Lesson 7: **Nonrenewable Energy Resources**

17-1: Evaluating Energy Resources

What Types of Energy Do We Use? Supplementing Free Solar Capital

- 99% of the energy that heats the Earth and our homes comes from the sun
  - The remaining 1% comes mostly form burning fossil fuels
- Solar energy (solar capital) comes from the nuclear fusion of hydrogen atoms that make up the sun's mass
- *Indirect forms of renewable solar energy*: wind, falling and flowing water (hydropower) and biomass (sola energy converted to chemical energy stored in chemical bonds of organic compounds in trees and other plants)
- The remaining 1% of energy we use is *commercial energy*
  - It comes from extracting and burning *nonrenewable mineral resources* form the Earth's crust
  - Oil, natural gas, coal

What Types of Commercial Energy Does the World Depend On?

- 84% comes from nonrenewable energy resources
  - e.g.) Fossil fuels
- 14% comes from renewable energy resources
  - e.g.) Biomass, hydropower, geothermal, wind, and solar energy
  - Biomass energy is renewable as long as wood supplies are not harvested faster than they are replenished

Why Is the Energy Future of the United States Important to Canada?

- The future direction of U.S energy policy will have important environmental and economic consequences for Canada
- The need to use cleaner and less climate-disrupting (noncarbon) energy resources – not the depletion of fossil fuels – is the driving force behind the projected transition to a solar-hydrogen energy age in NA and throughout the world before the end of this century
- The reduction in U.S use of oil would have negative consequences for the production of oil from Alberta's oil sands
  - However, lower U.S oil consumption would benefit Canada as a whole by reducing both cross-border air pollution and global political tensions stemming from U.S over-dependence on the oil resources of the Middle East

How Can We Decide Which Energy Resources To Use (See questions on page 373)

What Is Net Energy?

- **Net energy** is the total amount of energy available from the resource minus the energy needed to find, extract, processes, and get it to consumers
  - It is calculated by estimating the total energy available from the resource over its lifetime minus the amount of energy *used* (first law of thermodynamics), *automatically wasted* (second law of thermodynamics), and *unnecessarily wasted* in finding, processing, concentrating, and transporting the useful energy to users
  - It can be expressed as a ratio of useful energy produced to the useful energy used to produce it
    - e.g.) 10/ 8 or 1.25

17-2: Oil

What Is Crude Oil, and How Is It Extracted and Processed?

- **Petroleum,** or **crude oil**, is a thick and gooey liquid consisting of hundreds of combustable hydrocarbons along with small amounts of sulphur, oxygen, and nitrogen impurities
- We have oil today because of three events:
  - The first occurred when sediments buried dead organic material raining down onto seafloors faster than it could decay
  - The next took place eons later when the seafloor sediments ended up with the right depth for pressure and heat to slowly "cook" or convert the buried organic material into *oil*
  - The third came about because the oil was able to collect in porous limestone or sandstone rock covered by an impermeable cap of shale or silt to keep it form escaping and thus making it and other fossil fuels part of the carbon cycle
    - Any change in this chain of events would have meant no oil
- The oil and natural gas which provides energy to heat our homes and run our cars is called *conventional oil*
- Deposits of crude oil and natural gas are trapped together under a dome deep within the Earth's crust on land or under the seafloor
  - The crude oil is dispersed in pores and cracks in underground rock formations
  - A well is drilled into the deposit to extract the oil
  - Then oil drawn by gravity out of the rock pores and into the bottom of the well is pumped to the surface
  - After it is extracted, it is transported to a *refinery* by pipeline, truck, or ship
  - Some products of oil distillation, **petrochemicals** are used as raw materials in manufacturing pesticides, medicines, plastics, synthetic fibres and paint

Who Has The World's Oil Supplies?

- The 12 countries that make up the Organization of the Petroleum Exporting Countries (OPEC) have at least 60% of the world's estimated crude oil reserves
- Members:
  - Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela
- Saudi Arabia has the largest proportion of the world's proven oil reserves (22%) followed by Canada (14%)

Case Study: How Much Oil Do Canada and the US Have?

- Canada's oil reserves are concentrated in Alberta
- Another area of high potential is the East Coast Hibernia oil field and the nearby White Rose and Terra Nova oilfields
- Canada ships 30% of its production to the US, keeping 70% for domestic use
- Canada has a surplus of natural gas

How Long Will Conventional Oil Supplies Last?

- Known and projected global oil reserves should last 42 – 93 years depending on how rapidly we use oil
- M. King Hubbert: "Hubbert's Peak" looked like a bell curve, predicting that oil production in the US would peak in the 1970s

Case Study: Why Has the Arctic Suddenly Gained World Attention?

- In recent years, the Arctic sea ice has melted to unprecedented levels, opening one of the world's least explored regions to oil and gas discovery

What Are the Major Advantages and Disadvantages of Conventional Oil?

- Conventional oil is versatile fuel and reserves can last up to 50 years, but burning it produces air pollution and releases the GHG carbon dioxide
- Advantages:
  - Ample supply for 42 – 93 years
  - Low cost (with huge subsidies)
  - High net energy yield
  - Easily transported
  - Low land use
  - Technology is well developed
  - Efficient distribution system
- Disadvantages:
  - Need to find substitute within 50 years
  - Artificially low prices encourages waste and discourages search for alternatives
  - Air pollution when burned
  - Releases CO2 when burned
  - Moderate water pollution

How Useful Are Heavy Oils from Oil Sand and Oil Shale?

- **Oil sand** or **tar sand** is a mixture of clay, sand, water, and bitumen (a combustable organic material – thick and sticky heavy oil with a high sulphur content)
- Oil sands near the surface are dug up and mixed with hot water and steam to extract the bitumen, which is heated in huge cookers to convert it into a low-sulphur synthetic crude oil suitable for refining
  - Heating the cookers requires vast amounts of natural gas that reduces the net energy yield for the oil
- When the oil sands are too deep for open-pit mining:
  - Cyclic steam stimulation involves softening the bitumen with steam and then extracting it
    - This method uses a vertical well to inject steam and extract bitumen
  - Steam-assisted gravity drainage involves two horizontal wells:

        - The upper well injects steam while the lower well extracts the condensed steam and softened bitumen
    - Vapour extraction uses solvents such as butane to dilute and extract the bitumen without the need for energy-expensive steam
    - Toe-to-heel air injection involves igniting bitumen underground in order to soften the surrounding bitumen enough to pump
- To date, the largest oil sands projects are operated by Syncrude and Suncor (surface mines)
- *Oil shales* are fine-grained sedimentary rocks containing a solid combustible mixture of hydrocarbons called *kerogen*
    - It can be distilled from crushed oil shale rock by heating it in a large container to yield **shale oil**
    - *See advantages and disadvantages page 384*

17-3: Natural Gas

What Is Natural Gas?

- In its underground gaseous state, **natural gas** is a mixture of methane, ethane, propane, butane and small amounts of hydrogen sulphide
- *Conventional natural gas* lies above most reservoirs of crude oil
    - Natural gas was formed from fossil deposits of phytoplankton and animals buried on the seafloor for millions of years and subjected to high temperatures and pressures
    - Deposits of natural gas found above oil deposits cannot be used
- *Unconventional natural gas* is found in other underground surfaces
    - One is *methane hydrate,* in which small bubbles of natural gas are trapped in ice crystals deep under the Arctic permafrost and beneath deep-ocean sediments
- When a natural gas field is tapped, propane and butane gases are liquefied and removed as **liquefied petroleum gas (LPG)**
- At a very low temperature natural gas can be converted to **liquefied natural gas (LNG)**
    - This highly flammable liquid can then be shipped in refrigerator tanks

How Is Natural Gas Used?

- Natural gas can be burned to heat space and water, generate electricity, and propel vehicles
- Increasingly, natural gas is used to run medium-sized turbines that produce electricity

Who Has the World's Natural Gas Supplies and How Long Will the Supplies Last?

- Russia and Iran have almost half of the world's reserves of conventional natural gas
- Global reserves should last 62 – 125 years
- They project that conventional and unconventional supplies of natural gas should last at least 200 years at the current consumption rate, and 80 years if the consumption rate rises 2% per year

What Is the Future of Natural Gas in Canada and the US?

- Natural gas production in the US is expected to continue declining, whereas Canadian production is expected to peak between 2020 and 2030
    - Then, Canada, the US and the rest of the world will have to rely on Russia and the Middle East for supplies of natural gas

17-4: Coal

What Is Coal, and How Is It Extracted?

- **Coal** is a solid fossil fuel formed in several stages as buried remains of land plants
  - It mostly contains carbon and small amounts of sulphur
  - Anthracite is the most desirable type of coal because of its high heat content and low sulphur content
    - However, it takes longer to form, is less common, and therefore more expensive
  - Coal is mostly used by power plants and industrial plants

How is Coal Used, and How Long Will Supplies Last?

- Coal is burned mostly to produce electricity and steel
- Reserves in US, Russia and China could last for hundreds of years
- Coal is the world's most abundant fossil fuels, but mining and burning it has a severe environmental impact on air, water, and land and accounts for a third of the world's CO2 emissions
- See advantages and disadvantages on page 387

What Are the Advantages and Disadvantages of Converting Solid Coal into Gaseous and Liquid Fuels?

- Solid coal can be converted into **synthetic natural gas (SNG)** by **coal gasification** or into a liquid fuel such as methanol or synthetic gasoline by **coal liquefaction**
- Without huge government subsidies, synthetic fuels play a minor role in energy resources
- To reduce CO2 emissions during the coal gasification process, researchers hope to develop metal-ceramic membranes that trap carbon dioxide gas
  - The CO2 could then be compressed and piped off to underground repositories or other permanent storage sites

17-5: Nuclear Energy

How Does Nuclear Fission Reactor Work?

- In a nuclear fission chain reaction, neutrons split the nuclei of atoms (uranium and plutonium) and release energy mostly as high temperature heat as a result of the chair reactions
  - The rate of fission is controlled and the heat generated is used to produce high-pressure steam, which spins turbines that generate electricity
  - Some reactors use water or graphite for a *moderator* to slow down the neutrons emitted during fission so the chain reaction can be sustained
  - Other reactors use water or carbon dioxide as a coolant to keep the reactor parts from melting and to produce steam to make electricity

What Went Wrong in Chernobyl?

- Operators made adjustments to disable the automatic shut-down mechanisms, which would have interfered with their experiment
- As the flow of coolant water decreased, there was a surge of power
  - The fuel elements ruptured and an explosion of steam blew the plate off the reactor
  - A second explosion threw burning fuel and graphite into the air
    - It burned for 9 – 10 days releasing large amounts of radioactivity into the environment
- Chernobyl is known as the largest nuclear power plant disaster

See Advantages/ Disadvantages of Conventional Nuclear Fuel Cycle and Coal vs. Nuclear on page 393

How Safe is High-Level Radioactive Waste Stored at Nuclear Power Plants?

- Spent fuel rods stored underwater in pools or in dry casks outside of the containment shells at nuclear plants are vulnerable to attack by terrorists
- A spent fuel rod holds 5 – 10 times more long-lived radioactivity than the radioactive core inside a plant's sector
- If water drains out of a spent-fuel poor or a dry storage cask ruptures:
  - Highly radioactive and thermally hot fuel would be exposed to air and steam
  - This would cause the zirconium outer cover of the fuel assemblies to catch fire and burn fiercely for days
  - This would release significant amounts of radioactive materials into the atmosphere and contaminate large areas for decades

How Do We Dispose of Low-Level Radioactive Waste?

- The nuclear fuel cycle and other nuclear facility processes produce low-level radioactive wastes that must be stored safely for 100 – 500 years before they decay to safe levels
- Such wastes include tools, building materials, clothing, glassware, and other items that have been contaminated by radioactivity
- The nuclear and other industries have produced 2.3 million cubic meters of low-level wastes in Canada
  - These waste materials are stored in specifically designed aboveground buildings while awaiting a more permanent disposal option
  - There are plans to build a deep-disposal site at the Bruce Nuclear Plant for low- and medium-level wastes

How do We Dispose of High-Level Radioactive Waste?

- There is a disagreement among scientists over methods for the long0term storage of high-level radioactive waste
- Some proposed methods:
  - Shoot it into space or into the sun
    - High cost and a launch accident could disperse high-level radioactive wastes over large areas of the Earth (like the Challenger)
  - Bury it under the Antarctic ice sheet or the Greenland ice cap
    - The long-term stability of the ice sheets is unknown
    - Heat could destabilize it
    - Prohibited by international law
  - Dump it into descending subduction zones deep in the ocean
    - Prohibited by international law
    - Could be spewed out by volcanic activity
    - Containers might leak and contaminate ocean before being carried downward
  - Bury it in thick deposits of mud on the deep-ocean floor in areas that tests show have been geologically stable for 65 million years
    - Containers would eventually corrode and release radioactive chemicals
    - Prohibited by international law
  - Change it into harmless, or less harmful, isotopes
    - No way exists to do this
  - Bury it deep underground
    - Most favoured
    - Issues: Where to locate site, how to transport, how to avoid long-term unforeseen problems, how to gain public acceptance

What Can We Do with Worn-Out Nuclear Plants?

- When a nuclear reactor reaches the end of its useful life we have to keep its highly radioactive materials form reaching the environment for thousands of years
- When a nuclear plant comes to the end of its useful life, it must be *decommissioned*
  - 3 proposals:
    - *Dismantle*
      - How can a nuclear plant be safely dismantled when the plant itself will be radioactive and every took used – even water in the cleanup – will become radioactive waste?
    - *Mothball*
      - Erecting a physical barrier and setting up full-time security for 30 to 100 years before the plant is dismantled
      - Allows time for radioactive material to decay
    - *Entombment*
      - Enclosing the entire plant in a concrete tomb that must last and be monitored for several thousand years

Lesson Eight: Renewable Energy

How Can We Use Direct Solar Energy to Heat Houses and Water?

- A **passive solar heating system** absorbs and stores heat from the sun directly within a structure
  - Energy efficient windows and attached greenhouses face the sun to collect solar energy by direct gain
  - Walls and floors of concrete, adobe, brick, stone, salt-treated timber and water in metal or plastic containers store the collected solar energy as heat and release it slowly through the day and night
- An **active solar heating system** absorbs energy from the sun by pumping a heat-absorbing fluid (water or anti-freeze) through special collectors usually mounted on a roof or on special racks to face the sun
- A typical active collector has a flat black surface, a coil through which a heat-absorbing medium such as water is pumped and a cover consisting of two or three layers of glass
- *Advantages of both:*
  - Energy is free
  - Quick installation
  - No CO2 emissions
- *Disadvantages of both:*
  - Need access to sun 60% of the time
  - Need heat storage system
  - Active collectors are unattractive

How Can We Use Solar Energy to Generate High-Temperature Heat and Electricity?

- Large arrays of solar collectors in sunny deserts can produce high-temperature heat to spin turbines and produce electricity, but costs are high
- Australia is building a power tower that will consist of a concrete thermal chimney twice the high of the world's largest building surrounded by a gigantic sloped solar greenhouse
- *Advantages of solar energy for high-temperature heat and electricity:*
  - Moderate net energy
  - No CO2 emissions
  - Fast construction
- *Disadvantages*
  - Low efficiency
  - High costs
  - High land use

How Can We Produce Electricity with Solar Cells?

- Solar energy can be converted directly into electrical energy by **photovoltaic (PV) cells** commonly called **solar cells**
- The semiconductor material used in solar cells can be made into lightweight paper-thin rigid or flexible sheets and incorporated into traditional-looking roofing materials
- British Petroleum (BP) began building the world's largest factory to produce windows and siding and roofing materials that will incorporate BP's power-producing solar cells
- With financing from the World Bank, India is installing solar-cell systems in 38,000 villages
- Zimbabwe is bringing solar electricity to 2 500 villages
- *Advantages of Solar Cells:*
  - High net energy
  - Work on cloudy days
  - Quick installation
- *Disadvantages*
  - Low efficiency
  - High costs
  - DC current must be converted to AC

How Can We Produce Electricity from Flowing Water?

- Solar energy evaporates water and deposits it as water and snow in other areas as part of the water cycle
- Water flowing from high elevations to lower elevations in rivers and streams can be controlled by dams and reservoirs and used to produce electricity
  - This is called *hydropower*
- Hydropower is a major emitter of greenhouse gases
  - This occurs because reservoirs that power dams can trap rotting vegetation, which can emit GHG such as carbon dioxide and methane
  - Small-scale hydropower projects eliminate most of the harmful environmental effects of large-scale projects
    - BUT electrical output varies with seasonal changes in stream flow
- *Advantages of Large-Scale Hydropower*
  - High efficiency
  - Long life span
  - Low-cost electricity
- *Disadvantages*
  - High construction costs
  - Danger of collapse
  - Uproots people

Wind Energy

- The greater heating of the Earth at the equator than at the poles and the Earth's rotation sets up flows of air called *wing*
- Wind can be captured by wind turbines and converted into electricity
- Wind power has increased more than tenfold and is the world's second fastest growing source of energy (after solar cells)
- Europe is leading the world into the age of wind energy and out of the age of coal and other fossil fuels
- Denmark has banned coal and gets 90% of its electricity from wing
- Wind power is also being developed in India and to a lesser degree in China
- In Canada, the most powerful and consistent winds are in the East and West coasts
    - 13 windmill farms have been built in the Maritimes
    - A good deal of wind potential exists in the Great Lakes region
        - Lake Huron
- Wind power developers now make sophisticated studies of bird migration paths to help them locate onshore and offshore wind parks and are designing new turbines to reduce this problem
- *Advantages of wind power*
    - High efficiency
    - Very low environmental impact
    - No CO_2 emissions
- *Disadvantages*
    - Visual pollution
    - Steady winds needed
    - High land for wind farm

Producing Energy from Biomass

- Biomass consists of plant materials and animal wastes that can be burned directly as a solid fuel or converted into gaseous or liquid **biofuels**
- Burning wood and manure for heating and cooking supplies about 10% of the world's energy and about 30% used in developing countries (90% in the poorest countries such as Bangladesh, Ethiopia, Burundi, and Bhutan)
- Ecologists argue that it makes more sense to use animal manure as fertilizer and crop residues to feed livestock, retard soil erosion, and fertilize the soil
    - Not allowing these animal and crop wastes to return to the soil as a natural fertilizer can reduce food production and food supplies in poor countries
- Produces CO_2 (but there is no net increase)
- *Advantages of Solid Biomass*
    - Plantation can help restore degraded lands
    - No net CO_2 increase if harvested and burned sustainably
    - Large potential supply in some areas
- *Disadvantages*
    - Nonrenewable if harvested unsustainably
    - Plantations could compete with cropland
    - Soil erosion, water pollution, and loss of wildlife habitat

Geothermal Energy

- **Geothermal energy** consists of heat stored in soil, underground rocks, and fluids in the Earth's mantle
  - e.g.) Volcanic rock, geysers, and hot springs
- Three nondepletable sources of geothermal energy:
  - Hot dry-rock zones
  - Molten rock
  - Warm-rock reservoir deposits
- The world's largest operating geothermal system, called *The Geysers*, extracts energy from a dry steam reservoir north of SF, California
- Santa Monica, California, became the first city in the world to get all its electricity from geothermal energy
- *Advantages of Geothermal Energy*
  - Very high efficiency
  - Low land use
  - Low land disturbance
- *Disadvantages*
  - Scarcity of suitable sites
  - CO_2 emissions
  - Noise and odour

Hydrogen

- Some energy analysts view hydrogen gas as the best fuel to replace oil during the last half of this century
- Three problems with turning hydrogen into fuel as a reality:
  - First, hydrogen is chemically locked up in water and organic compounds (methane and gasoline)
  - Second, it takes energy and money to produce hydrogen from water and organic compounds
  - Third, fuel cells are the best way to use hydrogen to produce electricity, but current versions are expensive
- A problem is that getting hydrogen from organic compounds such as methane produces carbon dioxide
- Hydrogen is highly flammable and burns with an invisible flame
- *Advantages of Hydrogen*
  - Low environmental impact
  - Easier to store than electricity
  - Nontoxic
- *Disadvantages*
  - Not found in nature
  - Negative net energy
  - High costs

Lesson Nine: Biodiversity and Forest Resources

Concept of Biodiversity and Global Patterns

- Increase Factors:
  - Middle stages of succession
  - Moderate environmental disturbance
  - Small changes in environmental conditions
  - Physically diverse habitat
  - Evolution
- Decrease Factors:
  - Extreme environmental conditions
  - Large environmental disturbance
  - Intense environment disturbance
  - Severe shortages of key resources
  - Non-native species introduction
  - Geographic isolation
- Global patterns:
  - The impact of the human ecological footprint on the Earth's land has disturbed at least half and probably about 83% of the Earth's land surface (excluding Antarctica and Greenland)
  - 82% of temperate deciduous forests have been cleared, fragmented, and dominated because their soils and climate are favourable for growing food and urban development
  - Tundra, tropical deserts, and land covered with ice are the least disturbed biomes because their harsh climates and poor soils make them unappealing to most human activities
  - In Canada, most of the wetlands across the country were lost to agriculture and drainage before wetland programs began
  - The Carolinian forest of southern Ontario has been reduced to remnants in few places like Pelee National Park
  - Humans use, waste, or destroy about 10 – 55% of the net primary productivity of the planet's terrestrial ecosystems
  - Biologists estimate that the current global extinction rate of species is at least 100 times and probably 1000 to 10000 times what it was before humans existed
  - Threats to biodiversity projected to increase sharply by 2018
  - The overall pattern is that global diversity is decreasing
    - Naturally, ecosystems are dynamic and there is constant genetic change with new species being created and also going extinct

Main Causes for Extinction and Decline of Biodiversity Globally

- Natural causes of extinction include:
  - Ecological processes such as competition and predation as well as diseases and more extreme events such as meteorites that alter the climate
- Human activity:
  - The increasing reliance on human systems on very narrow or low diversity levels of resources in fisheries, forestry, and agriculture
    - As humans rely more on single crops or monocultures for subsistence, more species will be eliminated from the ecosystem
    - In fisheries, it is the combination of overfishing with new forms of fishing such as aquaculture that is leading to a collapse of marine systems
  - Population growth increases the demand for land which means less area available for natural and traditional land uses such as forests and wildlife habitat as well as cropland
  - The government chooses to support less sustainable systems
    - This means more subsidies to the development of traditional resources (forestry and agriculture) than to parks and ecotourism

Types of Forests Related to Management (plantation, secondary)

- Three major types of forests based on age and structure:
  - **Old-growth forest**: an uncut forest or regenerated forest that has not been seriously disturbed by human activities or natural disasters for several hundred years
    - They are storehouses of biodiversity because they provide ecological niches for a multitude of wildlife species
  - **Second-growth forest:** a stand of trees resulting from secondary ecological succession
    - They develop after trees in an area have been removed from human activities or by natural forces
  - **Tree plantation/ tree farm:** It is a managed tract with uniformly aged trees of one species that are harvested by clear-cutting as soon as they become commercially available

- Major Types of Forest Management
  - **Even-aged management** (sometimes called *industrial forestry)* involves maintaining trees in a given stand at about the same age and size
    - In this approach, a simplified *tree plantation* replaces a biologically diverse old-growth or second-growth forest
    - The plantation consists of one or two fast-growing and economically desirable species that can be harvested every 6 – 10 years
  - **Uneven-aged management** involves maintaining a variety of tree species in a stand at many ages and sizes to foster natural regeneration
    - Here, the goals are biological diversity; long-term sustainable production of high-quality timber; selective cutting of individual mature or intermediate-aged trees; and multiple uses of the forest for timber, wildlife, watershed protection, and recreation
- Governments own 80% of remaining forests in developing countries

Distribution of Forest Resources Globally

- Canada's main forest resources are found across Central Canada in the Canadian Shield and in the mountainous areas of BC and the Yukon
  - Canadian forests can be broadly classified as deciduous and coniferous

Facts and Figures

- 44% of the Canadian landscape is covered by forest and of this land, 77% is productive commercially
  - Only 4% is protected as parks or related land management units
  - The remaining 23% is *wild land* or *other wooded land* meaning that the trees are too small or scattered or not accessible enough to be commercially useful
  - 4% of productive forest is not available for lumber operations because it is protected within national parks
  - The productive forest consists of *softwood* (coniferous) trees
  - The harvest each year comprises about 82% softwood trees and 18% hardwood (broad-leafed) trees
  - More than 80% is harvested by clear-cutting
- The majority of the forest lands in Canada are public lands or crown land controlled by the government
- The allowable cut on crown land for harvesting by private companies is 0.2%
  - Most cutting is still dominated by clear-cutting
- The economic value of income from the Earth's ecological services is at least $36 trillion (U.S) per year
- Biodiversity

Environmental and Social Impacts of Deforestation

- **Deforestation** is the temporary or permanent removal of large expanses of forest for agriculture or other uses
- If left long enough, forests that have been logged or converted to cropland can revert to second-growth and even old-growth forests through secondary ecological succession
  - But this is not always the case – if deforestation occurs over a large enough area, it can cause a region's climate to become hotter and drier and prevent the return of a forest
- Deforestation can also contribute to projected global warming if trees are removed before they grow back
  - When forests are cleared for agriculture or other purposes and burned, the carbon stored in the trees' biomass is released into the atmosphere as the GHG carbon dioxide
- Decreased soil fertility from erosion
- Runoff of eroded soil into aquatic systems
- Premature extinction of species with specialized niches
- Accelerates flooding

Cutting Practices and Management Strategies

- Cutting practices:
  - **Selective cutting** – intermediate-aged or mature trees in an uneven-aged forest are cut singly or in small groups
    - It reduces crowding, encourages growth of younger trees, maintains an uneven-aged stand of trees of different specials, and allows natural regeneration from surrounding trees
    - Sometimes called *high grading*
      - It involves cutting and removing only the largest and best specimens of the most desirable species
  - **Shelterwood cutting** removes all mature trees in an area in two or three cuttings over a period of time
  - **Seed-tree cutting** is where loggers harvest nearly all of a stand's trees in one cutting but leaves a few uniformly distributed seed-producing trees to regenerate the stand
  - **Clear cutting** removes all trees in an area in a single cutting
  - **Strip cutting** involved clear-cutting a strip of trees along the contour of the land, with the corridor narrow long enough to allow natural regeneration
    - After regeneration, loggers cut another strip above the first, and so on

- Management Strategies:
  - Multiple Use Forests
    - It grew of of the demand for recreation opportunities following the Second WW
    - This attempts to combine forest use such as hunting, hiking, and logging in a manageable landscape
      - However, still a strong focus on the use of the forest for forestry related products
    - The approach is strongly practiced throughout NA
  - Multifunctional Forests
    - It recognizes the various goods and services provided by a forest
      - These goods and services are beneficial to the whole ecosystem and related human systems
      - Management with this in mind would include forestry, ecotourism, air quality, spirituality, etc
    - This approach is gaining acceptance and is a truer approach to sustainable forestry

Lesson 10: Biodiversity continued

Causes of Biodiversity Decline and Examples

- The loss of habitat is the principal causes of wildlife decline or extinction globally and is strongly linked to the various land uses practices (mining, forestry)
- The primary causes of tropical deforestation:
  - Population growth
  - Poverty
  - Environmentally harmful government subsidies
  - Debts owed to developed countries
  - Failure to value ecological services

- The expansion of settlement across the American west led to a rapid decline in populations of the Passenger Pigeon and the American Bison
  - Within the several decades, the pigeon was extinct and the bison on the brink
- Causes of Extinction (HIPPO):
  - Habitat destruction and fragmentation
    - Fragmentation is the process of carving up large natural blocks of habitat such as forests and replacing with another land use such as cropland or residential housing
      - By this, there is a creation of more edge habitat and less forest interior
      - Implications:
        - Weakening of larger trees now located on the edge and making them more susceptible to wind damage
        - Allows predatory species better access to prey such as eggs and young birds
      - The overall extent of the range of African Elephant has declined somewhat but there has been considerable isolation of the populations through fragmentation of the animal's habitat

  - Invasive species
    - If these species are strong competitors they will be able to out-compete local species for resources such as food or nutrients which could lead to the local extinction of certain species
      - Invasive species can alter the habitat making it less suitable for native species, initiating a shift in the ecosystem and related food chains
      - e.g.) The introduction of the zebra mussel in the Great Lakes
        - This has altered the level of sediment in the lake water which has increased the light levels within the water column

  - Population growth
    - Human demand for land leads to the loss of habitat for many species
      - Species that have specific habitats or narrow niches will show the greatest effect
      - This is true in southern Ontario where over the past several hundred years, many hectares of wetlands have been drained and forests cleared to provide agricultural and urban lands

  - Pollution
    - Arctic contaminants will enter the food chain and through bio magnifications, threaten the top predators in the food chain such as the Polar Bear
    - This species is also threatened indirectly by pollution through the effects of burning fossil fuels and the related change in climate

  - Overharvesting
    - Both the Passenger Pigeon and American Bison suffered from the stresses of overharvesting for food and clothing

Solutions and Impacts of Resource Use

- Governance:
  - At local, federal and international levels laws have established to reduce issues such as hunting and illegal trade
    - Canada introduced the Species at Risk Act (SARA) to establish rules that protect species at risk
    - Goals: to designate species at risk, to protect their habitats, to develop recovery plans
  - At the International level, the Convention on International Trade of Endangered Species (CITES)
- Monitoring:
  - In Grimsby, a hawk watch has been in place for many years
    - Volunteers watch for hawks migrating along the Niagara Escarpment
    - Watchers congregate and tally numbers of each species
  - e.g.) Great Lakes Marsh Monitoring Program
    - Designed to collect information about the presence and abundance of bird species in Great Lakes coastal and inland marshes, to contribute to our understanding of their habitat needs

Tracking and Monitoring Patterns of Change and Examples of Species + Programs

- Monarch Butterfly Migration
  - Citizens track the monarch butterfly migration each fall and spring as the monarchs travel to and from Mexico

Park Philosophies and Direction of Management

- Park philosophies:
  - Preservation – to protect species at risk and wilderness by restricting public access to land
  - Conservation – to control the use of natural resources within park boundaries but allow sustainable use of time, wildlife and mineral resources
  - Recreation – to provide opportunities for the public to enjoy natural landscapes by providing hiking, birdwatching, canoeing
  - Ecological Integrity – to allow natural processes to function unimpeded to maintain the natural ecosystems ** most currently promoted
- Directions in Park Management
  - Engaging in the local landowners and government agencies that border the park landscapes
  - The Greater Park Ecosystem has been the focus of park strategies in Canada recently
    - By combining land use strategies inside and outside the park boundaries, wildlife will not become isolated within the park boundaries
    - Landscape corridors allow species to move in and out of the park region
    - This will strengthen the genetic diversity within the park and reduce the threat of inbreeding
- What is the target percentage of land to be protected? 12%
- Is the park for recreation or preservation?
  - Recreation

- What is a biosphere reserve?
  - Biosphere reserves have an inner protected core surrounded by two buffer zones that can be used by local people for sustainable extraction of resources for food and fuel
  - Three zones:
    - Core area
      - Contains important ecosystem that the government legally protects from all activities except nondestructive research and monitoring
    - Buffer zone
      - Surrounds and protects the core area
      - Emphasis is on nondestructive research, education, and recreation
      - Local people can carry out sustainable logging, agriculture, livestock grazing, hunting, and fishing as long as such activities do not harm the core
    - Second buffer or transition zone
      - Surrounds the inner buffer
      - Local people engage in more intensive but sustainable forestry, grazing, hunting, fishing, agriculture, and recreation than in the inner buffer zone

Lesson 11: Agricultural Systems

Differences

- Natural vs. Agricultural (agroecosystems) systems
  - Natural ecosystems tend to stabilize the soil under plant cover
    - Soil moisture is protected from the drying effect of sunlight and air, and roots hold the soil in place preventing soil erosion by wind or water
    - Decomposing dead plants enrich the soil with nutrients and organic matter
  - Agroecosystems that involve plowing expose the soil to erosion and lose soil moisture that would normally be protected by plant cover
    - Major nutrients can be replaced artificially using chemical fertilizers, but trace nutrients and organic matter are depleted by these methods
  - Natural ecosystems are driven by solar energy
    - Agroecosystems are driven by large investments of fossil fuels, mechanization, and human intervention

- Traditional vs. Industrial
  - **Industrialized** or **high-input agriculture** uses large amounts of fossil fuel energy, water, commercial fertilizers, and pesticides to produce single crops (monocultures) or livestock animals for sale
    - Mostly in developed countries
    - **Plantation agriculture** (a form of industrialized) is used in the tropical developing countries
    - It involves growing cash crops (bananas, coffee, soybeans, sugarcane, cocoa) mostly for sale in developed countries
  - Traditional agriculture consists of two main types and practiced in developing countries
    - Traditional subsistence agriculture typically uses mostly human labour and draft animals to produce only enough for a farm family's survival
    - In traditional intensive agriculture, farmers increase their inputs of human and draft labour, fertilizer, and water to get a higher yield per area of cultivated land

- They produce enough good to feed their families and to sell for income

Pattern of Production in Canada

- Agriculture is limited by environmental factors such as soil quality and climate
- The majority of agricultural activity is in southern regions of the country along the border with the US
- The number of farms has been declining in recent decades, but the average size of farms has been increasing due to mechanization, economic pressures, and social changes
- The net result of land farmed has been about the same over the past 50 years
- Only 7% of our terrestrial area is considered to be agricultural land

Changing Patterns of Farms

- Size
    - The average size of a farm in 1900 was 50 hectares whereas today it is 242 hectares
- Numbers
    - Primary agriculture accounts for $14.5 billion and employs about 300,000 people directly
    - The total number of farms has declined by 50% since WWII

Environmental Issues and Solutions

- Soil Erosion
    - Soil erosion is a natural process that occurs when soil is exposed to wind and water processes
    - Soil erosion is enhanced by cultivation and tillage practices
    - Regions with extensive soil erosion experience degradation of the soil layer and loss of fertility
    - Impacts of soil erosion:
        - Loss of soil fertility
        - Decreasing water quality
        - Increased sedimentation in river and lake systems

Case Study of the Impacts of Desertification

- When human processes lead to extensive soil erosion this can push the system across a threshold which creates a desert-like condition
- Main causes:
    - Overgrazing
    - Deforestation
    - Salinization
    - Erosion
    - Soil compaction
    - Climate change
- In China, a significance portion of the country is at risk for desertification
    - Impacts could put crops and water supplies at risk
    - Almost 1/3 of China's land area has become a desert

Solutions

- Conservation of the land and specifically the soil system focuses on reducing soil erosion and increasing soil fertility
- In the traditional agricultural system, farmers work the land by conventional-tillage farming or plowing the land then breaking it up and smoothing it out to create a planting surface
- In areas where plowing takes place in the fall, the soil remains bare and exposed to wind and water through the winter and spring
- To reduce this impact some farmers practice minimum-tillage farming where the soil is only slightly disturbed, or no tilling-farming in which does not require plowing but simply injects seeds and chemicals into unplowed soil
- Other ways to reduce soil erosion:
    - Terracing can reduce soil erosion on steep slopes by converting the land into a series of broad, nearly level terraces that run across the land contour
        - This retains water for crops at each level and reduces soil erosion by controlling runoff
    - Contour Farming involves plowing and planting crops in rows across the slop of the land rather than up and down
        - Each row acts as a small damn to help hold soil and to slow water runoff
    - Strip Cropping involves planting alternating strips of a row crop and another crop that completely covers the soil
        - The cover crop traps soil that erodes from the tow crop, catches and reduces water runoff, and helps prevent the spread of pests and plant diseases
- GMOs and the role of organic farming
    - In organic farming, improved food production is achieved with technologies based on ecological knowledge leading to increased yields, control of pests and improved soil fertility
    - Some of these methods include:
        - Shift to polyculture cropping with perennial crops rather than monocultures with annual crops
        - Reduce dependence on pesticides and strengthen populations of natural predators
        - Rely on natural fertilizers including manure and tilled-in crop residues
            - Will maintain soil fertility, reduce runoff and improve water quality
    - GMOS:
        - The Green Revolution (Gene Revolution) has been through genetic engineering
        - Genetic engineering differs from traditional approaches such as cross0breeding in that there is a transfer of genes from one species to another rather than just between organisms from the same species
        - Advantages:
            - Modified crops will be resistant to heat, cold, herbicides, insect pests, parasites, viral diseases, drought, and stressful soils
            - Faster growing plants that need little water, fertilizers and pesticides
            - These new foods and plants could provide sustainable food source for many years
            - On the other hand, there is little known of the health and ecological side-effects from new strains

Lesson 12: Fisheries

Role of Fisheries in Global Food System

- Fisheries contribute to 7% of the world's food supply
- In 2006, 70% of the world's commercial fish supply came from ocean or marine sources
- The remaining 30% came from freshwater fisheries
- Overall, aquaculture contributes about a third of the world's supply of fish

Main Causes of Decline of Fish Stocks

- Overfishing
  - Improvements in technology have improved the abilities of fishers to catch large amounts of fish
  - Overfishing occurs when the fish catch is greater than the breeding stock's ability to renew their populations from year to year
- Technology
  - Technology has improved our ability to catch large numbers of fish
  - Overfishing leads to commercial extinction
    - Fleets supported by most government subsidies, use sonar, satellite global positioning systems, and aircraft to find dish
      - They they catch them by deploying gigantic nets or lines containing many thousands of hooks that can stretch as far as 80KM
      - Modern industrial fishing cause 80% depletion of a target fish species in only 10 – 15 years
      - Big fish in many populations of commercially valuable species are becoming scarce (e.g., swordfish, tunas, sharks)
      - Cod habitats have been almost completely destroyed
  - Most fishing boats are after one or small number of commercially valuable species
    - However, their gigantic nets and incredibly long lines of hooks also catch nontarget species – this is called **bycatch**
      - One third of the species caught are thrown overboard dead or dying
      - In addition to wasting potential sources of food, this can deplete the populations of bycatch species that play important ecological roles in ocean food webs
  - To sum it up, many species are being overfishes, big fish are becoming scarce, smaller fish are next, and we throw away 30% of the fish we catch
- Degradation
  - Trawlers drag large nets along the ocean floor which is referred to as bottom trawling
  - These nets catch wildlife and disturb habitat over large areas of the ocean floor

Cause of Collapse of East and West Coast Cod Fisheries

- The species has seen a significant decline over the past 50 years (Cod)
- Read: "Case Study: Management Gone Wrong: Cod on the Grand Banks" page 277

Differences in Management between East and West Coast Fisheries (p277+)

- East: In 1940 Canada and 10 other fishing nations created the International Convention for the Northwest Atlantic Fisheries (ICNAF) to help manage the resource
    - The ICNAF was granted authority to set Total Allowable Catch (TAC) limits for some stocks
    - Unfortunately, the TAC limits were high and there were loopholes that allowed over harvesting to continue
    - In 1977 Canada declared a 200-mile *exclusive economic zone (EEZ)* in an effort to protect the declining Grand Banks fishery from foreign fleets
    - The once-bountiful stock of cod on the Grand Banks collapsed when warnings were ignored and the resource was overharvested
- West: Even though the West Coast salmon fishery is clearly in decline, competing stakeholders are still fighting over allotments rather than cooperating to conserve the resource
    - Read "Managing West Coast Salmon" on page 278

Solutions

- **Aquaculture** involves raising fish and shellfish for food like crops instead of going out and hunting and gathering them
    - It is the worlds faster growing type of food production
    - Two types:
        - **Fish farming** involves cultivating fish in a controlled environment (coastal or inland pond, lake, reservoir, rice paddy) and harvesting them when they reach the desired size
        - **Fish ranching** involves holding anadromous species such as salmon that live part of their lives in fresh water and part in salt water for captivity for the first few years of their lives, usually in fenced-in areas or floating cages in coastal lagoons and estuaries
            - Then the fish are released, and adults are harvested when they return to spawn
- Where fish and plants are raised together, the term **aquaponics** is used;
    - The nutrient rich pond water is used hydroponically to nourish the plants
    - The plants cleanse the water, which can then be returned to the fish ponds

Countries Dependent on Aquaculture and Environmental Impacts

- Environmental impacts of aquaculture:
    - Produces large and concentrated outputs of waste
    - Destroys mangrove forests
    - Increases overfishing of smaller marine species used to feed farmed carnivorous species
    - The depletion of the seas to feed aquaculture farms could cause the collapse of both marine fisheries and carnivorous aquaculture
- Farmed salmon is now the largest agricultural export of BC and creates employment for at least 4000 people
- The Canadian aquaculture industry employed more than 14 000 people and achieved sales of about $600 million

Lesson 13: Waste Management

Main Components of Waste Stream and Management System

- Material in a waste stream:
  - Organic (40%)
  - Recyclable materials (40%)
  - Bulky goods (10%)
  - Other materials (10%)

Contents of the Stream

- Paper products and organic waste make up the largest percentage of municipal solid waste in Canada and the US
  - Followed by plastic, metal, and glass
- Types of waste:
  - Waste from residential sources
  - Waste from non-residential sources

Stats

- 2.8 million tonnes recycled/ composted – 22.6% Diversion Rate
- 9.63 million tonnes of waste
  - 3.2 residential
  - 6.4 non-residential

Main Stakeholders/ Components of the Ontario Waste System

- Stakeholders:
  - Provincial government – setting and enforcing standards, issuing approvals, promoting waste diversion
  - Municipal government – operating and maintaining recycling and waste management services used by public and planning for future waste management needs
  - Waste generators (Individuals) – each citizen responsible for reducing waste
  - Waste generators (Businesses) – all industrial responsible for waste generated
  - Waste Management Industry – manage most of waste generated by non-residential sector
  - Environmental Groups

Impacts and Advantages of Different Disposal and Examples

- Landfills
  - *Advantages:*
    - Little odour
    - No open burning
    - Can handle large amounts of waste
    - Can be built quickly
  - *Environmental Impacts:*
    - Leakage of toxic leachates can contaminate surface and groundwater
    - Exposure of waste that attracts rats and other pests
    - Fermenting bacteria generates methane
    - Slow decomposition
    - Competition for land
    - NIMBY:
      - Not in my backyard
- Incineration
  - *Advantages:*
    - Burning of waste produces alternative energy source
    - Reduces the bulk of wastes
    - Low water pollution
    - Quick and east
  - *Impacts:*
    - Harmful emissions – particulate matter, heavy metals, trace organics (dioxins)
    - Residual ask which ends up in landfills and increasing the input of potential toxic materials
    - Reduced air quality near plants

- Examples of contaminated land sites:
  - *Brownfields* are abandoned industrial and commercial sites usually contaminated with hazardous wastes
    - e.g.) Factories, junkyards, older landfills, gas stations

3Rs and Examples

- Recycle
  - Recycling involves reprocessing discarded solid materials into new, useful products
  - Benefits:
    - Creates useful products, encourages new kinds of jobs, saves us money and energy while reducing waste, decreasing air pollution, extending our resources, reducing our impact on the environment
  - What can be recycled:
    - Paper products, glass, aluminum, steel, and some types of plastics
  - Two ways:
    - Primary or closed-loop recycling occurs when waste is recycled into new products of the same type
      - e.g.) Turning used newspapers into new newspapers
    - Secondary recycling or downycling involves converting waste materials into different products
      - e.g.) Used tires can be shredded and converted into rubberized road surfacing

- Reuse
  - This strategy leads to a reduction in resource consumption and less resource use in the disposal and conversion of material than recycling
  - Involves cleaning and using materials over again
  - Environmental advantages:
    - Reduces use of matter and energy resources
    - Cuts pollution and waste

- Reduce
  - Requires examination of your use of resources and making decisions on changing your behaviour
  - By reducing dependency on certain materials, greater resource reduction is achieved
  - Strategies and benefits:
    - A life-cycle assessment of target materials by examining a material's life cycle from raw material to disposal
    - Conservation of energy and raw materials
    - Reduction in use of toxic, harmful substances
    - Reduction of the quantity and toxicity of wastes and pollutant discharges
    - Extension of product durability