line monitoring and emergency service and repairs. The system is currently being reworked.

- The Peace Pork anaerobic digester in Fahler has experienced difficulties with the colder Canadian winters.

- The High Mark Renewables pilot project in Vegreville, which has utilized the **Integrated Manure Utilization System (IMUS)** technology developed by the Alberta Research Council,

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[3] Renewables 2004Global Status Report
[4] http://www.naseo.org/Events/annual/2002/presentations/Roos.pdf
[5] http://www.agr.gc.ca/env/uncc-cnucc/pdf/UNCCC-treatment_e.pdf
[6] http://www.gov.ab.ca/acn/200603/19667518E2C4E-05E3-8699-26E03FBA5859CE04.html#backgrounder

has proven that the technology is sound for the Alberta climate. In the next stage of experimentation, solid cattle manure will be introduced. The capacity of the project is 1 MW. Constructing plants with greater capacity is currently restricted by regulations that need to be reviewed.

Adaptation of existing technology to Alberta needs and conditions will likely be of key importance.

An initial meeting of the newly formed Alberta Biogas Association is tentatively scheduled for June 22 in Red Deer.

III. Canadian Public Policy and Strategy

The Alberta government will soon be releasing a bioenergy policy, which will call for the generation of 90 MW of energy from manure sources by 2012. The current capacity is less than 2 MW.

IV. Education and Skills Requirements

Industry Size and Scope

At present, the Biogas industry in Alberta is in very early stages and meaningful forecasts of staffing requirements are difficult and beyond the scope of this project and will be dependent upon government strategies, and successful development or adaptation of technologies that will meet the needs of the Alberta climate. Opportunities for biogas include:

- Creating new income sources for Alberta's agricultural producers and processors and enhance rural sustainability;
- Meeting the growing demands placed for energy as a sustainable and environmentally friendly option;
- Utilizing livestock manure and food processing wastes as an important source for heating directly or in the process of generating electricity;
- Spinning off numerous value-added/recycled products such as biofertilizers, reusable water and recycled chemicals and minerals; and
- As the industry evolves, there will also be a need for testing laboratories and other infrastructure.

Training Requirements

Given the relatively early stage of introduction of anaerobic digester technology to Alberta farms, it is suggested that the best role for Clearinghouse colleges is to work with other stakeholders and institutions to develop the following types of resources:

- Overview of the anaerobic digestion process
- Material pertaining to “case studies” of existing installations, including suppliers and their “track records”)
- Resources pertaining to feasibility and design
- Resources pertaining to construction

- Costs and other considerations pertaining to “success factors”
- Safety issues and requirements
- Emergency procedures
- Environmental issues and requirements
- Financing related issues and incentives
- Sale of surplus electricity and grid connection issues
- Zoning considerations
- Operator training (inputs and their processing, safety, microbiological and pathenogen basics, controls, maintenance requirements etc.)
- Other resources and information sites available
- Marketing and use of other byproducts such as water and fertilizer.
- Quality control and monitoring
- Documentation

The experiences with the Iron Creek anaerobic digester reinforce the need for proper operator training and support. While each company involved in the design and installation of digesters is likely to develop their own training resources, based upon courses provided by California headquartered Varec Biogas [7] (a leader in providing equipment for biogas plants) the type of operator training that needs to be provided might encompass the following:

- Gas Safety Equipment specifications
- Safety hazards and precautions
- Operation
- Installation
- Start-up and Shut-down procedures
- Troubleshooting guidelines
- Preventative Maintenance
- Recommended spare parts
- Routine and Non-routine emergency procedures.

The cost of constructing a digester may be such that some farmers or consortiums might consider “going it alone” in due course. A site for digester resources for “average farmers” is below:

http://www.mnproject.org/e-biogaslinks.html - workshop

Following the recent Alberta Biogas conference [8], Karen Haugen-Kozyra, of Alberta Agriculture and Rural Development indicated that Dr. Claudio Da Costa Gomez of the German Biogas Association has agreed to cooperate in the development of training curriculum. Germany has the most developed biogas network in the world.

[7] http://www.varec-biogas.com/aboutus.asp
[8] http://www.climatechangecentral.com/default.asp?V_DOC_ID=2089

V. Potential Key Contacts and Advisors

The individuals and organizations referenced above, the following may also be of benefit:

Suggested Primary Contacts

- Karen Haugen-Kozyra, M.Sc., P.Ag Environmental/Land Use Member, Policy Secretariat, Alberta Agriculture, Food and Rural Development. (780) 427-3067

- Dr Xiaomei Li, Senior Scientist, Alberta Research Council (780) 450-5290 (Developing training program)

Other Contacts

- Claudius DA COSTA GOMEZ
  German Biogas Association
  Angerbrunnerstrasse 12
  DE-85 356 Freising
  Germany
  Tel: +49 8161 984660 Fax: +49 8161 984670
  Email: dcg@biogas.org
  http://www.managenergy.net/actors/A2010.htm

- Scott McKay, President, The Sustainable Energy Group (a joint venture between EnMac Consultants and Clark Builders and utilizing the technology of the swiss-based Kompogas Group) (780) 969-0410

- Ryan Radke, President, Bio Alberta (780) 425-3815

Other suppliers and manufacturers and those starting to make a presence in Alberta include:

- Clear Green Environmental Inc (www.clear-green.com)
- BioGem Power Systems Inc
- IMUS/Highmark Renewables (www.highmark.ca)
- ANDIGEN (www.andigen.com)

Chapter 10
Solar Power

The purpose of this chapter is to provide an analysis of some of the major characteristics, trends and issues associated with Solar Power (Photovoltaic and Thermal) that may have a bearing on the need for related training at colleges in Northern Alberta.

IA. Technological Aspects – Photovoltaic Power

Overview

Photovoltaic cells convert sunlight directly into electricity by the interaction of photons and electrons within a semiconductor material that is chemically treated with atoms from an element with one more or less electrons than occurs in its matching substrate (*e.g.,* silicon). They have no moving parts. A thin layer of each material is joined to form a junction. Photons, striking the cell, cause this mismatched electron to be dislodged. The "loose" electrons form an electrical current when gathered by wires that are attached to the cells to. The more cells, the greater the current and voltage. A number of PV cells laid side-by-side form a rectangular "module"; several modules together form an "array." The DC current produced depends on the material involved and the intensity of the solar radiation incident on the cell. Most widely used today is the single crystal silicon cell. The source silicon is highly purified and sliced into wafers from single-crystal ingots or is grown as thin crystalline sheets or ribbons. Polycrystalline cells are another alternative, which are inherently less efficient than single crystal solar cells, but also cheaper to produce. Gallium arsenide cells are among the most efficient solar cells today, with many other advantages, but are also expensive.

Infrastructure Requirements

The term balance-of-system (or BOS) is the name given to the equipment and activities of a PV system other than the actual PV modules. Typically, the term BOS has been identified with the DC-to-AC inverter; the foundation and structure that mount the PV modules (sometimes tracking the sun, sometimes fixed facing south); and the electrical wiring and connection equipment. If utilized, any storage components (usually batteries) and any backup generation also are included in the BOS.

Recent efforts now include other important total PV system "soft" costs as part of the BOS cost accounting. A more comprehensive listing of BOS could thus include:

- Project Management
- Inverter (power conditioning unit)
- Engineering & Design
- Foundation (including tracking systems)
- Procurement
- Structure
- Siting & Permitting
- Electrical Wiring
- Installation
- Electrical Protection & Safety Equipment
- Site Facilities
- Construction Management
- Start-Up & Testing
- Electrical Interconnection & Metering
- Data Monitoring
- Communications & Control
- Operation & Maintenance
- Training

Both AC and DC systems will have a foundation and support structure for the PV array. The type and construction are dependent on the type of mounting, ground-mounted or roof-mounted, the size of the array, local wind and snow loading conditions, the tilt of the array, and if any type of tracking is utilized. Fixed mounting-- that is, mounting an array south-facing at a fixed tilt-- is usually the least expensive method and requires no moving parts. The tilt of a fixed array is dependent on the sunlight and load match-- for summer peak loads the tilt is usually at latitude or slightly less than site latitude; for winter loads, the tilt may be at higher angles than the latitude. The solar array also might be oriented toward the southwest or even the west to obtain load coincidence.

Tracking the sun will increase the energy output of the array, but at a cost and complexity. The purchase price, along with the installation and maintenance costs of a tracking system, must be compared to the energy output requirements of an application. Extensive testing at Arizona Public Service in Phoenix, Arizona, U.S.A., and at PVUSA in Davis, California, U.S.A., has shown that tracking in a north-south, one-axis configuration gives 21% to 27% more annual energy output when compared to a fixed array, at near latitude tilt, and two-axis tracking improves the annual output energy by 37% to 43% compared to a fixed array, but again at additional cost and complexity.

Roof jack techniques have proven to be a popular and cost-effective mounting for PV modules on both flat and slanted roofs. This system uses a ballasted pan for attachment to a flat roof or is directly bolted to a slanted style roof.

One of the most important components of an AC PV system is the inverter - the electronic component that converts the PV array's DC power into conventional alternating current (AC). The inverter is sometimes referred to as a power conditioning unit or PCU or by other terms. Two basic types of inverters are available: (1) connected to the utility grid which is used for synchronization (also called line-commutated); or (2) a stand-alone inverter for operation in a grid-independent mode.

Grid-connected inverters must produce clean waveforms (minimal harmonics) and not degrade the power quality of the existing utility grid. They also must be able to disconnect from the grid if the utility grid is lost to prevent "islanding." Several new techniques have been developed that help reduce this problem. Stand-alone inverters must provide the quality of power required by the load and although newer designs can be of high power quality, some older designs produce high harmonic content waveforms. Inverters consume power when they are on but the PV array is not generating power, and they are much less efficient at low-load conditions.

The use of photovoltaics for stand-alone applications may require additional equipment, such as a charge controller, batteries (or some other storage medium such as water), or a backup generation source. The PV module is usually the same as is used for an AC system but the interconnection may require larger wire at low voltages in order to reduce current losses. The charge controller is a solid state device that prevents overcharging the batteries and may have a low-voltage disconnect to prevent the load from completely discharging the batteries. The charge controller must be carefully matched to the batteries to prevent overcharge or too much discharge. The batteries are usually of lead-acid or gel configuration and are treated the same as any stationary battery used for utility purposes. A photovoltaic system installed in extremely harsh environments may require a battery enclosure.

For DC systems operating motors with or without a DC converter and battery, it is practical to add what is called a "maximum power point tracker." This device determines where the solar array is on the current voltage curve and acts like a variable-turn transformer to adjust to the maximum power point.

There also may be the need for "hybrid systems" when loads must be met 100% of the time. The most common configuration is a system with a PV array with a battery bank and a natural gas or diesel engine generator. The solar array can be designed and sized to charge the battery slowly while the engine generator can be used to quickly charge the battery. Hybrid systems lower the cost and size of the solar array required to operate the loads and charge the battery. Control systems for a hybrid system are far more complicated than for other PV systems.

Applications

Current Applications

While currently costly compared to most conventional choices for grid power, (the cost of PV has fallen by 90 percent since the early 1970s), Photovoltaic applications are still a very small part of the energy make-up of any country. However, applications of the technology are wide, ranging from small calculators and wrist- watches to critical applications in extreme climates and outer space. There is a strong market today in developing countries to provide rural electrification with solar panels, which replace kerosene lamps, batteries, and wood fires at a far lower cost than the central station power plants. Photovoltaic cells are also making inroads as supplementary power for utility customers already served by the grid. Use is growing for reasons other than cost including: a desire to develop a clean, sustainable energy source; interest in a clean back-up power source; a need for placing power generation right at the source with no fuel, noise or moving parts; and an attraction to a power technology that can be built right into building roofs, facades, canopies and windows.

The Future

Today's prevalent cell technologies are based on a single junction, which can use only a portion of the sun's energy spectrum. However, emerging multi-junction cells will allow many layers to use progressive parts of this spectrum, resulting in higher efficiencies. Various means to produce these layers at acceptable costs are being actively pursued.

Another approach to producing solar cells that shows great promise is thin films. Commercial thin films today are principally made from amorphous silicon; however, copper indium diselenide and cadmium telluride also show promise as low-cost solar cells. Thin-film solar cells require very little material and can be easily manufactured on a large scale. Manufacturing lends itself to automation and the fabricated cells can be flexibly sized and incorporated into building components. The highest quality grids are produced using photolithography for image transfer. Crystalline cells typically use a layer of aluminum or molybdenum. The typical thin film does not use a metal grid for the electrical contact, but a transparent conducting oxide, such as tin oxide, indium oxide, or zinc oxide. All of these areas are under active research.

Advantages and Disadvantages

Advantages

- Inexhaustible fuel source
- No pollution
- Often an excellent supplement to other renewable sources

- Versatile--is used for powering items as diverse as solar cars and satellites

Disadvantages

- Very diffuse source means low energy production--large numbers of solar panels (and thus large land areas) are required to produce useful amounts of heat or electricity
- Efficiencies are still low and the energy generated is not suitable for higher intensity situations such as home heating
- Only areas of the world with abundant sunlight are suitable for solar power generation

History

In 1839, Edmond Becquerel noticed that, in addition to heat, the sunlight that is absorbed by certain materials can produce small quantities of electricity. This curious phenomenon was limited to measuring light levels in photography until the 1950s. Then, the combination of improved purification techniques for semiconductors, the advances in solid state devices beginning with the development of the transistor in 1947, and the needs of the emerging space program, led to the development of photovoltaic cells. In 1954, a 4% efficient silicon crystal photovoltaic cell was demonstrated. By 1958, a small silicon array was used to supply electrical power to a U.S. satellite.

Costs

The price of solar energy [1] is determined by the cost of the solar modules and the accompanying equipment (a 50:50 split), the interest paid on the capital, and the amount of sunshine received, calculated over an assumed life of 20 years. A typical 2 kW rooftop system costs $16,000 ($8/watt). In a hot sunny climate averaging 5.5 hours of sunshine a day, with a 5% interest rate, the price of solar is around 30 cents/kWh. If electricity costs 20 cents/kWh, the payback period is 30 years. If electricity costs 10 cents/kWh, the payback is 60 years. The perfect combination is a high price of electricity (eg Japan) and a low price for solar (by developing a mass market). When solar falls to $1/watt and electricity costs 20 cents/kWh, the payback will fall to 7 years.

IB. Technological Aspects – Thermal Solar Power

Overview

Unlike solar cells that use chemicals to transfer the sun's energy into usable electricity, thermal solar power, concentrates the sun's tremendous heat energy into heat conductors that transfer the energy to be used for heating water, heating air or generating electricity. There are many differing "liquid-based [2]" and "air-based" [3] technologies and systems for collecting solar energy. Some of the more widely used systems and their applications as well as advantages and disadvantages are discussed below.

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[1] http://www.earthfuture.com/climate/solaroverview.asp

[2] Liquid-based collectors use sunlight to heat a liquid that is circulating in a "solar loop". The fluid in the solar loop can be water, an antifreeze mixture, thermal oil, etc. The solar loop transfers the thermal energy from the collectors to a thermal storage tank. The type of collector needed depends on how hot the water must be and the local climate.

[3] The energy collected from air-based solar collectors can be used for ventilation air heating, space heating and crop drying. The most common application in Canada is for ventilation air heating.

- **Glazed flat-plate collectors:** Glazed flat-plate collectors are very common and are available as liquid-based and air-based collectors. In this type of collector a flat absorber efficiently transforms sunlight into heat. To minimize heat escaping, the plate is located between a glazing (glass pane or transparent material) and an insulating panel. The glazing is chosen so that a maximum amount of sunlight will pass though it and reach the absorber. These collectors are better suited for moderate temperature applications where the demand temperature is 30-70C and/or for applications that require heat during the winter months. The liquid-based collectors are most commonly used for the heating of domestic and commercial hot water, buildings, and indoor swimming pools. The air-based collectors are used for the heating of buildings, ventilation air and crop-drying.

- **Unglazed flat-plate collectors:** Unglazed flat-plate collectors are usually made of black plastic that has been stabilized to withstand ultraviolet light. Since these collectors have no glazing, a larger portion of the sun's energy is absorbed. However, because they are not insulated a large portion of the heat absorbed is lost, particularly when it is windy and not warm outside. They transfer heat so well to air (and from air) that they can actually 'capture' heat during the night when it is hot and windy outside. In North America unglazed flat-plate collectors currently account for the most area installed per year of any solar collector. Because they are not insulated, these collectors are best suited for low temperature applications where the demand temperature is below 30C. By far, the primary market is for heating outdoor swimming pools, but other markets exist including heating seasonal indoor swimming pools, pre-heating water for car washes and heating water used in fish farming operations. There is also a market potential for these collectors for water heating at remote, seasonal locations such as summer camps.

- **Vacuum tube solar collectors:** Vacuum (also "evacuated") tube solar collectors are amongst the most efficient and most costly types of solar collectors. They have a selective absorber for collecting sunlight that is in vacuum-sealed tube. These collectors are best suited for moderate temperature applications where the demand temperature is 50-95C and/or for very cold climates such as in Canada's far north. Like with glazed flat-plate solar collectors, applications of vacuum tube collectors include heating of domestic and commercial hot water, buildings, and indoor swimming pools. Due to their ability to deliver high temperatures efficiently another potential application is for the cooling of buildings by regenerating refrigeration cycles.

- **Batch solar collectors:** One hundred years ago, water tanks that were painted black were used as simple solar residential water heaters. Today their primary market is for residential water heating in warm countries. In Canada, they can be effectively used in campgrounds and for residential water heating in temperate climates such as Vancouver Island; during winter the tanks must be protected from freezing or they must be drained. Modern batch collectors have a glazing that is similar to the one used on flat plate collectors and/or a reflector to concentrate the solar energy on the tank surface. Because the storage tank and the solar absorber act as a single unit, there is no need for other components. On an area basis, batch collector systems are less costly than glazed flat-plate collectors but also deliver less energy per year.

- **Solar cookers:** Though there are many types of solar cookers, all of them have a couple of basic components: concentrator or lenses to increase the available solar energy and insulation to reduce heat loss. Often there is also an oven type cavity to place food into for cooking. Hot dog cookers, which do not need an 'oven' can also be made. Solar cookers are commonly able to reach cooking temperatures of 90-150 C (200-300 F) and some can even reach 230 C (450 F). With these temperatures, it is possible to cook virtually any food as long as it is sunny outside.

- **Concentrating solar collectors:** By using reflectors to concentrate sunlight on the absorber of a solar collector, the size of the absorber can be dramatically reduced, which reduces heat losses and increases efficiency at high temperatures. Another advantage is that reflectors can cost substantially less per unit area than collectors. This class of collector is used for high-temperature applications such as steam production for the generation of electricity and thermal detoxification. These collectors are best suited to climates that have an abundance of clear sky days and therefore are not so common in Canada. Stationary concentrating collectors may be liquid-based, air-based, or even an oven such as a solar cooker.

  There are four basic types of concentrating collectors:

  1. **Parabolic trough system:** Parabolic troughs are devices that are shaped like the letter "u". The troughs concentrate sunlight onto a receiver tube that is positioned along the focal line of the trough. Sometimes a transparent glass tube envelops the receiver tube to reduce heat loss. Parabolic troughs often use single-axis or dual-axis tracking. In rare instances, they may be stationary. Temperatures at the receiver can reach 400 °C and produce steam for generating electricity. In California, multi-megawatt power plants were built using parabolic troughs combined with gas turbines.

  2. **Parabolic dish systems:** A parabolic dish collector is similar in appearance to a large satellite dish, but has mirror-like reflectors and an absorber at the focal point. It uses a dual axis sun tracker. A parabolic dish system uses a computer to track the sun and concentrate the sun's rays onto a receiver located at the focal point in front of the dish. In some systems, a heat engine, such as a Stirling engine, is linked to the receiver to generate electricity. Parabolic dish systems can reach 1000 °C at the receiver, and achieve the highest efficiencies for converting solar energy to electricity in the small-power capacity range.

  3. **Power tower system:** A heliostat uses a field of dual axis sun trackers that direct solar energy to a large absorber located on a tower. To date the only application for the heliostat collector is power generation in a system called the power tower. A power tower has a field of large mirrors that follow the sun's path across the sky. The mirrors concentrate sunlight onto a receiver on top of a high tower. A computer keeps the mirrors aligned so the reflected rays of the sun are always aimed at the receiver, where temperatures well above 1000°C can be reached. High-pressure steam is generated to produce electricity.

  4. **Stationary concentrating solar collectors:** Stationary concentrating collectors use compound parabolic reflectors and flat reflectors for directing solar energy to an accompanying absorber or aperture through a wide acceptance angle. The wide acceptance angle for these reflectors eliminates the need for a sun tracker.

There are also four types of "air-based" collectors:

- **Unglazed perforated plate collectors:** The key to this type of collector is an industrial-grade siding/cladding that is perforated with many small holes at a pitch of 2-4 cm. Air passes through the holes in the collector before it is drawn into the building to provide preheated fresh ventilation air. Efficiencies are typically high because the collector operates close to the outside air temperature. These systems can be very cost-effective, especially when they replace conventional cladding on the building, because only incremental costs need be compared to the energy savings. The most common application of this collector is for building ventilation air heating. Other possible components for this system are: a 20-30cm air gap between the building, a canopy at the top of the wall that acts as a distribution manifold, and by-pass dampers so that air will by-pass the system during warm weather. Another application for this collector is crop drying. Systems have been installed in South America and Asia for drying of tea, coffee beans, and tobacco.

- **Back-pass solar collectors:** Air-based collectors use solar energy to heat air. Their design is simple and they often weigh less than liquid-based collectors because they do not have pressurized piping. Air-based collectors do not have freezing or boiling problems. In these systems, a large solar absorber is used to heat the air. The simplest designs are single-pass open collectors. Collectors that are coated with a glaze can also be used to heat air for space heating. This type of collector may be integrated in the building and combined with thermal mass such as in the Trombe wall (discussed below).

- **Glazed flat-plate:** as discussed above.

- **Trombe Wall:** A wall with high thermal mass used to store solar energy passively in a solar home. It is named after the French inventor, Felix Trombe, who popularized the design in 1964 al though Edward Morse had patented it back in 1881. A Trombe wall consists of a vertical wall, built of a material such as stone, concrete, or adobe that is covered on the outside with glazing. Sunlight passing through the glazing generates heat, which conducts through the wall. Warm air between the glazing and the Trombe wall surface can also be channeled by natural convection into the building interior or to the outside, depending on the building's heating or cooling needs.

  Designs for the first three collector types are simple. The collectors usually weigh less than liquid-based collectors because they do not have pressurized piping. Another advantage of air-based collectors is that they do not have freezing or boiling problems. All four of these air-based collectors can be integrated into buildings and form part of a building's envelope. These first three collectors are described in more detail on each of their own pages; the Trombe wall is described in detail at the Encyclopedia for Alternative Energy and Sustainable Living web site [4].

Examples of Applications in Alberta: Drake Landing Solar Community, Okotoks

Energy experts at Natural Resources Canada's (NRCan's) CANMET Energy Technology Centre (CETC), along with Experts in renewable energy, community planning, district heating, advanced integrated mechanicals and heating, ventilating and air conditioning, energy-efficient housing and energy-simulation software have with private-sector partners, to integrate renewable and advanced energy technologies in North America's first large-scale seasonal storage project to

[4] http://www.daviddarling.info/encyclopedia/T/AE_trombe_wall.html

demonstrate that solar technology is a viable energy source in cold climates. Solar energy will be used to meet 90 percent of residential space heating needs for 52 homes, drastically reducing this community's dependency on fossil fuels as an energy source.

The system designed will capture the sun's thermal energy, store this energy underground, and later retrieve it at a temperature of up to 80°C provide residential space heating. In addition, the community heating system features 800 solar-thermal panels integrated into the community design to capture solar energy to heat water. The panels will generate 1.5 megawatts of thermal power on a typical summer day. The heat will then be transferred underground using borehole thermal-energy storage technology. (This system consists of 144 holes stretching 37 metres below ground and covering a surface area 35 metres in diameter.) An advanced district heating system will retrieve the heat and distribute it on demand throughout the community.

The homes will be built to NRCan's R-2000 standard and the Built Green™ Alberta "Gold" standard, and are each fitted with a solar domestic hot water system. Each home will consume 30 percent less energy and produce five tonnes fewer greenhouse gas (GHG) emissions than conventionally built homes.

Advantages and Disadvantages

Advantages

- Solar thermal technologies minimally impact the environment and expel few greenhouse gas emissions.

Disadvantages

- The sun's intermittent nature and the fact that solar thermal technologies are not fully commercialized tend to be a disadvantage; however, hybrid system, fueled by other energy sources, tend to resolve part of this problem

History

Solar thermal heating has been used for thousands of years, especially in applications such as crop drying. It is difficult to chronicle the integration of solar energy with a variety of other technologies and applications.

Costs

The costs of solar thermal heating are dependent upon the specific application and other technologies utilized. As such, it is difficult to generalize. The Alberta Research Council objective of creating a "zero energy home" will undoubtedly require more substantial initial cost that will need to be reviewed on a longer-term, life-cycle basis.

II. Market Trends and Characteristics

Global Photovoltaic Market

Total global peak power of installed solar panels is estimated by the International Energy Agency to be approximately 5,300 MW as of the end of 2005 and has been growing by 35 to 40% per year. However, reliable figures are not available. Based on available data from the International Energy Agency, at the end of 2004, approximately 2,600 MW was installed in "first world" countries. Of these, Japan and Germany having the largest solar PV generating capacities (approximately 1.132 million MW and 794,000MW, respectively) A large proportion of the solar PV power generated in Japan and Germany (93% and 97%, respectively, connected to the grid). The United States was a distant third with approximately 365,000 MW of PV power capacity of which approximately 47% was connected to the grid. By comparison, Canadian solar PV capacity at the end of 2004 was only 14,000 MW and only 512 MW was grid connected. The following table provides an overview of installed PV solar power as of the end of 2004.
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GLOBAL INSTALLED PV POWER AS OF THE END OF 2004

Country	PV Capacity				
	Cumulative			Installed in 2004	
	Off-grid PV [MW]	Grid-connected [MW]	Total [MW]	Total [MW]	Grid-tied [MW]
Japan	84,245	1,047,746	1,131,991	272,368	267,016
Germany	26,000	768,000	794,000	363,000	360,000
United States	189,600	175,600	365,200	90,000	62,000
Australia	48,640	6,760	52,300	6,670	780
Netherlands	4,769	44,310	49,079	3,162	3,071
Spain	14,000	23,000	37,000	10,000	8,460
Italy	12,000	18,700	30,700	4,700	4,400
France	18,300	8,000	26,300	5,228	4,183
Switzerland	3,100	20,000	23,100	2,100	2,000
Austria	2,687	16,493	19,180	2,347	1,833
Mexico	18,172	10	18,182	1,041	0
Canada	13,372	512	13,884	2,054	107
Korea	5,359	4,533	9,892	3,454	3,106
United Kingdom	776	7,386	8,164	2,261	2,197
Norway	6,813	75	6,888	273	0
Sub-total	**447,833**	**2,141,125**	**2,585,860**	**768,658**	**719,153**

Canadian Photovoltaic Market

Grid connected solar photovoltaic systems are not generally able to complete with the costs of energy generated in Canada via other means, and as such, use of the power source is still very small in Canada. To date, the technology tends to be used in more isolated setting such as cottages or other recreational applications. Total power generated by the technology is less than 2 MW at present.

Global Solar Thermal Market

Over the course of this assignment, readily accessible estimates of the size of the global thermal market could not be found; and the complexity of overlapping technologies compounds the task. Such research does exist but is in the form of expensive and very specialized market research reports.

Canadian Solar Thermal Market

A detailed survey of the active solar thermal (ST) industry in Canada was undertaken in the period from January through March 2005. [5] The primary focus of the survey was to determine the size of the Canadian solar thermal industry and market. Some of the key findings of the study are presented below.

- At the end of 2001 there was an estimated 258 MWTH of operating solar systems in Canada. Since 2001, when the capacity was estimated to be 170 MWTH, capacity has grown by over 50% as below:

Year	Capacity Added (MWTH)
2002	24.2
2003	26.4
2004	37.5

- In terms of the value, while still relatively small, sales of all collector types (liquid unglazed, air collectors and liquid glazed) grew substantially during the three-year survey period from approximately $4.9 million to approximately $7.3 million over the period 2002 to 2004. Further to this growth, the survey respondents are expecting 20% growth in both 2005 and 2006. Approximately 10% of all sales were exported during 2002 - 2004.

- While unglazed liquid collectors (97% of which are used for swimming pool heating) constitute the majority of the collector area sold in Canada, the three major types of solar collectors (combining evacuated with liquid glazed as a single type) all hold roughly one third of the market, when measured on a revenue basis.

- The survey also confirmed that the markets and applications for different collector types are distinct:
  - Almost all liquid unglazed collectors are sold into the residential sector, for swimming pool heating (97%).

[5] http://www2.nrcan.gc.ca/es/erb/erb/english/View.asp?x=469&oid=1183

- The vast majority of air collectors are sold into the industrial/commercial/institutional (I/C/I) sector (90%), with most of these being used for space heating.
- Sales of liquid glazed and evacuated tube collectors were split between the residential and I/C/I sectors, with approximately 67% in the residential sector. The residential sector sales were primarily for domestic water heating, although in 2004 23% of sales in the residential sector were for combination domestic hot water (DHW) and space heating applications, indicating strong growth in this application. Sales of these collectors into the I/C/I sector were primarily for DHW applications.

III. Canadian Public Policy and Strategy

Research and Development

The principal research organizations of the governments of Canada and Alberta in relation to solar energy are discussed briefly below. In some instances, the hyper links may be activated for additional details.

Canada

Within the Canadian Government and in the CANMET Energy Technologies Centre (CETC) at Natural Resources Canada, research and development activities for active solar energy technologies and applications are ongoing in the Active Solar Energy Program. This program works with industry to improve the cost-performance of systems. System testing is a key component of the program and it is usually undertaken at the National Solar Test Facility (NSTF), which is owned by NRCan and operated by Bodycote-ORTECH International. Activities also include:

- on-site field monitoring
- development of analysis software for predicting system performance
- conducting targeted market studies

Technical support and collaborative work is also undertaken with the Renewable Energy & Electricity Diversification Program for its core activities, including the Renewable Energy Deployment Initiative (REDI) and with the Canadian Standards Association (CSA). The REDI promotes the use of active solar thermal systems, namely solar hot water and solar air heating, in the commercial, institutional and industrial sectors. The program also supports pilot projects in the residential sector. REDI offers incentives, and undertakes marketing and infrastructure development activities.

Alberta

In 1999, the Alberta Research Council (ARC) started developing solar technologies as a part of an effort to provide new solutions for the solar integrated systems that will use solar energy as a primary source of energy for residential housings. Under the program, ARC is developing and testing new solar energy components, highly efficient solar energy collecting systems and novel design concepts in residential housing as well as targeting demonstration opportunities to help validate the performance of integrated solar energy systems. In striving to achieve a zero energy home, current research activities and priorities include:

- Development of the solar system components;
- Testing and evaluating of the existing technologies products;

- Engineering next generation solar systems;
- Integration of solar systems with the house structure; and
- Research on advanced hybrid solar systems.

Market Stimulation [6]

The federal government has implemented a number of initiatives to stimulate use of solar power including:

- **Support Program for Certification of SDHW Systems (March 2005)**
  NRCan, working in conjunction with CanSIA, is offering a support program to cover up to 90% of the first time costs of certification of SDHW systems to CSA F379-5. The availability of certified solar domestic hot water (SDHW) systems in the Canadian market will enhance consumer confidence in the technology, simplify the building permit acceptance process and provide a clear acceptability criterion for government or utility deployment programs. Future NRCan funding of SDHW projects will require systems involved to hold Canadian Standards Association - International (CSA-I) certification. Program is on a limited "first come basis" and expires on March 31, 2007.

- **Renewable Energy Deployment Initiative (REDI) (Dec 2003)**
  REDI has a number of incentive programs for businesses to use solar thermal technologies. Currently REDI will sup ply 25% of the purchase price and installation consists of a qualifying solar air or water heating system, to a maximum contribution of $80,000.

- **EnerGuide for Houses (Dec 2003)**
  This retrofit program for homeowners program includes solar DHW systems and PV systems. The funding level is based on the energy improvements (as a percent above a base level) of the home. Funding is extremely low - typically $50 - $100 for most solar installations.

- **Energy Retrofit Assistance Program (Dec 2003)**
  The Energy Innovators Initiative through the Office of Energy Efficiency includes the installation of renewable energy technologies for commercial buildings.

- **Class 43.1 Accelerated Capital Cost Allowance and Canadian Renewable and Conservation Expenses (Dec 2003)**
  The Class 43.ACCA was introduced in the 1996 federal budget to promote energy efficiency and low-impact renewable energy through the income tax system. Class 43.1 allows taxpayers an accelerated write-off at up to 30% per year of equipment generating electricity from solar electric systems larger than 3 kW and active solar systems generating thermal energy.

[6] http://www.cansia.ca/government.asp

IV. Education and Skills Requirements

Number and Types of Jobs Within the Industry

There is a lack of employment statistics on the solar industry in Canada and, unlike other nations, there is no on-going annual survey that tracks the employment in the industry. The following comments are based upon a January 2005 study completed by the Canadian Solar Industries Association [7]:

- A number of estimates have been done in the past few years on the current job levels of solar in Canada. According to a study completed by Industry Canada in 2003, there were 1,000 jobs in the solar PV industry, 120 jobs in the solar water industry, and 60 jobs in the solar air industry. In 2001, Natural Resources Canada estimated that there were 625 jobs in the solar PV industry.

- CanSIA estimates that there are approximately 360-500 firms in Canada with the primary business of solar technologies (most of which employed fewer than five including the owner). Based on the number of estimated firms, the ratio of employment level ratios and the total employment reported by survey respondents CanSIA estimates that the solar industry in Canada employees between 900-1,200 employees (700-975 full time and 200-275 part time) in 2004.

- Almost 70% of solar firms expect to hire more staff over the next two years with an average staff increase of 10% annually.

- By 2025, the number of direct jobs in the Canadian industry <u>could</u> grow to over 60,000 if certain incentives are enacted and prior technical concerns are addressed.

- Direct job classifications fall into the three categories of Manufacturing, Installation and Operations and Maintenance.

- Indirect jobs associated with solar including the manufacturing of balance of system components include: PV system (batteries, inverters, mounting hardware); Solar hot water (pumps, plumbing, controls, mounting hardware, heat exchangers, water tanks); Solar pool heating (plumbing); Solar air ventilation (fabrication of metal, including ductwork and ventilation equipment); as well as general glass and metal framing.

- Currently the majority of solar manufacturing jobs in Canada are for products exported outside of Canada. The five main solar manufacturers in Canada, Conserval (solar air ventilation), Xantrex (inverters for PV), Thermo Dynamics (solar hot water collectors, Carmanaugh Technologies (PV lighting systems) and most recently – Spheral Solar (PV modules) are focused on the export markets with an estimated 50-95% of their products being exported.

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7 http://72.14.203.104/search?q=cache:W26_It7iNWYJ:www.cansia.ca/downloads/report2005/C07.pdf+Canadian+solar+industries+employment+opportunities&hl=en&gl=ca&ct=clnk&cd=1

Educational and Skill Requirements

More specific commentary on the skills and educational requirements of aspects of the Canadian solar industry are below. They are based upon the findings of the report "Renewable Energy Industry - Situation Analysis of the Knowledge, Competencies, and Skill Requirements of Jobs in Renewable Energy Technologies in Canada". Individuals with more detailed or specific interests are encouraged to reference the report, particularly in the context of more detailed descriptions of the types of jobs associated with the sector.

Solar Photovoltaic

In rough order of prevalence jobs in the solar photovoltaic industry are:

- Designer/installer
- Design engineer/consultant
- Assembler
- Technical Sales
- Process Engineer
- Technician/Technologist

The report also notes that the industry is still evolving and that the economics in Canada are "tenuous". Furthermore, the industry has a need to overcome image problems as a result of poorly trained technicians. As a result, the industry supports the development of training and certification standards. At this juncture, the standards are a "work in progress" and the details of implementation and enforcement are not known and the industry is split as to whether installation technicians should be considered as a stand-alone trade or whether other tradesmen should obtain specialized solar PV training.

The report further notes that the small size of the industry makes it difficult to justify general availability of specialized courses. However, in those schools and other venues where such training exists (Seneca College, BCIT), demand is high, and there may be justification for the development of a suite of courses once some of the preceding issues are resolved. In this regard, it is noted that From time to time, the Solar Energy Society of Canada has organized shorter (three day) courses dealing with photovoltaic power in conjunction with MacEwan College and using instructors from BCIT (Eric Smilley). Contact: Guy Chalifoux at 780-450-6186.

Solar Thermal

Typical solar thermal jobs (excluding common jobs in administration) in rough order of prevalence, encompassing both water and air applications) are:

- Dealer (designer/installer)
- Design engineer/consultant
- Technical sales

The industry association, CanSIA, supports the development of certification standards for Solar Water designer/installers, but will be focused for the next 2-3 years on standards for photovoltaic designer/installers as the priority. Training is provided by the manufacturer and appears to be sufficient from a technology transfer point of view. While the industry association, CanSIA strongly supports the development of certification standards for PV and Solar Water designer/installers, there appears to be no impetus for similar certification standards to be developed or applied in the case of Solar Air.

There is no justification for general availability of specialized training for solar water jobs across the country. The base is small and the growth in demand insufficient to support large numbers of technologists entering the field. Not unlike the Solar Air industry, dealers provide solar water solutions either as part of a comprehensive solar or renewables suite of services or as part of a comprehensive plumbing or pool suite of services. With over half the dealers in the latter category, the most appropriate training solution may be to integrate solar water into plumbing certification programs.

There is also no justification for general availability of specialized training for solar air jobs across the country. Dealers appear to come to solar air installations either via a more traditional business in HVAC or via a wish to provide comprehensive solar or alternate energy options to customers. It is clearly not a unique trade, since even the most successful dealer in Canada insists that an HVAC heating solutions perspective is essential to success with the customer. On the other hand, most existing HVAC trades people are little aware and unschooled in solar air applications. Therefore, the best model for integrating better awareness and exposure to solar air would likely be modules in HVAC diplomas and certification programs.

However, there is certainly an interest and likely a demand for a suite of courses, which would provide basic education in a range of renewable energy technologies, since many designer/installers, distributor and component salespeople combine more than one type of technology in their line of business. In the event that such a specialty program is developed, solar water should form part of the renewables suite.

V. Potential Contacts and Advisors

Some additional contacts and resources that may be useful include:

- US Solar Energy Industries Association
  http://www.seia.org/

- Canadian Solar Industries Association
  http://www.cansia.ca/

- **Doug McClenahan**, Project Leader, Sustainable Buildings and Communities - Renewables
  CANMET Energy Technology Centre, Natural Resources Canada
  (613) 996-6078
  dmcclena@nrcan.gc.ca

- Alberta Research Council
  http://www.arc.ab.ca

- **Solar PV Education Programs**
  US Department of Energy – Office of Energy Efficiency and Renewable Energy
  http://www1.eere.energy.gov/solar/adult_ed.html

Chapter 11
Major Conclusions and Recommendations for Moving Forward

The previous chapters have presented considerable information regarding the technological, business and skills and educational requirements associated with a range of alternative and renewable energy forms. This chapter attempts to provide a concise summary of key factors and make more specific suggestions and recommendations for the consideration of Clearinghouse members.

General Comments and Observations

Interest in alternative and renewable energy is growing rapidly driven by rising energy costs and environmental concerns; however, the industry as a whole is faced with a number of issues that may inhibit the development of educational programs and initiatives required to meet the growth demands. In particular:

Equivalency and Recognition of Qualifications

Education is a provincially regulated issue for emerging industries and, as such, there are differing standards between provinces. In order to achieve the "critical mass" likely required to make certain training programs viable for the allocation of public funds, it is necessary to achieve inter-provincial recognition of training. While much is being done to address such issues, it is likely that this will be a medium to long-term initiative.

Certification, Accreditation and Standards

Recognition of technologies, as well as trades and technical training specific to renewable energy is a problem, as most professional associations do not recognize renewable energy technologies. The National Building Code does not yet contain standards for renewable energy (aside from CSA standards, which apply to system components and technologies, and the Canadian Electric Code, which defines installation standards. These issues act as a deterrent to the market place as they give consumers additional reason to avoid the technologies and cause regulatory bodies (such as those responsible for issuing building permits) to withhold approvals.

Recruiting and Retention

The seasonality of some work in the renewable energy industry (such as solar thermal in relation to swimming pools) can act as a deterrent, given the strong labour market for individuals with trades and technical training.

A Need for a New Outlook

Notwithstanding the above, there will be a need to introduce a renewable and alternative energy "culture" to the training and skills requirements. In this regard, it is suggested that renewable and alternative energy training needs to encompass the following "softer" issues if a true industry or group of industries are to flourish from a value-added perspective:

- Principles of sustainable energy and global climate change as a rationale for seeking more efficient and alternative means of supplying energy;
- Global energy supply and demand issues;
- The Canadian energy market "profile" – sources and uses;

- The rationale for various energy sources;
- Assessment of energy use practices;
- Calculation of energy supply and consumption – including conversion of data to common sets of energy units and various conversion factors;
- The energy content of various fuel sources;
- Relevant federal and provincial regulatory issues and constraints;
- Government policies that pertain to renewable energy;
- Kyoto protocol and/or other climate control initiatives;
- Economic aspects of various energy sources including costs and benefits that need to be considered;
- Assessment of the economics of various alternative energy projects in terms of operating and capital costs;
- RETScreen International software (Renewable Energy Technology Assessment);
- Describe the steps involved in developing and managing and alternative energy project; and
- Identify issues that characterize project development and implementation.

The list is not necessarily comprehensive but illustrative in nature and may need to be modified for each specific alternative or renewable energy source or form, the specific nature of the training and the audience.

With the following backdrop, each of the specific alternative and renewable energy forms is dealt with in the balance of this chapter.

Wind Energy

Overview of Findings

Large turbine wind energy capacity is growing rapidly globally and in Canada. The industry is the most mature of the "renewables suite". Between 2003 and 2008/09, capacity in Canada will have grown from approximately 324 MW to over 2,000 MW. There are some indications of a potential growth market in Northern Alberta (based upon developments in the Dawson Creek area of British Columbia. Based upon some of the employment estimate data available and discussed n Chapters 2 and 3, the labour force required for operation and maintenance from approximately 30 in 2003 to over 200. On the basis, the Insightrix Research survey referenced in Chapter 3, entire direct industry could grow from the estimate of 725 in 2005 to over 2,100 by 2008/09.

Use of small scale wind turbines has the potential to increase dramatically, particularly in more remote and northern communities; however, at this time, the market is still relatively small with annual sales of 600 to 800 units with a value of approximately $4.2 million. On this basis, the Northern Alberta "market" might be in the order of 60 to 80 units per year and $400,000. Most units are relatively simple to install and service and extensive specialized training is not required. For many retail suppliers, small wind turbines are a portion or side line of their overall businesses.

From the perspective of the development and delivery of training programs, while growth is rapid, there may not be the "critical" mass of numbers to support the development of training programs on an Alberta-wide basis and certainly not on the basis of demand and need in Northern Alberta at this time. It is likely that the training developed will need to be "sponsored" by one or a small number of organizations and developed in such a manner so that the content can be distributed to others.

Furthermore, as discussed in Chapter 3, there are still no formal and specific standards for training requirements and there is no consensus as to the form of delivery for some training programs.

Some of the specific skills required for the types of jobs most likely for community college graduates in Alberta are discussed in Chapter 3 and the requirements for other jobs associated with the industry are discussed in the report "*"Renewable Energy Industry - Situation Analysis of the Knowledge, Competencies, and Skill Requirements of Jobs in Renewable Energy Technologies in Canada".*

Conclusions and Recommendations

At this juncture, there is no strong evidence of demand for wind power training that would justify development of "stand-alone" programs by Clearinghouse members to serve Northern Alberta. As such, it is recommended that Clearinghouse members:

1. **Start to develop more formal arrangements with industry and other associations and Canadian educational institutes to foster better networks for sharing of information, explore programs in other countries, raise awareness, ascertain needs, and explore how existing programs and curriculums might be modified or adapted to be suitable for a broader audience.**

   Stakeholders might include the wind energy companies in Alberta, Canadian Wind Energy Association, the Association of Canadian Community Colleges and government departments such as Natural Resources Canada.

   In terms of programs in other countries, the North American Wind Research and Training Center (NAWRTC) being developed at Mesalands Community College in Tucumcari, New Mexico might be a useful model. It is being developed in collaboration with Tucumcari Economic Development Corporation, New Mexico Economic Development Department, New Mexico Energy, Minerals, and Natural Resources Department, Sandia National Laboratories, Coalition for Clean Affordable Energy, Regional Development Corporation, and New Mexico State University to train wind energy technicians and wind farm managers, highlight the potential for wind power as a source of renewable, non-polluting energy, and provide a location for applied research.

   The NAWRTC will focus on training the two primary levels of technicians that are regularly employed on modern wind farms. The NAWRTC will develop a curriculum for the Operations and Maintenance technician that will focus primarily on maintenance and safety issues, as well as a curriculum for Wind Farm Management, which will emphasize power electronics, grid interface, etc. The latter will be a two-year Associate Degree course. The research component will be developed in partnership with National Renewable Energy Laboratory, Sandia National Laboratories, and New Mexico State University, as well as other public and commercial research concerns that will focus on wind energy storage technologies, as well as but not limited to operations and maintenance efficiencies.

2. **Monitor developments in the Dawson Creek region (Bear Mountain Wind Farm) for possible impact on the large turbine industry in Northern Alberta.**

The Dawson Creek region is s similar to portions of the "Peace Country" and similar qualities and characteristics conducive to the development of the large scale wind turbine industry may be present.

3. **Stay abreast of research and development initiatives such as the new small wind turbine technology being developed by the University of Alberta in order to ascertain the potential impact on use in more northern and remote locations.**

Potential technological break-throughs may provide the necessary impetus for the expansion of the small-scale wind turbine market.

Small-Scale Hydro

Overview of Findings

While small-scale hydro is utilized extensively in developing parts of the world an is a significant part of the energy baskets of other provinces such as British Columbia, Ontario, Quebec and New Brunswick, it has a relatively limited use in Alberta with most facilities in the southern portion of the province and tending to be associated with irrigation works. At present, projects that fit the "small-scale" definition of less than 30 MW account for 102 MW of the 844 MW hydroelectric capacity in Alberta. Hydro-electricity is not a major component of Alberta's "energy basket" and accounts for less than 8% of the total electrical generating capacity of approximately 11,500 MW.

Conclusions and Recommendations

While there is potential for an additional 185 MW of power development in Alberta that could be considered small-scale, only 29 MW is located in the northern regions of the province. The increased operations and maintenance staffing requirements associated with the potential northern projects is approximately six man-years. It is doubtful that special stand alone programs could be justified for such as small base.

The potential "Dunvegan" project with a proposed capacity of 100 MW is well in excess of the generally accepted "small-scale limit" of 30 MW and should be considered a "conventional" size project, even though it is proposed to have a "run of the river" design. If it were to proceed, the additional operating and maintenance staffing requirements would be in the order of 22 man =-years.

Given the above, it is recommended that:

1. **No significant efforts are placed by Clearinghouse stakeholders toward the development of small-scale hydro training at this time.**
2. **Clearinghouse stakeholders take steps to expand contacts to share information and stay apprised of developments within the industry in the event that circumstances within Alberta change.**

Fuel Cells

Overview of Findings

On a world-wide basis, expenditures related to fuel cells are expected to double to $US 10.8 billion between 2005 and 2009.

Use of stationary and portable units for the generation of electrical power is expected to be one of the largest commercial markets over the next 10 years.
The Canadian industry is relatively small and in 2004 consisted of approximately 1,800 employees and less than 20 companies with the principal focus of fuel cell development or systems integration. Most employees had post-secondary educational training at the university level. The revenues of Canadian companies in 2004 were approximately $244 million.

The Canadian industry is still very much in the research and development phase in many aspects, and as such, it is likely to be several years before there is a larger "trickle down" effect to the community college level. However, Chris Curtis, Vice President of Fuel Cells Canada, an industry support and advocacy organization, has indicated that it may be timely and appropriate for industry to begin to forge links at the community college level to facilitate the development of curriculum for several years hence and would welcome the opportunity to become involved.

Conclusions and Recommendations

1. **At this time, there are no specific recommendations regarding the development of curriculum and training materials for fuel cells at the community college level.**

   The industry is still in a "research and development" phase and few tangible examples exist of wide-scale application of the technology, primarily due to cost and technical barrier issues and the lack of other infrastructure such as hydrogen fueling stations.

2. **Notwithstanding, recommendation "1", it is recommended that clearinghouse stakeholders, most likely in conjunction with other colleges and the Association of Canadian Community Colleges, begin to forge networks and contacts with the fuel cell industry and other educational institutions.**

   Such steps will be of great benefit in helping with the flow of information for planning purposes, including curriculum design and garnering industry cooperation and in-kind support.

   Some of the programs and developments associated with colleges and universities in the United States and organizations such as Heliocentris Energy Systems in Canada, may afford useful models and insights for Canadian and Northern Alberta interests.

Earth Energy (Ground Source Heat Pumps)

Overview of Findings

On a global basis, there are an estimated 2 million ground source heat pumps. In Canada, there are an estimated 30,000 installations with some indications of federal government objectives of increasing the amount by a further 25,000. Clearly, additional efforts and training may be required to achieve the target.

On a life-cycle basis, earth energy systems are more efficient and less expensive than other "combustion" systems; however, up-front costs are higher and the general public does not understand the technology, and other impediments are lack of harmonization of standards and inefficient infrastructure.

The industry, in conjunction with the Association of Canadian Community Colleges appears to be taking step to address concerns through the development of a new training program. Details of some of the needs are outlined in Chapter 6.

The size of the industry at present, will likely dictate that the training be delivered by distance methods or via "traveling Instructors".

Conclusions and Recommendations

It is highly unlikely that there is the critical mass of demand in Northern Alberta required to justify the development of stand-alone training programs by Clearinghouse stakeholders. As such , it is recommended that Clearinghouse stakeholders monitor developments with respect to the new training being developed, expand networks with industry and other prospective trainers and attempt to act in a "facilitator" role. This might include providing space for training programs or infrastructure for remote learning modes when there is sufficient interest to justify a program in a location, assistance in providing space for administering exams, or in the provision of career or occupational information for those considering the field.

Cogeneration and Use of Wood Waste

Overview of Findings

Cogeneration is a well-established technology that results in significantly improved utilization of energy resources to produce both power and heat. As such, it is rapidly gaining broader acceptance and being integrated into the design of power plants. Approximately 1,500 MW of new cogeneration capacity will be added to Northern Alberta over the next three to four years, mostly associated with oilsands development. Cogeneration plants can be designed to operate on a variety of fuels ranging from biomass and biogas, through to natural gas, hydrogen and nuclear power. The precise systems and technologies used depend upon specific circumstances and all have potential advantages and disadvantages.

Most employment opportunities for community college graduates will be associated with the operation and maintenance of cogeneration power plants. Basic cogeneration is covered in existing advanced level Power Engineering curriculums at technical institutes in Alberta; however, cogeneration might best be thought of as an array of skills and technologies that can vary according to the unique circumstances and fuels available to power plants. As such, from time to time, special refresher or upgrading training may be required. In addition, there is the possibility that training in cogeneration may be of benefit to others such as municipal planners, regulatory officials and others engaged in aspects of commerce.

The exact impact on the demand for Power Engineers (that may be as a result of the expansion of the cogeneration plant capacity is not known at this time; however, the Athabasca Regional Issues Working Group may be able to provide insights in the near future. Consultation with new cogeneration plant owners and operators may also be of benefit in assessing specific training needs and potential roles for Clearinghouse colleges.

The use of wood waste as a feedstock for power generation is long in existence with most of such plants being associated with or in close proximity to forestry or pulp and paper industries.

The operation of wood waste power plants does not require extensive detailed or specialized training beyond that covered in the existing Power Engineering programs in Alberta. The proportion of Alberta's power generating capacity associated with biomass is very small (178 MW or approximately 1.6% of the total capacity of approximately 11,477 MW) and is associated with three facilities located in Boyle, Grande Prairie and Drayton Valley. Over the foreseeable future only an additional 15 MW of biomass related power generation will be added in Alberta and no capacity will be located in Northern Alberta.

Conclusions and Recommendations

Cogeneration

Cogeneration will be of increasing importance in Northern Alberta's energy supply; however, it is not a "stand-alone trade" but more like a combination of skills and technologies for which the basics are covered in existing Power Engineering programs at more advanced levels. As such, the following recommendations are made:

1. **Clearinghouse colleges should consult with the Athabasca Regional Issues Working Group, and if warranted, other technical institutes and owners/operators of new cogeneration power plants to better ascertain the number of trained staff that may be required and any specific or new training that might be beneficial.**

   The roles and objectives in this instance are likely to explore how increases to the basis supply of Power Engineers might be achieved and how colleges might assist with the provision of other shorter-term and specialized training that might be required.

2. **Clearinghouse colleges should consider roles that they might play in coordinating efforts for cogeneration training for individuals such as municipal planners, regulators or contractors.**

   It is more likely that this will be a longer process that will require involvement from a variety of interests and, due to the "critical mass" required, will need to be "championed" by a specific group or organization with resources greater than those available to the Clearinghouse colleges.

Wood Waste

Use of wood waste to generate power does not require any specialized or new skills and will not be a significant factor in Northern Alberta's future energy supply. As such, the area or field should be low priority in terms of the efforts of Clearinghouse colleges.

Renewable Liquid Fuels (Ethanol and Biodiesel)

Overview of Findings

Ethanol

Most of the limited manufacture of ethanol in Canada is from wheat in the west and corn in the east; however, new production technology has the potential to utilize wood, agricultural crops and a variety of waste products. Use of wood waste materials should help to reduce the manufacturing cost associated with ethanol.

The five leading nations and regions of the world produced 33 billion litres of ethanol in 2004; by comparison, Canadian production was 240 million litres. Through the Ethanol Expansion Program, the federal government has placed a significant priority on expanding the Canadian ethanol industry and a production target of 1.33 billion litres by 2010 has been set. To achieve this target, Canada (as a net importer of corn and wheat) will need to place priority on increasing feedstocks.

While it contains less energy than gasoline per equivalent unit of measure, ethanol burns cleaner and, as such, has fewer “greenhouse gas” emission; however, the true advantage of ethanol is that the plant materials from which it is derived absorb greenhouse gases as they grow.

The ethanol industry in Canada is in an early stage; however, a large expansion of the industry can be expected to affect training and skills requirements in a variety of ways. One of the largest, outside of “commerce” applications, is in the way that feedstocks are developed and harvested for manufacturers.

The Alberta industry will still be relatively small with manufacturing facilities in Red Deer (20 million litres) and plants planned for High Level (20 million litres). The direct increase in employment associated with the High Level plant is likely in the order of 40 (bringing the provincial total to about 80); however, many jobs will be lower skilled.

Developments in the United States and educational curricula being developed may provide insights into the trends and needs soon to be faced by Canada.

Biodiesel

Although oily plants such as canola are the primary feedstocks for biodiesel, it is relatively easy to make and has the added benefit that food wastes such as greases and fats can be recovered for use as a feedstock.

The Canadian biodiesel industry is in the very early stages, and behind the stage of development in Europe. At present, there are only two production facilities in Canada (Hamilton and Montreal) with a combined capacity of approximately 90 million litres per year. However, the Canadian federal government has set a production target of 500 million litres by 2010.

In Alberta, up to 10 smaller biodiesel plants with a total capacity of 150 to 200 million litres per year are being considered. Most will be “kits” that will be relatively easy to assemble and operate without detailed or complex training.

Conclusions and Recommendations

While on a national basis, there is scope and opportunity for growth of the ethanol industry and development of strategies and programs at the provincial or national level, for the Northern Alberta shorter-term, despite the proposed plant in high level, the needs of the industry may be limited, and it may be difficult to justify the allocation of resources until issues, regulations and other players become clearer and lessons have been learned from studying progress in other nations. Several training programs and initiatives in the United States are highlighted in an earlier chapter.

For biodiesel, there are similar broader issues that are best dealt with in cooperation with others. most likely role for colleges over the short-term until the industry begins to take greater definition are to be in educating feedstock producers on opportunities and providing assistance to farmers and cooperatives in the manufacture of biodiesel. Both are considered to be suitable for shorter-term, continuing educational style delivery.

Based on the above, the following recommendation is made:

1. **That Clearinghouse stakeholders begin to consult with some of the contacts mentioned in earlier chapter to start to develop appropriate networks, forums and strategies to address longer-term issues.**

   It may be that the training needs of the renewable fuels industry in the medium term are addressed through participation in for example a "Western Canada Renewable Fuels Institute" or other bodies such as a consortium of the Association of Canadian Community Colleges, industry and organizations like the Canola Council or Renewable Fuels Association.

2. **Over the shorter-term, there may be some benefit to explore how Clearinghouse colleges might utilize other industry and provincial and federal resources to host open houses or short, "continuing education" courses to familiarize potential interested parties.**

3. **Over the shorter-term, there may be some benefit to exploring potential interest in course regarding the "small batch" production of biodiesel for farmers and cooperatives.**

Biogas (Anaerobic Digestion)

Overview of Findings

Interest in anaerobic digestion in the agricultural sector is increasing as a result a desire to reduce energy costs and handle agricultural wastes. Anaerobic digestion systems are best designed with an integrated approach to produce electricity and heat (in a cogeneration approach) as well as to handle waste (as required) and produce other desired by-products that have value such as fertilizer. In this regard, a more recent development within Alberta is the formation of an Alberta Biogas Association and an initial meeting in Red Deer for June 22.

Alberta is about to release a bioenergy policy that would call for the amount of electrical energy produced in the province to increase from approximately 2MW to 90 MW by 2012.

So far, the anaerobic digesters in existence in Alberta need to be considered as “experimental”. There have been a variety of problems in adapting existing technologies. To this point, the Integrated Manure Utilization System (IMUS) at the High Mark Renewables site in Vegreville and developed by the Alberta Research Council shows the best promise.

Germany is a leading nation in the use of biogas systems, and in this regard, the resources of the German Biogas Association (Dr. Claudio Gomez) may be very helpful for assessing the skills requirements and training needs of the Canadian and Alberta industries. Experience to date (with the Iron Creek project in particular) has shown the need to have proper operator training and maintenance.

Conclusions and Recommendations

While the industry will create a variety of skills requirements and training needs over the longer term, it is somewhat premature to be able to develop precise and meaningful forecasts. The proof and adoption of specific technologies and processes, and perhaps regulations, will help to clarify matters. In any event, such an assignment will likely be beyond the scope and resources of Clearinghouse colleges on their own.

In the shorter term, there will likely be a need for training that will help potential operators, government, municipal and county planners, lending institutes and contractors to better understand the process, benefits and issues. There will also be a need for operator training, although it might be more appropriate for systems designers and developers to take the lead in this regard

Based on the above, the following recommendation is made:

1. **Clearinghouse colleges should begin to work with stakeholders in the scientific and demonstration field to make contacts and gain a better appreciation of developments and needs of the industry.**

   This process might start with attending the June 22 Alberta Biogas Association meeting. Goals will be to develop shorter-term steps that are actionable by Clearinghouse colleges (perhaps such as facilitating shorter informational sessions; but also to begin to develop a framework, strategy and schedule to address some of the longer-term skills and training needs as the industry unfolds.

   Due to the limited resources of Clearinghouse colleges, the longer-term needs will likely best be addressed through cooperation with institutes and bodies at the provincial and national levels.

Solar Power (Photovoltaic and Thermal)

Overview of Findings

While solar photovoltaic power is the renewable energy form with the highest growth rate and led by countries such as Germany and Japan, the technology is not widespread in Canada do to its high cost compared to other energy forms and unsuitability for applications, such as heating, that require higher intensity forms of energy. Most applications are for recreational situations or in more remote locations where costs of traditional energy are very high. The industry has suffered as a result of poor quality of work and inadequate training; however, needs to come to terms with developing certification standards and agreement on delivery of training programs.

The solar thermal industry encompasses many trades and technologies and it is difficult to provide an estimate of size in Canada. The portion that is readily identifiable is growing rapidly; however, at approximately $7.5 million is very small. There is also considered to be a need for standards within this sector of the industry; however, the priority over the next two to three years will be on solar photovoltaic.

There are an estimated 625 to 1,000 jobs in the Canadian solar Photovoltaic industry (although many are with smaller companies where solar photovoltaic is not the sole focus) and less than 200 in the direct solar thermal industry.

Conclusions and Recommendations

While there is potential significant long-term growth in the solar industry if costs become more competitive, the Canadian industry is still small and in a need to resolve a variety of issues associated with standards and delivery of educational programs. At the present time, the size of the industry does not justify the allocation of resources to develop more generalized training programs. However, shorter-term continuing education style programs that have been delivered in the past have been well attended, according to available sources.

Given the above, the following recommendations are made:

1. **The primary activities of Clearinghouse members are focused on extending networks with other stakeholders such as CANSIA during the period of reassessment of standards and training requirements**.

   In this regard, Clearinghouse colleges will be best positioned to define their potential roles at the appropriate time.

2. **If resources allow, it may be warranted to explore the facilitation of a shorter “continuing education” style course pertaining to solar photovoltaics. The target audience may be recreational users but also primary industry clients operating in more remote locations.**

   Institutions such as BCIT have experience in this regard and may be best positioned to determine the most appropriate content, if warranted. However, the following content may be appropriate: Principle of Photovoltaic lighting system, Solar Array, Battery Bank, Electronic Controller, Inventor, Solar photovoltaic street lighting system, Maintenance of Battery, Cleanliness, Adding water, Kind of water, Discharge limits, Hydometer readings -

Specific gravity, Full charge specific gravity, Readings - Written records, Trouble shooting, Basics of Lead-Acid Batteries, Discharge limits of Lead-Acid batteries, Solar photovoltaic pumping systems.

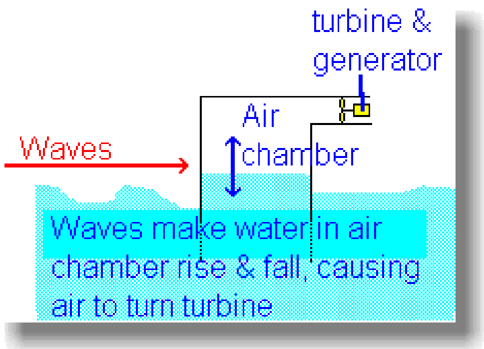
Appendix 1
Other Renewable and Alternative Sources of Power

To add perspective to the study, this chapter provides a very brief discussion of other alternative energy sources: Wave; Tidal: Geothermal; and Nuclear. The first three are not well suited to Northern Alberta due to geological characteristics. The fourth, Nuclear, is mentioned because of some more recent consideration of using the energy form to exploit the Athabasca oilsands.

I. Wave Power

Ocean waves are caused by the wind as it blows across the sea. Waves are a powerful source of energy. There are several methods of getting energy from waves, but one of the most effective works like a swimming pool wave machine in reverse. At a swimming pool, air is blown in and out of a chamber beside the pool, which makes the water outside bob up and down, causing waves. At a wave power station, the waves arriving cause the water in the chamber to rise and fall, which means that air is forced in and out of the hole in the top of the chamber. A turbine is placed in the hole and the air rushing in and out drives a generator to produce electricity. The process is depicted in the following graphic.

PRODUCTION OF POWER FROM WAVE ENERGY



Advantages and Disadvantages

Advantages

- The energy is free - no fuel needed, no waste produced.
- Not expensive to operate and maintain.
- Can produce a great deal of energy.

Disadvantages

- Depends on the waves - sometimes you'll get loads of energy, sometimes nothing.
- Needs a suitable site, where waves are consistently strong.
- Some designs are noisy (with air rushing in) unless fitted with a “silencer”.
- Must be able to withstand very rough weather.

II. Tidal Power

The ebb and flow of the tides, as a result of the gravitational attraction of the moon and sun [1] can be used as a source of energy. The moon has the greater effect on Earth despite having less mass than the sun because (accounting for mass) it is much closer. The gravitational force of the moon causes the oceans to bulge along an axis pointing directly at the moon. The rotation of the earth causes the rise and fall of the tides. The rotational period of the moon is around 4 weeks, while one rotation of the earth takes 24 hours; this results in a tidal cycle of around 12.5 hours.

The technology involved to harness tidal power is very similar to wind energy[2], but there are some differences. Water is 800 times denser than air and has a much slower flow-rate; this means that the turbine experiences much larger forces and moments. This results in turbines with much smaller diameters. The turbines must either be able to generate power on both ebbs of the tide or be able to withstand the structural strain.

The energy to turn turbines from tides can be captured through: harnessing **tidal streams** (fast flowing volumes of water caused by the motion of the tide that usually occur in shallow a sea where a natural constriction exists which forces the water to speed up); or through the construction of **tidal barrages** (similar to dams).

Tidal Streams

Energy can be captured from tidal streams using two methods, **Tidal fences** and **Tidal turbines**.

- ***Tidal Fences*** - These are effectively another form of tidal barrage. They therefore share some of the same environmental and social concerns, but also have the advantage of being able to have the electrical generators and transformers above the water.

- ***Tidal Turbines -*** This form of generation has many advantages over its other tidal energy rivals. The turbines are submerged in the water and are therefore out of sight. They don't pose a problem for navigation and shipping and require the use of much less material in construction. They are also less harmful to the environment.

Tidal Barrages

A dam (called a "barrage") is built across a river estuary. When the tide goes in and out, the water flows through tunnels in the dam.

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[1] When the sun and moon are in line their gravitational attraction on the earth combine and cause a "spring" tide. When they are as positioned in the first diagram above, 90° from each other, their gravitational attraction each pulls water in different directions, causing a "neap" tide.

[2] Tidal mills were built in the eighteenth century when their major competition were windmills and water wheels but declined in popularity with the advent of cheaper steam engines.

The energy potential of tidal basins is large — the largest facility, the La Rance station in France, generates 240 megawatts of power. France is the only country that successfully uses this power source.[3]

Advantages and Disadvantages

Advantages

- Once infrastructure is installed, tidal power is free.
- No greenhouse gases or other wastes are produced.
- Requires no fuel.
- Produces electricity reliably.
- Not expensive to maintain.
- Tides are totally predictable.
- Offshore turbines and vertical-axis turbines are not extremely expensive to build and do not have a large environmental impact.
- Even though tidal stream systems often need to be installed in difficult coastal waters and the installation and maintenance methods are often complicated, the technology has the advantage over tidal barrages when environmental and ecological issues are considered. This technology is also less intrusive than on and offshore wind, and tidal barrages.

Disadvantages

- A barrage across an estuary is very expensive to build, and affects a very wide area - the environment is changed for many miles upstream and downstream. Many birds rely on the tide uncovering the mud flats so that they can feed.
- There are few suitable sites for tidal barrages: an increase of at least 16 feet between low tide to high tide is needed, and on this basis, only around 20 sites in the world have been identified as possible tidal power stations.
- Only provides power for around 10 hours each day, when the tide is actually moving in or out.
- Barrages can trap sewage and other wastes that tides would normally “flush”.

III. Geothermal Power

Geothermal energy uses steam or hot water in the earth's crust to power turbines or to heat buildings or water. The earth's crust contains a large amount of energy. Geothermal energy requires a source temperature of more than 100°C to drive a generating turbine. The most suitable areas for exploiting geothermal power have strong tectonic activity, movements of the Earth's plates that produce heat, bringing underground water temperatures as high as 350°C. By drilling into these aquifers, the heated water and steam can be brought to the surface and used to drive turbines. Ideally, the water is re-injected into the ground, preserving the pressure and the ability of the aquifer to generate power. On the temperature scale, geothermal resources are classified into:

[3] http://inventors.about.com/library/inventors/bltidalplants.htm

- High-temperature (higher than 150 C)
- Medium-temperature (lower than 150 C but higher than 90 C)
- Low-temperature (less than 90 C)

First developed at the end of the 19th century, geothermal technology is currently used in about 30 countries, and generates close to 9,000 MW of electricity annually. The World Energy Council estimates global geothermal power potential at about 64,400 MW using current technologies. Still, the method only accounts for a miniscule percentage of total electricity used worldwide. (In comparison, large hydro and nuclear plants together have a worldwide capacity of one million megawatts.) The U.S. is the largest producer of geothermal power, generating about 2,800 MW in 2003, but that figure amounts to only 0.4% of the country's total electrical generation, and 20% of its renewable non-hydro power. The Philippines, which produced almost 1,900 MW geothermally in 2003, is the country most dependent on the technology. It generates a quarter of its electrical output from geothermal sources. Geothermal has a much smaller profile in Canada because the number of suitable locations is relatively limited.

High-grade resources are commonly associated with recent volcanic areas (such as the west coast of British Columbia). This type of resource can be commercially tapped for electric power generation such as being developed by Western GeoPower Corp. (TSXV: WGP) The company headquartered in Vancouver, is the only one with a project based in Canada. It's developing the geothermal resources at South Meager Creek, about 170 km north of Vancouver, which it believes has the potential to support plants generating 100 to 250 megawatts of electricity. The estimated cost would be more than $340 million for the first 100 MW plant. If successful, Meager Creek will be the first commercial geothermal generating plant in Canada. It remains to be proven if the plant can be viable on a commercial basis.

Advantages and Disadvantages

Advantages

- Geothermal energy does not produce any pollution, and does not contribute to the greenhouse effect.
- The power stations do not take up much room, so there is not much impact on the environment.
- No fuel is needed.
- Once you've built a geothermal power station, the energy is almost free. It may need a little energy to run a pump, but this can be taken from the energy being generated.

Disadvantages

- Sites with the required geological characteristics are limited in number in Canada and concentrated in British Columbia (and to a minor extent in Alberta) Sometimes a geothermal site may "run out of steam", perhaps for decades.
- Hazardous gases and minerals may come up from underground, and can be difficult to dispose of safely.

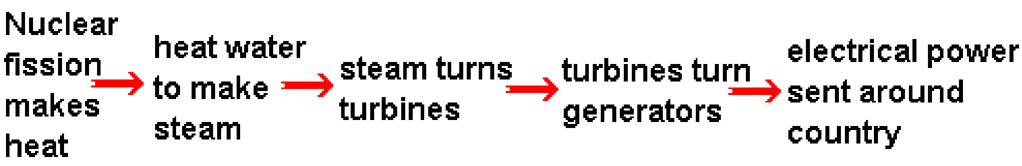
IV. Nuclear Power

The description borrows from the wikipedia web site.

Nuclear power is the controlled use of nuclear reactions to do useful work including propulsion, heat, and the generation of electricty. Nuclear energy is produced when a fissile material, such as uranium-235, is concentrated such that the natural rate of radioactive decay is accelerated in a controlled chain reaction and creates heat - which is used to boil water, produce steam, and drive a steam turbine.

The reactor is controlled with "control rods", made of boron, which absorb neutrons. When the rods are lowered into the reactor, they absorb more neutrons and the fission process slows down. To generate more power, the rods are raised and more neutrons can crash into uranium atoms. The process is depicted in the following graphic.

PRODUCTION OF ENERGY FROM NUCLEAR SOURCES



The first large-scale nuclear power station opened at Calder Hall in Cumbria, England, in 1956.

Advantages and Disadvantages

Advantages

- Power costs are comparable to those for coal.
- Smoke or carbon dioxide is not produced to contribute to the greenhouse effect.
- Large amounts of energy are produced from small amounts of fuel.
- Produces small amounts of waste.
- Nuclear power is reliable.

Disadvantages

- Although the waste produced is small, it is very dangerous and must be sealed up and buried for many years to allow the radioactivity to die away.
- Nuclear power is reliable, but if problems occur, there is large potential for disaster. Accordingly, the industry requires a considerable commitment to safety.

The Industry

In the 1990's nuclear power was the fastest-growing source of power in much of the world. In 2005 it was the second slowest growing. Concerns over safety have slowed the growth.

Nuclear power plants provide about 17 percent of the world's electricity. Some countries depend more on nuclear power for electricity than others. In France, for instance, about 75 percent of the electricity is generated from nuclear power, according to the International Atomic Energy Agency. In the United States, nuclear power supplies about 15 percent of the electricity overall, but some states get more power from nuclear plants than others. There are more than 400 nuclear power plants around the world, with more than 100 in the United States.[4]

In Canada nuclear power from 18 reactors contributes about 14%-15% of the total electricity supply. [5] Total Canadian nuclear electricity production was 74 TWh(e) in 1999 (a net total of about 1.5 million TWh(e) from June 1962 to December 1999.)

In the province of Ontario in 1997 about 48% of the electricity supply was nuclear (along with 27% hydro, 24% fossil, 1% "other"). The other two provinces with nuclear power, New Brunswick and Québec, receive about 21% and 3%, respectively, of their supply from nuclear. (source: *Electric Power in Canada 1997*, Natural Resources Canada)

The top level agency responsible for research and development, design, marketing, and project development is Atomic Energy of Canada Ltd. (AECL), a federal crown corporation established in 1952. In addition, over 150 private companies manufacture components or provide services for CANDU and research reactors. About a third of these companies belong to the Organization of CANDU Industries, representing the CANDU export industry. The industry as a whole is represented by the Canadian Nuclear Association. Either of these two groups can provide more information on their membership.

[4] http://people.howstuffworks.com/nuclear-power.htm
[5] http://www.nuclearfaq.ca/cnf_sectionC.htm#n

Appendix 2
Individuals and Organizations Contacted

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