BCS 312: Land and Environments of the Circumpolar North II

Module 1: Energy Resources

Developed by

Monique Haakensen, Ph.D., P.Biol. (Contango Strategies Ltd)

Sheri Praski, FEC, P.Eng.

Colleen Yates, M.Sc., MCIP

Overview

The Circumpolar North holds vast supplies energy in the form of non-renewable sources (mainly in the form oil and natural gas that exist underground and under the seabed and the potential for renewables) and also renewable sources such as solar, biomass, wind and water. However, only very little of the energy sources in the Circumpolar North are currently being utilized to produce energy.

Efforts are being made to access the non-renewable energy sources which have become more accessible as the polar ice caps recede and technological advances are made. More knowledge, research, and international cooperation will be required before these energy resources can be captured economically and sustainably.

A better understanding of the benefits of renewable energy sources and the continuing reduction in cost for renewables (and improved economics), as they become more commercially available, has increased the interest in the potential for renewable energy in the Circumpolar North. Small-scale renewable energy sources will continue to be developed in areas that cannot support the cost of large fossil-fuel based energy generation.

Learning Objectives

Upon completion of this module, you should be able to:

1. Describe exploration/extraction methods, transport, and utilization of oil, natural gas, and coal resources of the Circumpolar North.
2. Identify locations with large-scale hydropower developments and nuclear power generation in the Circumpolar North.
3. Assess the current and future prospects for the utilization of hybrid renewable energy systems in isolated northern environments.
4. Identify environmental concerns associated with energy resources and steps being taken to lessen these impacts in the future.

Required Readings (including web sites)

The list below can be used for required readings and supplementary resources.

Arctic Circle Website, Natural Resources, (Sustainability, Equity and Environmental Protection – Norman Chance); accessed June 25, 2012; http://arcticcircle.uconn.edu/NatResources/

Ground Truth Trekking, Arctic Coal, by Erin McKittrick, David Coil, Bretwood Higman,; accessed June 25, 2012; http://groundtruthtrekking.org/Issues/AlaskaCoal/WesternArcticCoalDeposits.html

BBC News World: Richard Galpin, BBC News Moscow, The Struggle for Arctic Riches, September 22, 2010; accessed June 25, 2912; http://www.bbc.co.uk/news/world-11381773

Nordic Solutions, Article written by Guri Nordgreen Romtveit, Article produced by Marie Loe Halvorsen 31.10.2011 Solar Power at the Arctic Circle; accessed June 25, 2012; http://www.nordicenergysolutions.org/inspirational/solar-power-at-the-arctic-circle

Key Terms and Concepts

- Biomass
- Casing
- Geophysical
- Hybrid Renewable Energy Systems (HRES)
- Hydropower
- Miscible flooding
- Outcrop
- Overburden
- Reclamation
- Seismic modelling
- Topography
- Thermal coal
- Tertiary recovery
- Wellbore
- Wellhead

Learning Material

Introduction

The Circumpolar North holds vast supplies energy. The majority of this energy currently being used is in the form of oil and natural gas, underground and under the seabed. There are also deposits of uranium and coal scattered throughout the circumpolar north. There are also renewable energy sources available such as solar, biomass, wind and water. However, very little of the total available energy is being utilized. More knowledge, research, and international cooperation is required before these energy resources can be captured economically and sustainably.

The melting ice coverage and permafrost in Circumpolar regions has made the potential of previously inaccessible oil and gas deposits becoming accessible and new technologies both for renewable and non-renewable energy forms continues to make Circumpolar resources more desirable. Ultimately, demand for energy will eventually make these resources economical. While there is a large amount of energy resources extracted from the circumpolar north, there are few large-scale energy facilities due to a dispersed human population. Because of the rural Arctic's sparse populations, long distances between settlements, and the lack of transportation infrastructure, the cost of power is a significant issue for residents. The cost of diesel-generated power is relatively high compared to other available energy forms, so residents in rural areas have been proactive in using alternative and renewable forms of fuel for power generation. The vast energy resources of the Circumpolar North also pose an environmental concern as resource exploration and extraction methods can have severe impacts.

1.1 Fossil Fuel Exploration, Extraction, Transport and Utilization

Coal

Coal is a complex mixture of organic compounds. Coal is composed primarily of hydrocarbons and small amounts of oxygen-, nitrogen-, and sulfur-containing compounds. The composition of coal varies with its type and the location of the deposit. Formation of coal deposits requires special conditions. Some forms include:

- Lignite (also called brown coal) may be no older than 2 million years;
- Bituminous coals (also called black coal) range from 100 to 300 million years;
- Anthracite coals (also called mineral coal) may be much older.

The carbon content of the coal also increases with age, with brown coal at approximately 25-35%, black coal 60-80% and anthracite 92-98% (Eberhard Lindner; Chemie für Ingenieure; Lindner Verlag Karlsruhe, S. Pg 258). Coal has been formed from the remains of land-dwelling plants that were deposited in swamps and covered rapidly enough so that there was little exposure to oxygen from the air. Biochemical and physical processes then transformed this plant debris into various types of coal.

Coal is a very important resource in some areas of the circumpolar North, for example, Alaska’s identified coal resources are an estimated 120-140 billion metric tons which is roughly half of the tonnage of this resource produced United States (United States Department of Energy Website, accessed June 24, 2012; http://www.netl.doe.gov/technologies/oil-gas/AEO/FossilEnergy/AlaskaCoal.html). However, due to the high operating and transportation costs, Alaskan coals have not been economic to develop even though they have the desirable environmental qualities of high moisture and low sulphur content. Alaska’s only operating coalmine is the Usibelli Mine near Healy.

Extraction

Surface geology and the amount of coal in the deposit generally determine the method of coal production that will be used. There are two primary methods currently used to extract this resource: where coal seams are close to the surface and generally not intersected by other materials, surface mining is used. Where the coal deposit is deeper, underground mining is used.

Surface Mining Techniques:

Topsoil must be cleared from the area and stockpiled for future reclamation. (Reclamation is the process of restoring the mine site to a more natural state after mining is complete).

Overburden is removed next, and is also stockpiled. (Overburden is the material between the top soil and the coal).

The coal is removed with power shovels or wheel excavators and moved by enormous dump trucks or high-capacity conveyor belts to where it will be processed or shipped.

As the production or mining area moves along the coal deposit, the area that has been mined is reclaimed by replacing overburden and soil from the areas currently being stripped of topsoil and overburden.

Generally, the land is shaped to its original topography and replanted.

With open pit mining, coal is produced from large excavations that are deepened and widened as mining progresses downward. In this instance, the overburden and topsoil continue to be stockpiled with the intent of filling with overburden, topping with topsoil, shaping and replanting to occur after all of the coal has been removed.

Surface mining techniques generally recover a greater amount of the coal deposit. Approximately 95% of Canada's coal is mined using surface techniques (Centre for Energy, accessed June 24, 2012; http://www.centreforenergy.com/Aboutenergy/Coal/Overview.asp?page=5).

Underground mining techniques (2 methods):

Room-and-pillar mining:
The room-and-pillar method cuts large rooms into the coal deposit leaving large pillars of coal to support the mine roof. This technique may leave up to half of the coal in place (although there is the potential to remove the pillars at a later date after some backfilling has occurred).

Longwall mining:
Longwall mining techniques utilize machines to cut and remove coal. The roof (overburden or material above the deposit) is held in place with supports. Once the coal is mined out, the machinery and supports are withdrawn and the roof is allowed to collapse.

Each technique has its advantages and disadvantages. Obviously, removal of coal by either technique will leave permanent deformations in the geology of the area.

Transport and Utilization

Coal is primarily burned as a fossil fuel for the production of electricity and/or heat, and is also used for industrial purposes such as refining metals. Coal is used for electrical generation all over the world. Only a small amount of coal is actually used within the Circumpolar North and thus coal extracted from Arctic regions must be transported long distances to its final destinations for use and is reliant on transportation systems..

Thermal coal, which is coal burned to generate the steam that drives turbines to generate electricity, is used by Canadian electric utilities. The majority of this coal comes from nearby operations, requiring little or no transportation. Exporting coal from Canada involves rail transportation and is generally long distances to other coal facilities.

Petroleum and Natural Gas

Petroleum and natural gas are known as fossil fuels because they were formed millions of years ago from dead, organic plant and animal matter. This matter, including microscopic plankton settled to the bottom of the bogs, lakes, and shallow seas that covered much of the planet. Over time, this matter mixed with and was covered by more layers of sediment, blocking oxygen and creating pressure and heat. Under these conditions, the matter slowly decomposed, forming oil and natural gas.

The bacteria responsible for the decomposition removed much of the oxygen, sulfur and nitrogen, leaving behind carbon and hydrogen, which is why petroleum is sometimes referred to as hydrocarbons. The type of petroleum created varies based on the original organic material, the amount of heat and pressure, the length of time the deposits were buried and the depth of the deposits.

Natural gas was created where temperatures and pressures were higher which resulted in gasifying the matter. Natural gas has a high methane content with small amounts of ethane, propane and butane. It burns almost completely during combustion so is considered less polluting than petroleum.

Over time, petroleum escaped to the surface through cracks or fissures in the earth's crust. Some deposits however were trapped under cap rock which is rock that was too dense to allow the petroleum and natural gas to escape. It is from under these cap rocks, or domes, that most petroleum and natural gas is produced. Some formations contain both natural gas and oil.

Petroleum and natural gas are considered non-renewable resources because they took millions of years to produce under conditions that no longer exist.

Mankind has used fossil fuels which escape naturally through fissures in the ground for thousands of years, it has only be drilled for and used commercially for less than 200 years, first for lighting and heating and then for fueling equipment and vehicles and more recently to produce plastics. It is now estimated than over 50% of the world's oil and natural gas deposits have been exhausted and the deposits which remain are more difficult to extract and process.

As the demand for fossil fuels continues to grow and easily accessible sources become exhausted, the price per barrel of oil and cubic meter of natural gas has been increasing. Because of this, sources that had not previously been considered economical to extract, now are. The most significant of these are the Canadian tar sands and shale oil. Both of these require strip mining and the use of a significant amount of water and other resources for extraction.

Exploration

Petroleum and natural gas were first discovered though natural escape from rock cracks. These findings were sometimes expanded through digging and later by drilling to increase flows.

With the advent of the industrial age and the greatly increased demand for fossil fuels, natural gas and petroleum sources have been actively sought out. Oil is generally found in sedimentary rock, within tiny pores. Scientists searching for oil use a variety of methods including:

- aerial and satellite surveys,
- magnetic fields surveys,
- gravity surveys,
- radiation surveys,

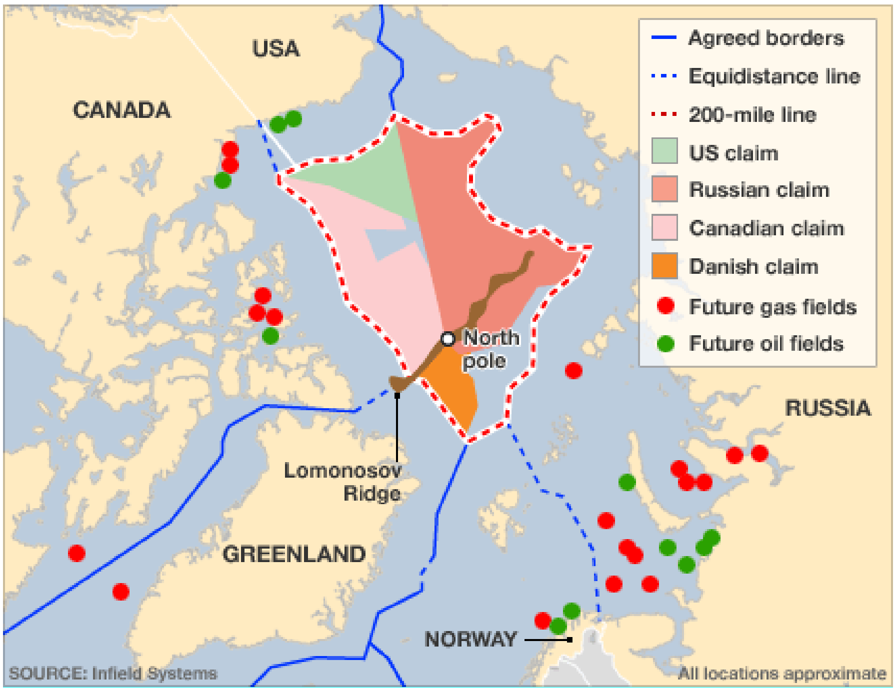
- outcrop surveys; and
- historic records to identify areas of potential oil-bearing rock.

Once potential sources have been identified, a seismic survey is usually conducted. A seismic survey involves sending sound waves through the earth and recording the way in which these waves bounce back after hitting different types of rock under the surface. Exploration companies know how oil-bearing rock bounces back sound waves so can evaluate the potential of a site. Seismic waves can be produced through a number of methods including setting off an explosive devise, utilizing a vibrating machine or, in the case of offshore exploration, through the use of large air guns.

In addition to seismic surveys, magnetic surveys are also commonly used. These involve sending an electric current through the earth. Water conducts electricity better than oil so by determining the conductivity of the sub-surface rock, the probability of it containing oil can be determined.

Once areas of high potential are identified, test holes are drilled using a drill that produces tubular cores of the subsurface material. Exploration companies then study these cores to determine if any of the rock is oil-bearing and if it is economically viable to develop.

The final major stage is to conduct well flow tests to determine the flow rate in barrels per day (bbls/d) of oil or thousands of cubic meters per day (Mcf/d) of natural gas. If it is determined that the well will be economically viable, it is developed for production. Below is a map showing future oil and gas fields in the circumpolar north, as well as the claim areas of some countries.



Source: BBC website http://www.bbc.co.uk/news/world-11381773)

Extraction

Both oil and natural gas are extracted through production wells. Once a well is drilled, a concrete casing or steel pipe is inserted into it and cemented in place. The casing prevents water and material from the sides of the well from entering it.

Production tubing is installed within the casing and connected to the wellhead on the surface. The wellhead contains equipment to control production rates.

The next step is to perforate the casing at the depth of the producing formation. Oil and/or gas can then seep into the well. Initially, flow rates are usually relatively high since the well releases pressure from the formation. In older or low producing wells, stimulation may be required to increase production levels. Stimulation involves pumping material such as acid, water, carbon dioxide or natural gas into the well to increase pressure and force the oil or gas to the surface.

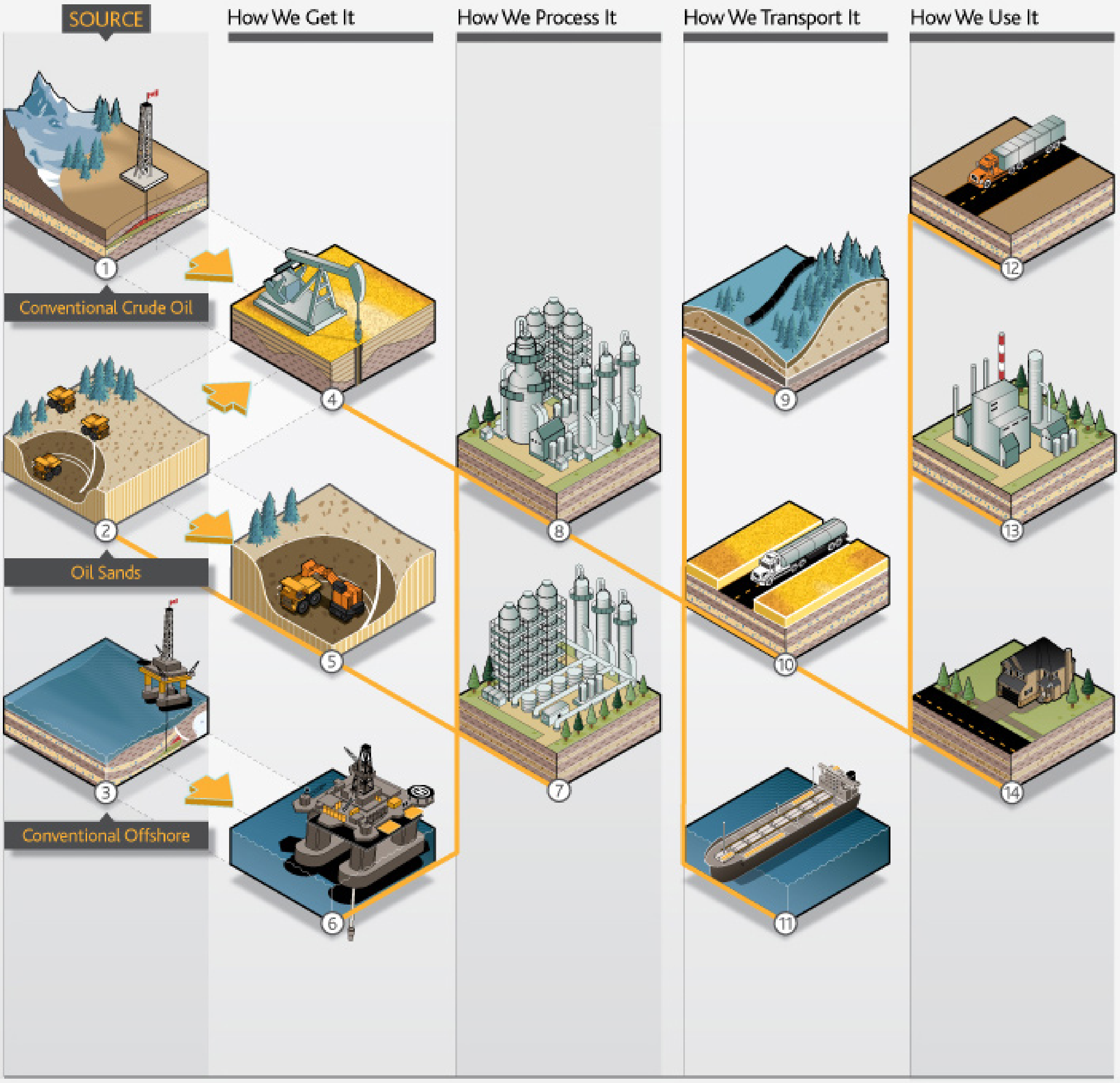
Traditionally wells have been installed vertically above a source. New technologies have allowed horizontal drilling along an oil-bearing formation to intersect more or the reservoir which enables increased flow rates.

When an economically viable oil or gas field is discovered, a series of wells is generally required for extraction. This is referred to as an oil field. Oil and/or gas from the individual wells is transported through a system of pipes to a battery. The battery is a tank or series of tanks that hold the oil. At the battery, initial cleanup occurs, including removal of water and impurities. From the battery, oil is transported by pipeline to a refinery for further processing, natural gas is flared if volumes are low or is transported by pipeline for further processing is volumes are high enough to make the transportation infrastructure economically viable. Water is disposed of in a separate well.

In addition to the environmental impacts from the burning of fossil fuels, there are many potential environmental concerns related to the extraction of fossil fuels including:

- potential for problems during drilling and casing that could result in fossil fuels being released onto surrounding lands or water systems;
- potential for spills from trucks or pipelines onto surrounding lands or water systems;
- environmental impacts on the land due to disturbance of sensitive permafrost from infrastructure; and
- impacts to wildlife from construction of wells, batteries, roads and/or pipelines.

Crude Oil



LEGEND

1. Conventional oil is found in deep, porous, sealed reservoirs in consolidated rock and is pumped to the surface using pump jacks
2. Oil sands consist of unconsolidated sand grains surrounded by a film of very heavy oil called bitumen
3. Offshore reservoirs are conventional reservoirs deep below the seabed
4. Oil sands deposits less than 75 metres deep can be mined with trucks and shovels
5. Deeper oil sands deposits require heating or dilution before the bitumen can be pumped to the surface using pump jacks like those used to recover conventional oil
6. Pumps on semi-submersible platforms bring the oil to surface and transfer it to tanker ships
7. Crude oil is refined into its component hydrocarbons
8. Conventional oil and upgraded bitumen are refined by distillation into their component hydrocarbons and further processing gives us gasoline, diesel, heavy fuel oil and lubricants
9. Pipelines are the safest, least expensive and most commonly used form of transportation
10. Tanker trucks are used primarily to take oil from the field to pipeline terminals
11. Ships transport oil across oceans
12. Transportation fuel for cars, trucks, trains, planes and ships
13. Fuel oil electricity generation
14. Raw materials for household products such as plastics, pharmaceuticals, synthetic fibres, paint, pesticides and fertilizers

YOU NEED TO KNOW

CANADA'S ENERGY MAP

174

Whether it's found in a conventional reservoir or in oil sands deposits, Canada has lots of it – 174 billion barrels of recoverable crude oil, third largest reserves in the world.

41

Crude oil accounts for about 41 per cent of Canadian primary energy production and petroleum products account for about 40 per cent of Canadian energy consumption.

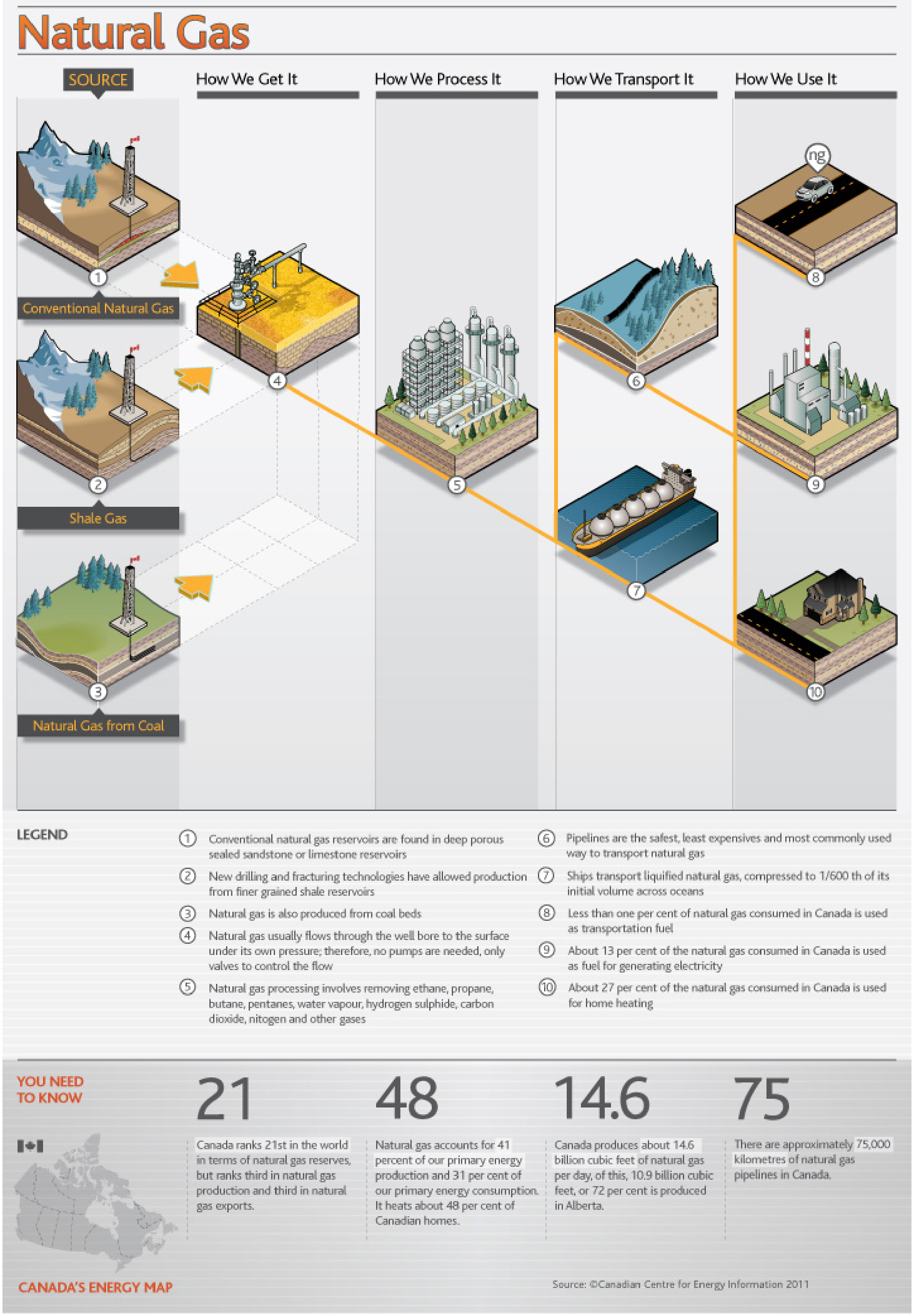
85

About 85 per cent of the crude oil refined in Canada is made into fuels for transportation, heating and generating electricity.

500

The oil and gas industry in Canada provides about 500,000 jobs for geologists, geophysicists, chemical engineers, construction workers, manufacturers, even accountants and lawyers.

Source: ©Canadian Centre for Energy Information 2011



Source: Canadian Centre for Energy Information, 2011.

In the case of natural gas, once the gas is brought to the surface, gathering systems bring it from individual wells to processing plants. Processed natural gas consists almost entirely of methane; however, natural gas in its unprocessed state consists of methane; natural gas liquids (NGLs) such as ethane, propane and butane; pentanes, water, hydrogen sulphide and other gases such as carbon dioxide and nitrogen. Most of these components are removed from the natural gas either at processing facilities at the gas field or at plants located along the pipeline systems. The hydrogen sulphide is extracted in the form of elemental sulphur and is used in the manufacture of fertilizers and other products. The NGLs are sold separately for use as diluent in heavy oil processing, as feedstock for petrochemical plants or as fuel.

Transport and Utilization

Much more oil and natural gas is produced in the circumpolar north than is needed by its inhabitants. Therefore, very little of the oil and natural gas from the Arctic gets used in the arctic. There are various methods for shipping, including truck, train and pipeline. All of these methods have issues related to availability and or construction of infrastructure for transportation to occur (roads, rail lines, pipelines).

One example of transporting large quantities of fossil fuels is the Alaska pipeline, which was built between 1974 and 1977. The pipeline takes oil 1,299 kilometers (800 miles) through Alaska to the shipping port of Valdez. Building the Alaska Pipeline posed many challenges – similar to those of any pipeline on permafrost. Oil in the pipeline must be kept above 60° Celsius (140° Fahrenheit) so that it flows easily. However, this means the oil would be warm enough to thaw the permafrost and cause the pipeline to sink and break. It was decided to build the pipeline above the ground in many places. Approximately half of the pipeline was built on thrermosyphon piles to keep the ground frozen below.

Although the pipeline addressed the transportation concern, it created other concerns including effects on habitat and potential breaks in the pipeline and potential repair costs. These concerns could be elevated due to melting permafrost and could become even more significant in the future. Very little of the natural gas produced in the Arctic is utilized locally. Typical uses of petroleum products in the circumpolar north include space heating and industrial process heat. Natural gas from circumpolar regions is generally transported through pipelines. Pipelines can vary in diameter and can range from thin plastic lines to steel conduits that are more than one meter in diameter. Natural gas is compressed by pumps as it enters the pipeline and can travel up to speeds of 40 kilometers per hour.

The simplest and most common method of refining petroleum into its various components involves a fractionating tower (or sometimes called fractionating column), which allows a mixture of different liquids to be separated from one another. Distillation in a fractionating tower separates crude petroleum into the fractions based on their boiling points. One of the more common petroleum-refining processes is hydrocracking. Hydrocracking involves adding hydrogen to “crack” apart carbon atoms in the hydrocarbon to produce desirable petroleum products, but this also produces smaller amounts of tar and other less- desirable compounds. An advantage of hydrocracking is that sulfur contained in the petroleum is converted through reaction to hydrogen sulfide. This allows for the sulfur to be captured in processing and not released when the petroleum product is burned.

1.2 Large-scale hydropower developments

Hydropower is electrical energy derived from falling or running water. The pressure from the water is used to turn the blades of a turbine. The turbine is connected to a generator, which converts the energy into electricity.

Hydroelectric power generation is used around the arctic. In fact, hydroelectricity is the main source of power in Sweden for well over fifty years and plays a major role in other Scandinavian countries. Hydroelectricity has played a major role in Sweden's bid to become the world's first oil-free economy (Government of Sweden’s website, accessed June 24, 2012; http://www.sweden.se/eng/Home/Society/Sustainability/Facts/Energy/). Hydroelectricity still plays a growing role in power generation, and new facilities are planned for development in Alaska and the Canadian North.

Concerns related to hydropower:

Although hydropower presents significant benefits of using a renewable resource, there are significant environmental concerns associated with the destruction of large areas of land associated with flooding for damming projects to create consistent water levels and flow rates.

Nuclear power generation

Nuclear marine propulsion is the propulsion of a ship by a nuclear reactor and has been in use since the 1940's. This form of power is now commonly used in marine vessels and ships, and is also commonly used in in arctic marine vessels. The use of nuclear power is of particular importance to marine vessels and ships used in the arctic as opportunities and locations for fueling can be scarce and separated by large distances. Additionally, because of its high power density and the elimination of the need for large fuel bunkers, a nuclear propulsion plant allows more space for paying cargo. Nuclear propulsion has proven both technically and economically feasible for nuclear powered icebreakers in the Soviet Arctic. These nuclear-fuelled ships operate for years without refueling and have powerful engines, making them well suited to the task of icebreaking. The world's first nuclear powered surface vessel was the Soviet icebreaker "Lenin" which came into commission in 1959 and remained in service for 30 years (with new reactors being fitted in 1970). Russia is also currently building 'floating' nuclear power plants for use in the Arctic as early as 2012 for powering oil and gas exploration facilities and likely other uses as exploration activity accelerates (The Guardian newspaper website, accessed June 24, 2012; http://www.guardian.co.uk/world/2009/may/03/russia-arctic-nuclear-power-stations).

While use of nuclear facilities in the circumpolar north has more commonly been associated with military activities and bases, several circumpolar nations use nuclear power as a source of electricity and its use and numbers of nuclear power generating facilities appears to be growing. Although located slightly south of the boundaries of the circumpolar north as defined by the University o the Arctic, nuclear power has been used since the 1960's in Scandinavia. For example, Sweden has been supplementing their hydroelectric production with nuclear power since 1965 to avoid volatility in oil prices. Sweden currently has three operational nuclear power plants, with ten nuclear reactors producing approximately 45% of the country's electricity (Government of Sweden's website, accessed June 24, 2012; http://www.sweden.se/eng/Home/Society/Sustainability/Facts/Energy/). Finland has been generating nuclear power since the 1970's (the Loviisa and Olkiluoto facilities), and has plans to build another nuclear power generating facility in the Northern community of Pyhajoki which is to be operational by 2020 (Reuters, "Finnish Fennovoima to build nuclear power polant", accessed June 24, 2012; http://af.reuters.com/article/metalsNews/idAFL5E7KL63X20111005?sp=true).

The United States also have a proposed nuclear power facility for their circumpolar state of Alaska. The Galena Nuclear Power Plant is a proposed nuclear power plant to be constructed in the Yukon River village of Galena in the U.S. state of Alaska. If built, it would be the first non-military nuclear power plant built in Alaska to be utilized for public utility generation. However, there is no certain date provided for the construction of the Galena power plant, it has been speculated by some that due to the low population density in Alaska, nuclear energy may not come to Alaska at all until a newer generation of small reactors reaches the market. The difficulty of implementing nuclear energy in Alaska isn't unique to that region. Nuclear energy doesn't make sense for many areas of the circumpolar North because the current gigawatt-sized reactors are too big for the population's power needs. However, smaller-scale modular reactors are approaching the permitting process and could prove to be very beneficial to remote communities. Because of its high power density (compared to other fuel sources such as oil, natural gas, or coal) small-scale nuclear power technologies could be ideal for remote northern communities where year-round access and transportation of goods is not possible.

Concerns related to nuclear energy:

There are varying concerns about nuclear energy including a high up-front cost for infrastructure, devastating affects when damage occurs to a reactor, issues related to storage of nuclear waste, cost and safety of mining and transportation and issues related to the production of nuclear weapons.

1.3 Hybrid renewable energy systems in isolated northern environments

Hybrid renewable energy systems (HRES) are slowly becoming a possibility for remote northern power generation due to advances in renewable energy technologies and the rise in prices of petroleum products. A hybrid energy system usually consists of two or more renewable energy sources used together to provide increased system efficiency. For example, solar and wind power system combined provides more hours per year of power supply than either system alone as it may be windy when it is not sunny and vice versa.

Concerns related to HRES:

More research and development is required to overcome the issues of extreme cold, lack of winter sunlight, and energy storage, before these systems become practical for widespread use.

Alternative Energy Sources

Alternative energy sources are generally non-fossil fuel based and are renewable.   Some of the more common, current alternative sources include biomass, wind, solar, and hydrogen.

Biomass

Biomass is biological material that can be used as a source of energy. Examples include wood, crop residues, plants, manure and sewage sludge. Like fossil fuels, biomass can be burned directly to provide energy in the form of heat and/or power. It can also be converted to methane (natural gas) and liquid fuels such as methanol and ethanol.

A wide variety of materials including, organic waste, manure and sewage sludge can be used to produce methane and other gaseous and liquid fuels through a process known as bioconversion. Bio-conversion involves using bacteria to digest the material in an anaerobic (oxygen-free) environment.   This process produces biogas, which is between 60 and 70% methane. Methane or natural gas can also be produces by gasifying coal and converting the gas to methane or by distilling wood

The type of biomass used is usually based on available local supply of material. A number of communities world wide, including some in the arctic and subarctic burn municipal solid waste (MSW) as a heat and energy source. It is considered biomass as it is typically comprised of about 40% paper. Obvious potential biomass sources in the arctic include wood and MSW.

Concerns related to biomass:

It is unlikely that all energy needs could be met with biomass; however, biomass can play a role in creating a use for waste products and in areas where other technology is expensive or non-existent.

Wind

Wind energy was one of the first renewable energy sources to be harnessed. From sailboats to windmills, wind energy has been used for centuries. Windmills were used to grind grain and pump water, both for water wells and drainage. Turbines are a form of windmill that uses the spinning action of the blades to generate electricity. Early turbines were usually small scale and used for local sites. With developments in power transmission technology, large, centralized power plants were built and the use of individual turbines declined.

With the increase awareness of the harmful effects of fossil fuel emissions and the knowledge that fossil fuel supplies will eventually run out, there has been renewed interest in wind power. Wind power is captured traditionally using large three bladed turbines (although other turbines are being developed) or a vertical turbine mounted on a tower approximately 80 meters above the ground. Towers can be individual or grouped into wind farms – some developments have several hundred turbines in areas with favourable wind conditions. Power is then fed either into a power grid system or stored in batteries. Ideally these sites will have steady winds and be in open areas where there are not a lot of obstacles (building or trees) that would create turbulence.

Many areas in the Arctic would have conditions favourable for wind farm development. In areas of the world with abundant coal supplies and well established grids, coal-fired plants appear more economical, however, this is not the case for much of the arctic, making wind a more economically viable option.

Disadvantages to wind power include:

- the need to store and/or supplement energy as wind is neither predictable nor matched with supply/demand throughout the day;
- turbines can also pose a danger to birds and bats, particularly if located along migration routes;
- shadow flicker, caused by the shadow of the blades can be an annoyance if turbines are located adjacent to developed areas.

Tidal

The regular, twice daily rise and fall of the tide can be harnessed to produce emission-free energy. This is achieved by constructing a dam across an inlet or small bay. The incoming tide turns turbine blades to generate power. When the tide goes out, the blades are reversed, creating a steady flow of energy. Effective tidal power generation requires a difference in elevation between low and high tide of at least 6 meters (20 feet). Tidal plants are currently operating in France, Korea, the former Soviet Union, Northern Ireland and Canada (Bay of Fundy and Vancouver Island).

Concerns related to tidal power:

- The infrastructure of tidal plants impacts the flora and fauna of the immediate area by impeding movement in and out of the inlet. The turbine blades may also injure or kill sea life

Solar

Solar energy can be utilized in two forms, electricity and heat.

Solar photovoltaic (PV): include panels that transform the sun’s radiation (photons) into electricity

Solar thermal: use the sun’s energy to heat water or other liquid and transfer that heat to water or air, usually using a heat exchange system.

Most PV panels contain silicone. The light activates the silicone molecules. Large silicone crystals are relatively difficult to produce however, which makes PV panels relatively expensive. Other materials including copper indium gallium selenide (CIGS) are now being used for PV panels. These materials are cheaper to produce and can be formed into thin, lightweight film. New materials plus the increased demand for PV panels continues to bring the cost down.

Solar panels can be grouped into solar "farms" to create large scale power and/or heat generation. These farms often have concentrator, which use reflectors to focus the sun's energy onto the panels.

Concerns related to solar energy:

- Solar energy has the potential to provide energy to arctic areas through the long summer daylight hours however, the low angle of the sun's rays and the dark winters hamper the effectiveness of this source.

Geothermal

Geothermal is a broad term used to describe energy derived from the naturally warmer area beneath the earth's surface. These systems use either fluid-filled pipes installed below ground, with pumps bringing the heated fluid to the surface or natural features such as hot springs or geysers, which bring heated water or steam to the surface. Through the use of a heat exchanger, the fluid or steam can be used for heat. Power can also be generated through geothermal systems in three ways.

Where geysers are present, the steam can be used to drive turbines directly.

In hot water systems, the heated water can be passed from a higher pressure vessel to a lower pressure one. The change in pressure creates a flash of steam that turns turbines.

Newer systems usually utilize a binary system because it can use lower temperature source water. In a binary system, heated water from the geothermal system is transferred, though a heat exchanger to another fluid, usually butane or pentane hydrocarbon with a low boiling point. This fluid then vaporizes and the steam is used to drive turbines.

Areas along tectonic plate boundaries are usually most suited for geothermal heat and power development, as the earth's crust is thinner and magma closer to the surface. The edge of the Pacific Ocean is a tectonic area, known as the Ring of Fire. Canada is the only major Ring of Fire country without geothermal development. Geothermal offers the advantage of a relatively steady, predictable energy source.

Concerns related to geothermal:

- Although virtually emission-free, geothermal energy does have environmental impacts. Water drawn up to the surface can contain carbon dioxide (CO_2) and methane (CH_4), which are greenhouse gasses as well as sulfur, which contributes to acid rain. Most plants re-inject the water, which helps mitigate these effects. Special care would also be required to protect permafrost from melting if geothermal were to be developed in the arctic.

Hydrogen

Hydrogen is one of the most abundant elements on the Earth and offers a realistic, long-term alternative to fossil fuels. It releases more energy that coal, natural gas or gasoline and can be used for heating, vehicle fuel and to generate electricity. It is clean burning and emissions combine with oxygen in the atmosphere to create water. It can be transported cost-effectively (with a low energy input) through pipelines.

Although not yet mainstream, there is proven technology that has shown certain metals absorb hydrogen, forming hydrides, which readily re-release hydrogen. Fuel cells also use hydrogen to produce power. Hydrogen within the fuel cell oxidizes when exposed to oxygen and this chemical reaction produces electricity.

Concerns related to hydrogen:

- The primary factor affecting the widespread adoption of hydrogen as a fuel source is supply. Although abundant, it is almost non-existent in free form, requiring it to split off from other compounds such as water, which contains two hydrogen and one oxygen atom. Splitting or cracking these compounds requires more energy than can be produced by the hydrogen. Currently hydrogen-based energy is used in applications such as spacecraft, where their lightweight and dependable energy counterbalance the energy input required. As other renewable energy sources such as solar, wind and tidal become more developed they can be utilized to produce hydrogen.

1.4 Environmental concerns associated with energy resources

When resource extraction began, few people thought about or recognized the negative environmental and socio-economic impacts of extracting and/or burning these fossil fuels. Now scientists and the public are becoming concerned about the long-term effects of development, particularly in sensitive area such as the arctic. These concerns include not only developments in the arctic, but also greenhouse gases and other pollutants affecting the atmosphere globally.

These impacts include:

- Human activity including mining operations and the associated transport systems have caused irreparable damage to permafrost.
- Pollutants including petroleum and other chemicals can devastate basic food sources at the bottom of the food chain, impacting all species in an area.
- Changes to the flora and fauna due to man-made factors can change the seasonal growth of many plant species. Animal species in these ecosystems, which have evolved migration patterns and calving periods that coincide with these plant cycles, can be negatively impacted by the changes in basic food sources.
- Climate change has been related to an increase in greenhouse gasses in our atmosphere from the burning of fossil fuels. Our climate is already changing, particularly in the Arctic where permafrost is melting, glaciers are receding, and sea ice is disappearing. As permafrost melts, there will be dramatic costs due to repair and replacement of infrastructure that was designed utilizing the local permafrost conditions.
- Offshore drilling, supertankers, and loading and unloading procedures at refineries have resulted in oil spills. Petroleum products are spilled into the ocean every year through loading and unloading onto cargo ships, pumping from under-ocean-floor oil deposits and accidents.

As well as environmental degradation issues, the northern resource extraction industry has had negative socio-economic impacts. Historically developments occurred with little or no regard to the indigenous people of the area and the impact on them and their lifestyle. In some instances there was a deliberate assimilation policy (which changed some cultures from a hunter gather subsistence base to a settlement base) and indigenous peoples have not shared in the wealth generated from the resource extraction industry. This has begun to change although there are still social issues in many northern communities.

Representatives of the eight arctic rim countries have attempted to develop an Arctic Environmental Protection Strategy. No specific strategy has been developed, however, it was agreed that all would cooperate in ensuring"...the protection of the Arctic environment and its sustainable and equitable development, while protecting the cultures of indigenous peoples." (Arctic Circle Website, Norman Chance, Sustainability, Equity and Environmental Protection; accessed June 25, 2012; http://arcticcircle.uconn.edu/NatResources/sustain.html)

In summary, although the impact of development on the human and ecological environment is recognized, the ongoing demand for raw materials, including oil and natural gas to fuel global industrial demand continues to drive the development of these resources. This demand will likely continue to grow as rapidly industrializing countries such as Brazil, Russia, India and China require raw materials and energy.

Conclusion

The Circumpolar North has rich deposits of many fossil fuels and also has the potential for generation of renewable energy. As demand increases for energy, new ways of extracting fossil fuels and new ways of generating clean energy are being developed – and as the demand increases, the price will rise which will make previously un-economical sources viable.

The circumpolar region needs to be aware of the advantages and disadvantages of every energy source – both renewable and non-renewable – and make decision based on this information. Our energy-hungry world will need energy from the circumpolar region. It will be up to the decision makers to ensure this delivery considers the economics, environment and social considerations of their actions.

Discussion Questions

1.What energy sources exist in your region (or a Circumpolar region of your choice)?

2. What energy sources are available that are considered renewable?

3.What are some of the concerns that are associated with non-renewable energy source?

Study Questions and Answers

Question: What are the available energy sources in the Arctic? Which ones are non-renewable? Which ones are renewable?

> Non-renewable include oil, gas, coal and uranium.
>
> Renewables include potential for wind, solar, geothermal and tidal.

Question: What challenges are related to energy sources from Circumpolar regions?

> There are significant costs related to transporting energy from the Circumpolar North to regions where it can be utilized. Costs linked to transportation can be prohibitive to development and extraction of raw materials such as coal, oil and natural gas as they must be shipped by tanker, train, truck or pipeline – this infrastructure often does not exist and must be considered as part of the cost of a development. The cost of transporting (vehicles, fuel, labour, etc) must also be considered.
>
> Other challenges include issues related to disruption of permafrost and associated damage, local cultures and local flora and fauna.

Question: What are some of the advantages of renewable energy? What are the challenges?

> Renewable energy includes all energy produced from naturally replenished sources including wind, sun and water.
>
> Renewable energy has the advantage of being renewable – it can be used for many years to come and is not consumed and depleted (as opposed to non-renewable which once used, no longer exists in a useable form).
>
> Renewable energy sources are considered 'clean energy' and thus do not produce greenhouse gasses which are associated with climate change.
>
> Challenges related to renewable energy currently include cost (although as more people switch to renewables, there are more producers and thus costs have been decreasing) and some of these forms are intermittent. Solar, for example, is only produced during daylight hours so it is not available during periods of darkness (and thus storage becomes an issue). Wind, is only produced when there is enough wind to turn the turbines and must be stored or have a backup power source.

Glossary of Terms

Biomass: any accumulation of biological materials

Casing: tubular steel pipe that lines the hole to prevent water and rock from entering the wellbore and to ensure control of the production

Geophysical: the study of the Earth using quantitative physical methods.

Hybrid Renewable Energy Systems (HRES): consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply.

Hydropower: electrical energy derived from falling or running water.

Miscible flooding: a process in which natural gas liquids such as ethane, propane and butane are injected into the reservoir to act as solvents that reduce surface tension and viscosity, making it easier for the oil to flow. Carbon dioxide has also been used in miscible flooding.

Outcrop: a visible exposure of rock.

Overburden: the material between the top soil and the coal seams

Reclamation: restoring land to its original natural form.

Seismic modelling: a way of modeling the earth's subsurface. The seismic method involves transmitting sound energy into the earth and recording the energy reflected back from subsurface geological boundaries.

Topography: the surface shape of the land.

Thermal coal: coal burned to generate the steam that drives turbines to generate electricity

Tertiary recovery: a technique used to recover oil from previously drilled wells

Wellbore: a hole drilled for the purpose of exploration or extraction of natural resources such as water, gas or oil where a well may be produced and a resource is extracted for a period.

Wellhead: the component at the surface of an oil or gas well that provides the structural and pressure-containing interface for the drilling and production equipment.

References

Arctic Circle Website, Natural Resources, (Sustainability, Equity and Environmental Protection – Norman Chance); accessed June 25, 2012; http://arcticcircle.uconn.edu/NatResources/

Ground Truth Trekking, Arctic Coal, by Erin McKittrick, David Coil, Bretwood Higman,; accessed June 25, 2012; http://groundtruthtrekking.org/Issues/AlaskaCoal/WesternArcticCoalDeposits.html

BBC News World: Richard Galpin, BBC News Moscow, The Struggle for Arctic Riches, September 22, 2010; accessed June 25, 2912; http://www.bbc.co.uk/news/world-11381773

Nordic Solutions, Article written by Guri Nordgreen Romtveit, Article produced by Marie Loe Halvorsen 31.10.2011 Solar Power at the Arctic Circle; accessed June 25, 2012; http://www.nordicenergysolutions.org/inspirational/solar-power-at-the-arctic-circle

Journal of Energy Security, May 2011, issue: Arctic Energy: Pathway to Conflict or Cooperation in the High North, written by Nong Hong; accessed June 25, 2012; http://www.ensec.org/index.php?option=com_content&view=article&id=310:arctic-energy-pathway-to-conflict-or-cooperation-in-the-high-north&catid=116:content0411&Itemid=375

Canadian Centre for Energy Information 2011, What is Oil?; accessed June 25, 2012; http://www.centreforenergy.com/AboutEnergy/ONG/Oil/Overview.asp?page=1

National Energy Technology Laboratory, The Arctic Energy Office, Alaska Coal http://www.netl.doe.gov/technologies/oil-gas/AEO/FossilEnergy/AlaskaCoal.html

Eberhard Lindner; Chemie für Ingenieure; Lindner Verlag Karlsruhe, S. pg. 258.

United States Department of Energy Website, accessed June 24, 2012; http://www.netl.doe.gov/technologies/oil-gas/AEO/FossilEnergy/AlaskaCoal.html

The Guardian newspaper website, accessed June 24, 2012; http://www.guardian.co.uk/world/2009/may/03/russia-arctic-nuclear-power-stations).

While use of nuclear facilities in the circumpolar north has more commonly been associated Centre for Energy, accessed June 24, 2012; http://www.centreforenergy.com/Aboutenergy/Coal/Overview.asp?page=5

Reuters; “Finnish Fennovoima to build nuclear plant in Pyhajoki» http://af.reuters.com/article/metalsNews/idAFL5E7KL63X20111005?sp=true

(Government of Sweden’s website, accessed June 24, 2012; http://www.sweden.se/eng/Home/Society/Sustainability/Facts/Energy/).

Supplementary Resources

Please see the required readings section for a list of potential supplementary resources.

Appendix

Learning Activities

Introduction

Engage students by getting them to think about your learning material and interact with their instructor and other students using student activities. Student activities should help students demonstrate for themselves that they are achieving the learning objectives set out for them.

Module authors are required to draft three to five activities for each module.

It is important that students know that the activities fulfill an educational role. Activities should prepare the student for learning the material, complement it, or connect the student's own reality to what is being taught. Students will not spend a lot of time on an activity that is not graded unless they see that it will help them learn the material.

Types of Learning Activities

Student Reflections

Use reflection activities to support the development of students' meta-cognitive skills. Examples:

Ask students whether the concept being discussed has affected their community, if so, how, and if not, why not.

At the end of the module, another activity could be asked of students to determine whether their ideas, opinions, or knowledge has changed; in other words, to demonstrate whether students have learned something.

Information Research

Information research is a skill students will use long after completing the course. Examples:

Ask students to find, online or through their libraries, or from members of their communities, some piece of information that is pertinent to the course. For example: "Research how much oil each of the Arctic Eight countries produced in 2000."

Ask students to evaluate information sources based on criteria selected by the instructor.