Tses 3002 - Energy and Sustainability

Introduction - Quiz 1

- ❖ 5 quizzes, grades of best 4.
- ❖ 2nd option of 2 quizzes and optional group project may be available.
- ❖ Generally not at the school mondays and fridays
- ❖ Be sure to use WebCT email
- ❖ Book report discussion should include worldview models.
- ❖ what do you think of when someone says sustainability?
  - Brundtland - sustainable development
  - not putting the future at risk
  - meeting needs of the present without compromising future generations
  - living with permanance
    - materials and design, conservation
  - resource management
  - factory farming
  - renewable energy
    - running out of oil (ooo)
  - diversity of the ecosystem
  - you don't want dead people.

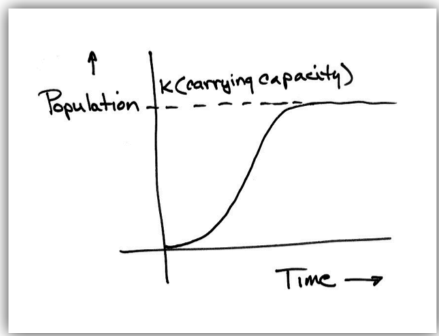
Worldviews Module - Quiz 1

- ❖ There are 3 worldviews
  - Dominant Wester Worldview (DWW)
  - Human Exemptionalism Paradigm (HEP)
  - New ecological Paradigm (NEP)
- ❖ Each worldview is comprised on 4 tenents
  - Nature of human beings
  - Social causation
  - Context of human society
  - Constraints on human society
- ❖ Nature of human beings
  - DWW - "People are fundamentally different from all other creatures on Earth over which they have dominion."
    - human progress
  - HEP - "Humans have a cultural heritage in addition to and distinct from their genetic inheritance, and thus are quite unlike all other animal species."
    - disinterested in natural world
  - NEP - "Despite exceptional characteristics, humans remain one among many species that are interdependently involved in global ecosystem"
    - regardless of how great we think we are there is a natural world that has a lot of influence on us.
- ❖ Social Causation
  - DWW - "People are masters of their destiny, they can choose their goals and learn to do whatever is necessary to achieve them"
  - HEP - "Social and cultural factors (including technology) are the major determinants of human affairs"
  - NEP - "Human affairs are influenced not only by social and cultural factors, but also by intricate linkages of cause, effect, and feedback in the web of nature"
- ❖ Context of Human Society
  - DWW - " THe world is vast and thus provides unlimited opportunities for humans"
  - HEP - "Social and cultural environments are the crucial context for human affairs and the biophysical environment is largely irrelevant"
  - NEP - "Humans live in and dependent on a finite biophysical environment that imposes potent physical and biological restraints on human affairs"
- ❖ Constraints on human society
  - DWW - "The history of humanity is one of progress; for every problem there is a solution, and thus progress need never cease"
  - HEP - "Culture is cumulative; thus technological and social progress can continure indefinitely, making all problems ultimately soluble"
  - NEP - "Although human inventiveness may appear to temporarily extend carrying capacity limits, ecological laws cannot be repealed"
- ❖ Corollaries to DWW Contraints on Human Society
  - All problems are soluble
  - All problems are soluble by people

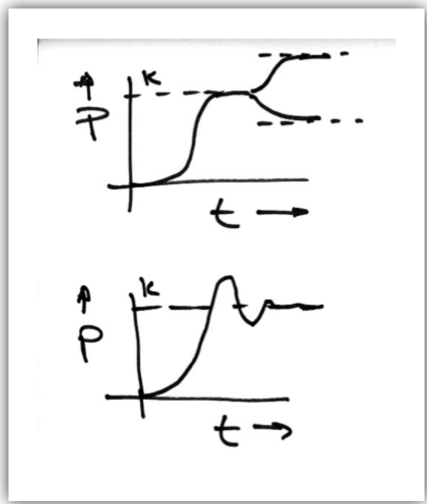
- Many problem are soluble by technology
- Those problems that are not soluble by technology, or by technology alone, have solutions in the social world (of politics, economics, etc)
- When the chips are down, we will apply ourselves and work together for a solution before it is too late

❖ A note on carrying capacity

- populations of organisms grow exponentially until something (disease, predation, resource limitation...)slows the growth
- The maximum population that a given geological area can sustain is the carrying capacity (K).



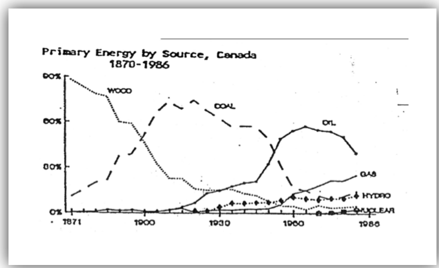
❖ Carrying capacities can rise and fall depending on the limiting factors and if they are changing. Food could increase, population could over shoot carrying capacity and crash.



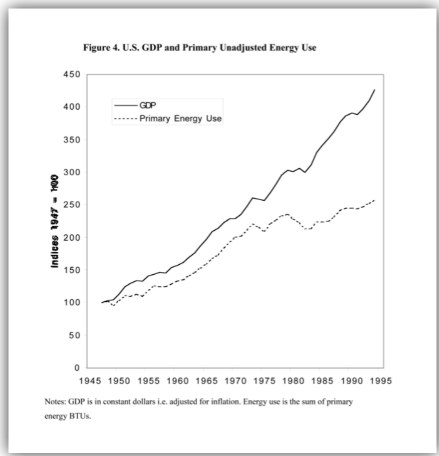
❖

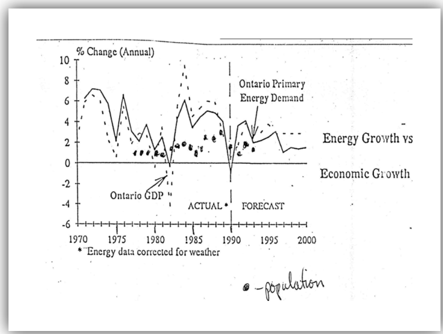
Why Energy and Sustainability Module - Quiz 1

- ❖ Some definitions
  - Primary energy - energy that exists in crude form (example: fossil fuel that is extracted from a sedimentary deposit) It is transformed into:
    - Delivered Energy - energy made available to the consumer, This is converted into:
      - Energy services (energy slaves): light, sound, heat, entertainment, motion, etc.



- ❖ 1870 - 1986 Primary Energy Graph in Coursepack
- ❖ wood was the original primary energy course
  - overtaken by coal
  - which was overtaken by oil, gas, hydro and nuclear energy
- ❖ Primary Energy Consumption in Canada 2003
  - Refined petroleum products 40%
  - Natural gas 34%
  - Coal 13%
  - Primary electricity 14%
    - electricity not produced by coal or oil, e.g. water power or nuclear
- ❖ Peak Oil
  - This is the point in time when oil production cannot be increased (oil production peaks)
  - Dr. M. King Hubbert predicted, in the mid-1900s, that the US oil production would peak by 1970. It peaked shortly thereafter.
  - It is not predicted that world oil production will peak sometime between now (some think it peaked in 2005) and 2040.
  - World oil demand has increased about 1.7% per year over the last 20 years. There is no sign of this trend changing.
  - So one problem that must be faced in order to provide a "sustainable" future is what to do as increasing oil demand meets decreasing oil production.
  - Another more general issue can be seen in the following graphs:

- 

- Note: GDP is the total market value of all final goods and services produced in a country in a given year.
- Energy use not quite increasing as fast as GDP
- 

- Percent annual change in both GDP and primary energy demand.
- They move together.
- If GDP is not going up youre having a recession

❖ One way to interpret these graphs is that energy demand tends to track GDP. When GDP increases, primary energy demand increases. When GDP decreases, primary energy demand decreases.

❖ Everyone wants their GDP to increase...continually. So to have a sustainable future would appear to require continual grown in primary energy demand. To meet his demand will require continual growth in primary energy supply. Energy, it would seem, is important to "sustainability"

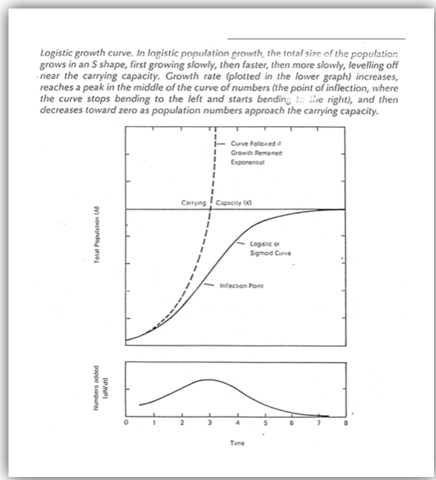
❖ How do we uncouple the two to sustain energy.

Futurity Module - Quiz 1

- ❖ Giving "moral standing" to future generations:
- ❖ For an entity to have moral standing its interests and well-being must be considered when decided what to do.
- ❖ Presently our culture is anthropocentric by which is meant: all and only humans have moral standing. This includes: healthy people, people with disabilities, people in vegetative states, the newly dead but (in Canada) not human fetuses.
- ❖ Possible reasons for giving moral standing to coming generations:
  - Future generations will be essentially the same as we are.
  - One in born into a given generation by historical accident.
  - Our survival as a species is more important than our individual survival.
  - Even after we die the effects of our lives continue.
- ❖ Future generations will be essentially the same as we are
  - may have different wants and priorities but will have same basic needs for food, water, air and space
  - will have the same basic physical and mental capacities with which to deal with environmentl
  - once born they will have the same basic claim to life and protection from life-threatening harm (extreme temp, toxins, famine and disease)
  - Cruel to give like without the means to sustain and enhance it. for the species to survive must provide means for survival.
- ❖ One is born into a given generation by historical accident
  - None of us chooses when to be born or to whom
  - Thus we have no special claim to this time and place
  - Justice requires we have no more rights over the world's resources than anyone else(future)
- ❖ Out survival as a species is more important than our individual society
  - Parents of many species spend energy to reproduce and care for young before they die.
  - Many parents risk their own lives for their offspring
  - Life is not ours to keep, but to share with others.
- ❖ Even after we die the effects of our lives continue
  - Present in memory
  - Present in traditions/habits we shared
  - Our ideas enlarged the range of options for others.
  - These memories and ideas actively influence the course of the future.
  - We are the product of our ancestors...and our own decisions.
- ❖ Are there threats to future generations?
  - consider Intergenerational Equity.
    - The aamjiwnaang First Nation is Sarnia, Ont.:
      - Lowest rate of live male births in the world
        - 2 girls for 1 boy.
      - 20 meters away from all chemical plants in sarnia
      - most rate is 106 males for 100 females

Renewable and Non-Renewable Resources - Quiz 1

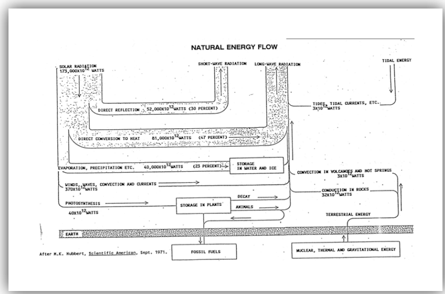
- What types of resources are there in general?
  - Rewable
  - Non-Renewable
  - Non-Renewable renewable
- Renewable Resources
  - Capable of being replaced by natural processes
  - Capable of being replaced by sound resource management
    - e.g. fish
  - Capable of being replaced on a human time scale
    - as fast as humans need it
- Non-Renewable resources (Abiotic - not alive)
  - Changes in Concentration (Something can come non-renewable through changes in concentration)
    - Story about cars and lead, romans and now gas has manganese in it.
    - Gold in ores: low grade ore 5 grams per tonne (5 parts per million or ppm)
    - Gold in seawater: 0.1-2 mg per tonne (0.1 to 2 parts per billion or ppb): it would take a long time and it would be unprofitable to isolate this gold with current technology.
    - Gold in Earth's crust (avg) 0.005ppm (5ppb)
  - Changes in composition
    - Burning fossil fuels (see link to CO2 to gasoline)
    - Taken something and turned it into something else, losing the original thing.
    - But carbon dioxide to fuel (see link)
    - Radioactive decay (uranium)
      - e.g. nuclear reactors using it and it will no longer be uranium
  - Changes in Amount - using too much of it that it becomes non-renewable
    - Draw down of aquifiers and surface water bodies
      - aquifier = underground water that can be used for something
        - south central US, ogalawa? used up, might refill it with water from Lake Michigan
        - Surface water body - ARAC, used up
      - if you're using this water too much, you can use it up.
- Non-Renewable renewable resources (biotic)
  - Changes in Population Structure
    - Extinctions (for the time being)
    - "Mother" Limitations

- 

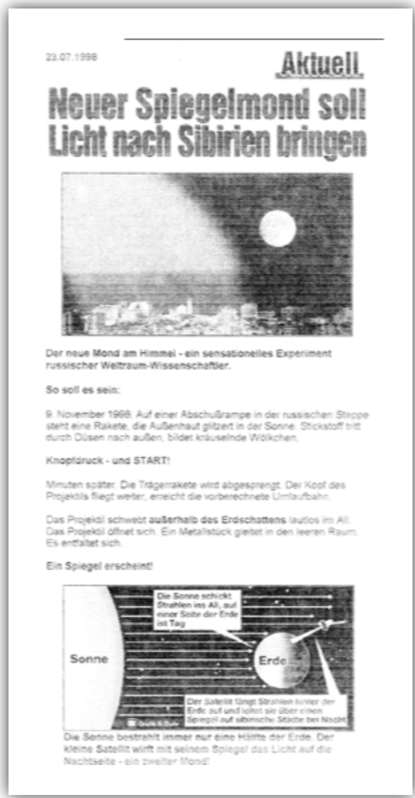
  Logistic growth curve. In logistic population growth, the total size of the population grows in an S shape, first growing slowly, then faster, then more slowly, levelling off near the carrying capacity. Growth rate (plotted in the lower graph) increases, reaches a peak in the middle of the curve of numbers (the point of inflection, where the curve stops bending to the left and starts bending to the right), and then decreases toward zero as population numbers approach the carrying capacity.

  - Growth rate grows and then levels off, population reaches a limit, the carrying capacity.
  - Not enough mothers to bring the population back if you pull the population down too much, slows back the population regrowth.
- Changes in community structures
  - (habitats, niches, structures)
    - Habitat - an organism's address (habitat loss)
      could ruin the animals habitat
    - Niche - an organism's occupation (invasive species)
      invasion of other species. e.g. zebra mussels.
- Changes in ecosystemd
  - (soils, microclimates, pollution)
    - Nutrient depletion in soil by agriculture (added fertilizer which comes to fossil fuel energy)
    - disturbing a forrest to the point that it doesn't come back within our lifetime.

Renewable Energy - Quiz 1

- ❖ Some energy sources practically inexhaustible (fusion)
  - e.g. the sun.
- ❖ Some energy sources are exhaustible (fossil fuel, uranium)
- ❖ Some energy sources limited in flux/flow but cannot be depleted (tidal)
  - only so much energy there that we can capture.
  - and hydroelectric.
- ❖ Where does renewable energy come from
  - Image from Coursepack
  - 

  - Nuclear, thermal, gravitational energy, some left over from earth formation
  - energy from the sun and moon
  - energy from radiant energy and the sun
  - 173 trillion jules per second of energy from the sun
  - the sun is where most of our energy input is from.
  - 47% of it is absorbed and made into heat
  - 30% is just directed reflected back into the atmosphere
  - 23% absorbed by the water cycle and evaporation and moving water.
  - The rest involved in ocean movement and wind, photosynthesis.



23.07.1998

Aktuell

Neuer Spiegelmond soll Licht nach Sibirien bringen

Der neue Mond am Himmel - ein sensationelles Experiment russischer Weltraum-Wissenschaftler.

So soll es sein:

9. November 1998: Auf einer Abschußrampe in der russischen Steppe steht eine Rakete, die Außenhaut glitzert in der Sonne. Stickstoff tritt durch Düsen nach außen, bildet kräuselnde Wölkchen.

Knopfdruck - und START!

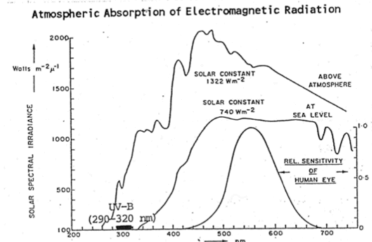
Minuten später: Die Trägerrakete wird abgesprengt. Der Kopf des Projektils fliegt weiter, erreicht die vorberechnete Umlaufbahn.

Das Projektil schwebt **außerhalb des Erdschattens** lautlos im All. Das Projektil öffnet sich. Ein Metallstück gleitet in den leeren Raum. Es entfaltet sich.

Ein Spiegel erscheint!

Die Sonne bestrahlt immer nur eine Hälfte der Erde. Der kleine Satellit wirft mit seinem Spiegel das Licht auf die Nachtseite - ein zweiter Mond!

- ❖ Top Picture - composite artist rendering of two versions of the night sky. On right - full moon, bottom - village scape. on left - how bright it will be if there experiment works, will make night brighter.
- ❖ Bottom picture shows - satellite up behind the earth, collects sunlight from the sun and aims it back at the earth.



Atmospheric Absorption of Electromagnetic Radiation

Adapted from Chemistry of Atmospheres, R.P. Wayne, Oxford University Press.

Note that the atmosphere transmits a fair amount of radiation in the range of wavelengths visible to the naked eye. Most ultraviolet and a good deal of infrared radiation is absorbed. The absorption of infrared radiation will be discussed further in the section on climate.

- ❖ Showing intensity of radiation and wavelength
- ❖ Atmosphere picks up UV-B rays which is good for us.
- ❖ We've talked about solar radiation but just what is it?
  - Most energy comes from the sun, the sun's energy is electromagnetic energy

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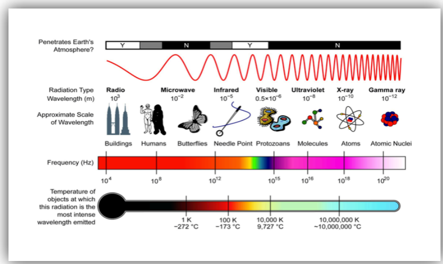
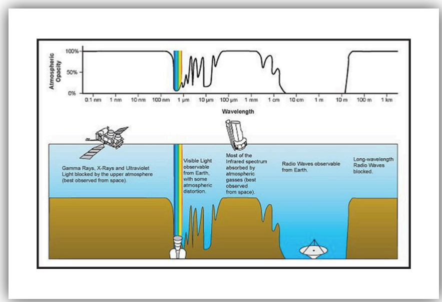
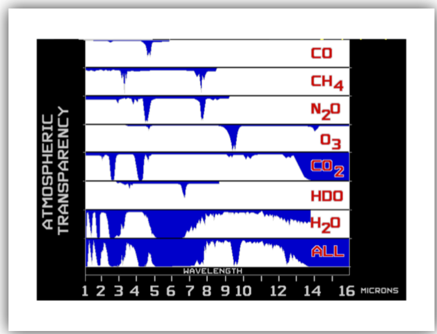


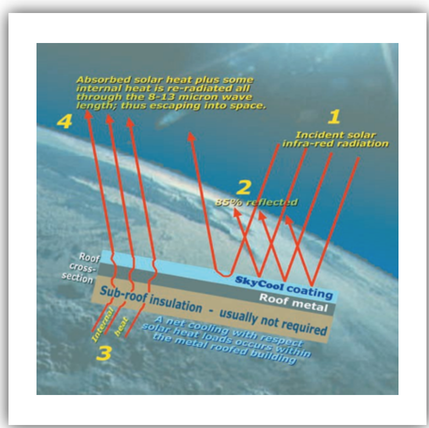
• Comes in different comes and are visualized as wave forms. The wave length goes from close together to farther apart. In the different ranges you find different energies identified by different names.



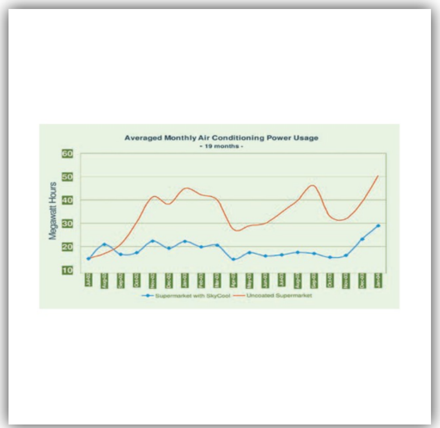
❖ Shows how opaque the atmosphere is, suns radiation at various wavelengths. The sun is opaque to the tighter wavelength. Starts to transmit sun energy at the looser wavelength. becomes opaque again around the radio waves. Only can transmit in the middle wavelengths.



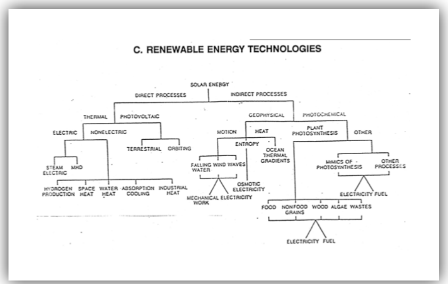
❖ Common gases that interact with infrared. Mostly the greenhouse gases. Wherever the white is is where the materials aren't absorbing radiation. The window is important, it is how energy gets back into outerspace.



❖ If you could build a surface that reflected all wavelengths except the ones at the wavelength that can escape, built skycool paint, pulls heat energy out of the structure and pumps it out through the atmosphere. saves the building air conditioning.



❖ Comparing one grocery store with skycool paint to the one without.



❖ From the Coursepack

- Showing everything that uses solar energy.
- Will explore this chart throughout the course.

Sustainability Module - Quiz 1

- ❖ Precise definition of sustainability
  - There is no precise definition of sustainability. The term has come to be used to describe a wide variety of social concerns
  - There may not be a precise definition of sustainability, but people use the term in discussions in several disciplines which leads to a variety of views of sustainability such as:
    - Biological view, economic view point, sociological view, urban planning view and environmental ethics view.
- ❖ Biological view
  - Basiago's article cites G.T. Miller's "biological" method of defining sustainability (in coursepack)
  - Miller contrasts "Sustainable" natural ecosystems with simplified (and by implication unsustainable) human systems.
    - Comparing Sustainable Natural Systems to the Simple Human System
      - Natural system captures and stores sun's energy, humans - consumes stored energy: fossil/nuclear fuels
      - Natural - Produces O2 and consumes CO2, Humans = Produce CO2, and consumes O2
      - Natural - Creates fertile soil, Humans - Depletes or covers fertile soil
      - Natural - Stores/purifies/releases water, (gradually) Humans - Uses/contaminates and releases water (rapidly)
      - Natural - Produces wildlife habitats, Humans = Destroys some wildlife habitat
      - Natural - Filters and detoxifies polutants/waste products, Humans - Produces pollutants and waste
      - Natural - Self maintenance and renewal, Humans - Continual, costly maintenance and renewal.
    - Biological view of sustainability
      - Views relationship between the natural biological and human systems
      - Emphasizes the importance of biodiversity which 1) maintins the health of natural systems 2) provides resources (new drugs, crops, fibres. 3) produces environments that are "psychologically restorative"
    - Note of biodiversity
      - The variation among organisms that is based on genetic factors which includes:
        - Gene variation
          in our species.
        - Species variation
          all the different species.
        - Ecosystem variation
    - The biological view is concerned with preserving biodiversity since biodiversity loss is seen as a threat to a region's economy.
    - Sustainability is defined in terms of biodiversity plus social and economic viability.
    - Example - California's Agreement on Biological Diversity (1991)
      - trying to keep biodiversity in California.
- ❖ Economic View of Sustainability
  - Also concerned with environment/economy connections,
  - L.W. Milbrath
    - Economies expand continually
    - Necessary to create jobs (population increase and productivity displacement)

            - Leads to waste accumulation/resource depletion
            - Constant push to make things more productive, make things more efficient.
    - Need a new "sustainable" economics
        - According to Gilman, such an economics would consider five forms of capital
            - Environmental (all natural/biological systems)
            - Human (Health, Knowledge,skills, motivations)
            - Socio-organizational (habites, norms, roles, traditions)
            - Manufactured (all buildings, tools, equipment)
            - Credit (money, debt)
        - Economics views of sustainability propose a "new" economics with consideration of such new categories of capital and their interactions.

❖ Sociological view of sustainability
- Sustainability of individuals, families and neighbourhoods
- Causal relationship between race and the location of toxic and hazardous enterprises in inner city ghettos.
- Sociological view of sustainability incorporates
    - Sustainability of human beings against, for example, environmental racism
    - Decision making by human interest groups use of natural resources affect on other humans' daily lives, equity issues
    - Negative impacts of economics on the environment also affect human beings
    - Sustainability not just about biota and natural processes
    - Want world where both humans and nature thrive.

❖ Planning methods of viewing sustainability
- Interactions between future and spatial domains.
- "Restorative design" that mimics diversity and efficiency of nature
- Reduce sustainability to the practical planning of regions, communities and neighbourhoods.
- Pursue design science that integrates urbanization with the preservation of nature.

❖ The environmental ethics view of sustainability
- Are humans part of, or apart from, nature?
- How this should guide moral choice?
- Involves a choice between the "business as usual" view of sustainability as substitution of capital and the view that the environment has significant standing.

❖ From these views, Basiago formulates
- Four Principles of Sustainability
    - 1) Futurity
        - Concern for future generations
    - 2) Equity
        - Fair intra and intergenerational sharing of economic benefits and burdens.
    - 3) Global environmentalism
        - global dimension of ecological problems (use of depletion of natural capital by one or some at the cost of others)
    - 4) Biodiversity
        - Continued integrity of ecological processes and systems

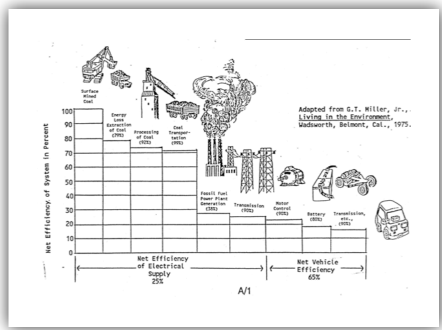
❖ Sustainability as research methodology
- The four principles of sustainability are to be used at the initial stages of a proposed development
- They make possible systematic form of questioning about what is being proposed
    - Will the development leave an undiminished stock of natural capital for future generations?
    - Is it equitable, today and for the future?
    - What is its impact on the global environment likely to be?
    - Will biodiversity be lost?
    - Look at p118 of basiago paper to see examples
- The method does not produce definitive answers, but it does make one think systematically about the impacts of activities.

Sustainable Development - Quiz 1

- Understanding Sustainable Development by Neil Carter - next to last article in the coursepack
-
- Blueprint for a Green Economy, David Peace, Anil Markandya and Edward Barbier
- Over 40 definitions of sustainable development most used definition
  - Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
  - This definition is taken from: Our Common Future, published by the World Commission on Environment and Development (sometimes called the Brundtland Report)
- Two fundamental principles
  - Intragenerational equity and Intergenerational equity
- Two key concepts
  - Needs and limits
- Intragenerational equity needs
  - Give "overriding priority" to the essential needs of the worlds poor
  - Poverty/unequal resource distribution are major causes of environmental degradation.
  - Everyone should have an opportunity for a better life.
  - Consumption in richer countries must be adjusted.
- Intragenerational equity limits
  - Current technology/social organization limits the ability of the environment to meet present and future needs
  - We must moderate our demands on the natural environment
  - However, eco-friendly growth in developing countries should be encourages to help alleviate poverty and provide for basic needs.
- Intergenerational equity: Sustainable (economic) development (SED)
  - The continually rising or non-declining composite of chosen indicators of development
  - Fundamental to SED
    - Actions taken now that are likely to significantly impair the well-being of the future must be associated with actual compensation for the future. Otherwise the future will be worse off than us.
  - How to compensate the future?
    - By a transfer of capital bequests...which means that this generation leaves a stock of capital no smaller than it has now.
- Types of Capital
  - Human-made capital (machines, infrastructure)
  - Human capital (knowledge, skills)
  - Natural capital (Natural resources, biodiversity, habitat, clean air and water, ecological processes etc.)
- Very Weak Sustainability
  - Overall stock of human capital and natural capital stays constant over time
  - Allows infinite substitution between the carious kinds of capital
  - Decrease in natural capital compensated by increase in human capital
- Weak Sustainability
  - Some (critical) natural processes are essential to life
  - These represent critical natural capital that shouldn't be substituted
  - Substitution between other types of natural capital allowed.
    - cannot substitute something like the ozone layer than is critical but somethings can be substituted.

- Strong Sustainability
  - Wider definition of critical natural capital
  - Use of the precautionary principle
  - Use of any natural resources should be compensated
    - e.g. by reforestation/recycling/social improvements (better communities/ reduced inquality)
- Very strong sustainability
  - Radical: like bioregionalism or deep ecology
  - Steady-state economy
    - no growth.
  - Local social, political, economic self-reliance
  - Redistribution of property rights.
- Concerning the Precautionary Principle
  - Burden should be on people causing problems.
  - up to the people to prove that it is not bad instead of up to the people to prove that it is bad.
  - Both San Francisco and Berkeley, Cali have passed Precautionary Principle Ordinances.
  - See Wingspread Consensus statement
- Core Principles of Sustainable Development
  - Equity
    - Promote economic and social justice within and amongst nations
  - Democracy
    - Secure effective citizen participation in decision making
  - The precautionary principle
    - Apply the precautionary principle
  - Policy Integration
    - Move beyond narrow preoccupations and compartmentalised concerns
  - Planning
    - Sustainable development must be planned. the issue is not whether but how much planning should take place

Energetics

- ❖ Two important concepts
  - Energy and Power
- ❖ Richard Feynman (physicist):
  - "It is important to realize that in physics today, we have no knowledge of what energy is. We do not have a picture that energy comes in little blobs of a definite amount"
- ❖ What can we say about energy?
  - There are many forms of energy:
    - Mechanical, electrical, solar, chemical, nuclear...
    - Energy can be transformed from one form to another.
  - Conservation of Energy
    - Energy can neither be created nor destroyed (1st law)
    - The total energy of an isolated system is constant.
    - In Coursepack: what happens if you start with coal to run your electric car.
    - 

  - Energy has the ability to transform a system
  - Associated with a transformation of a system is a transformation of energy from one type into another
  - Basic unit of energy is a Joule: SI unit of energy (=1newton-meter) or in England it is called a foot-pound (1J=1.356 ft-lb)
  - Potential energy - energy of position or configuration: gravitational potential energy, electric/magnetic energy, elastic potential energy, chemical potential energy
  - Kinetic energy - energy of motion
  - Thermal Energy
    - Calorie (small c): heat needed to raise one gram of water from 14.5 degrees C to 15.5 degrees C
    - Note: 1 calorie = 4.184J
    - Calorie (large C)=1000 calories = 1kcal (dietary calorie)
  - BTU(british thermal unit): heat required to raise 1lb. of water 1 degree Fahrenheit
    - note:1BTU=1054.35J
    - Quad (quadrillion 10to the 15th BTU): 1Quad = 1.055 EJ
  - Prefixes

k (kilo)	10^3	thousand
M (mega)	10^6	million
G (giga)	10^9	billion
T (tera)	10^{12}	trillion
P (peta)	10^{15}	quadrillion
E (exa)	10^{18}	quintillion

m (milli)	10^{-3}	thousandth
μ (micro)	10^{-6}	millionth
n (nano)	10^{-9}	billionth
p (pico)	10^{-12}	trillionth
f (femto)	10^{-15}	quadrillionth
a (atto)	10^{-18}	quintillionth

❖ Power - the rate at which energy is transformed
  - Watt: SI unit of power = 1j per second (1J/s)

❖

Be careful about units.

1 kJ = 1000 J (energy)

1 kW = 1000 W (power)

1 kWh = 1000 Wh = 1000 (J/s) x (h)

= 1000 (J/s) x (h) x (3600s/h)

= 3600000J

= 3.6 MJ (energy)

❖

Some energy values

Typical Caribbean hurricane	38 EJ
Largest H-bomb tested in 1961	240 PJ
Hiroshima bomb	84 TJ
Daily Adult Food Intake	10 MJ
Striking a typewriter key	20 mJ
A flea hop	100 nJ
1l of gasoline	~ 35 MJ
30l fill-up	~ 1GJ
Ave. energy use by Canadian per capita per day (direct and indirect)	825 MJ

❖ 240PJ = .2 exojoules

❖

Mass energy ($E=mc^2$)

Convert 1 gm grape into energy

Mass (m) = 1 g = 0.001 kg, c = $3x10^8$ m/s

$E = mc^2$ = $(0.001)(3x10^8)$

= 9×10^{13} J = 90 TJ

❖ about the size of the hiroshima bomb? if you could change the mass of the grape into energy.

❖

Some power values

Insolation	122 PW
Total primary energy supply (TPES)	13 TW
Terrestrial net primary productivity (NPP)	55-60 TW
Wind-generated ocean waves	90 PW
Worldwide fossil fuel combustion	10 TW
Large thermal power plant	5 GW
Basal metabolism 70 kg man	80 W

❖

More power values

Richter magnitude 8 earthquake (30s)	1.6 PW
Large volcanic eruption (10 hours)	100 TW
Average U.S. tornado (3 min)	1.7 GW
Running 100m dash (10 sec)	1.3 kW
Machine-washing laundry (20 min)	500 W
Playing a CD (60 min)	25 W

❖

If you were a light bulb?

1 Calorie = 1000 calories = 4186 J

2000 Calories = 8.4 MJ

1 day = 60 x 60 x 24 = 86,400 seconds

P = Energy/Time = 8.4×10^6 J/8.64×10^4 sec = 97.2 W

You' d be about 100W, but not much light.

❖

Energy density J/m^3 (Joules per cubic meter)

natural gas density = 0.7-0.9 kg/m^3

aviation kerosene density = 0.791 kg/l

Note: 1 m^3 = 1000 l

- Kerosene is a lot denser

❖ Specific energy J/kg (Joules per kilogram)

- would take power bars on a Mount Everest climb rather than vegetables, since vegetables have about 1/10th the specific energy.
-

Specific energy: amount of energy stored in a unit mass of a resource

	MJ/kg		MJ/kg
Gasolines	46-47	Pure protein	23
Crude Oils	42-44	Pure carbohydrate	17
Natural Gases	33-37	Cereal grain	15.2-.4
Butter	29-30	Lean meat	5-10
Ethanol	29.6	Fish	2.9-9.3
Best bituminous coal	27-29	Potatoes	3.2-4.8
Good lignite	18-20	Fruits	1.5-4
Air-dried wood	14-15	Vegetables	0.6-1.8
		Human feces	1.8-3.0
		Urine	0.1-0.2

- Energy intensity
  - energy consumed per unit output
- Energy efficiency

        - output per unit energy input
    - Energy intensity (or energy cost): energy to produce, extract, manufacture or provide goods and services (MJ/kg)
    - **Energy intensity of energy (J/J)**
      high for Persian natural gas
      not high for first ethanol from corn

      Energy intensity of an economy (J/$)
      in appropriate currency units
      in $ (constant monies) for long term comparison
      reveals disparities
        - want a high energy intensity.
- ❖ Power density (W/m2): The number of usable watts than can be produced per square meter of land (or water) by a given technology.
    -

Source	low	high
Natural Gas	200	2000
Coal	100	1000
Solar (PV)	4	9
Wind	0.5	1.5
Biomass	0.5	0.6

    - If you look at the area for the power plant and the wattage that the plant produces and work it out at watts per meter. power density is variable.
    -

Power density (W/m²)

Use	low	high
Cities	5	200
Industry	50	500
Supermarket	200	500
Steel mills, refineries	400	1000
High-rise buildings	500	4000

- ❖ Fossil Fuel Civilization
    - Power densities of electricity generation are 1-3 order of magnitude higher than most power densities of electricity use in buildings, factories and cities.
    - After fossil fuels, power densities of use will be higher than power densities of production which means more area will need to be devoted to energy generation.
- ❖ First law: Energy is conserved when it is transformed (it is not created or destroyed)
    - This doesn't explain the observation that changes seem to happen in a given "direction"
    - Put an ice cube on the counter top and over time it melts into liquid water. Over time the liquid evaporates into water vapor
    - How long will i have to wait for an ice cube to reappear on the counter top (from water vapor)?
- ❖ Second law of thermodynamics - Energy may not have been created or destroyed but something changed and it isn't likely to change back on its own
    - heat won't flow from a colder body to a warmer body without work being done to

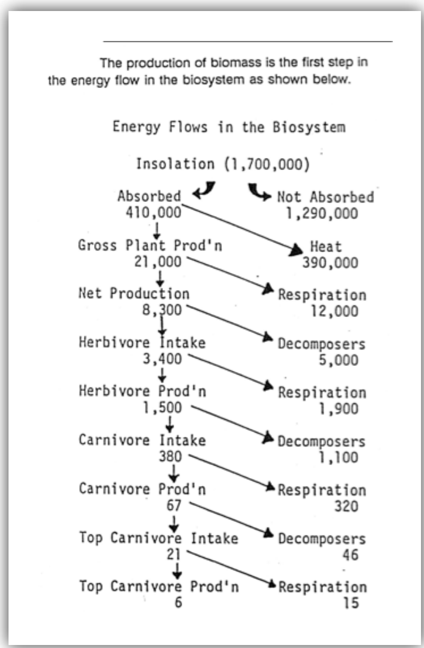
make it happen or...

- You cant extract heat from a hot reservoir and use it all to do work
- This mean that while energy can be transformed into another form without energy being created or destroyed, the quality of different forms of energy differs.
- Mechanical, gravitational, electrical, chemical energy are high quality and can always be converted into heat energy. Best natural gas furnace (household): Chemical energy to thermal energy (efficiency 95%)
- However, heat energy can only be converted into mechanical, gravitational, or electrical energy with limited efficiency. large steam turbine: Thermal energy to mechanical energy (efficiency 45%)

❖ Exergy

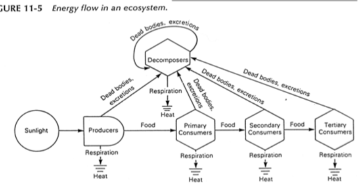
- the maximum useful work possible from a transformation that brings a system into equilibrium with its surroundings.
- Steam: high temperature water, can be used to make electricity (high quality, high exergy)
- Room temperature water: can't make electricity(low quality, low exergy)

❖ Anergy

- The low quality energy produced in an energy transformation that cannot produce useful work
  - Energy = Anergy + Exergy
  - E.g. heat given off by something in use
- sometimes, anergy can be useful as in the case of using process waste heat to heat a facility rather than using exergy to heat the facilty
  - Loblaws used heat from fridges to heat hot water.
- Example from nature
  - sun energy.
  - certain amount of energy captured as chemical energy in plants, some goes away through respiration but there is a net plant production the plant can then die and it goes to decomposers which produce heat or the plant can be eaten which provides energy to the animal eating it.
  - 

- net result is that there is no energy gained or lost in the system but sun energy in changed into all these different things.

- FIGURE 11-5 *Energy flow in an ecosystem.*



❖ Energy Consumption

- **World per capita energy consumption 2006 (source: EIA)**

  World (72.4 Million Btu)
  North America (276.2 Million Btu)
  USA (334.6 Million Btu)
  Canada (427.2 Million Btu)
  Russia (213.9 Million Btu)

- **World per capita energy consumption 2006 (source: EIA)**

Conversion (1 Btu = 1055 J)	**<u>Daily</u> (/365)**
World (76.4 GJ)	**(209.3 MJ)**
North America (291.4 GJ)	**(798.4 MJ)**
USA (353 GJ)	**(967.1 MJ)**
Canada (450.7 GJ)	**(1,235 MJ)**
Russia (225.7 GJ)	**(618.4 MJ)**

- **World Primary Energy Consumption (Quads) 2006**

  World (472.27 Quads) (498.2 EJ)

  Petroleum (171.723 Quads) (180.1 EJ)
  Dry Natural Gas (107.998 Quads) (113.9 EJ)
  Coal (127.548 Quads) (134.6 EJ)
  Net Hydroelectric (29.728 Quads) (31.36 EJ)
  Net Nuclear Electric (27.758 Quads) (29.28 EJ)
  Net 'Alternative' (4.721 Quads) (4.98 EJ)

  Conversion (1 Quad = 1.055 EJ)

  - the net alternative energy is small compared to the rest.

- **Energy Consumption <u>USA</u> 2007**

  Petroleum (40.642 Quad) (42.88 EJ)
  Nuclear electricity (8.13 Quad) (8.58 EJ)
  Natural Gas (23.37 Quad) (24.65 EJ)
  Coal (22.35 Quad) (23.58 EJ)

  Renewables Biomass (3.62 Quad) (3.82 EJ)
  Hydroelectric (2.46 Quad) (2.59 EJ)
  Geothermal (0.342 Quad) (0.36 EJ)
  Wind (0.342 Quad) (0.36 EJ)
  Solar (0.0683 Quad) (0.072 EJ)

  Conversion: 1 Quad = 1.055 EJ

- Total Energy (Canada 2006) domestic demand by sector

Mining, Oil and Gas Extraction	503 PJ
Total Manufacturing	1,727 PJ
Forestry	21.5 PJ
Construction	60.7 PJ
Total Industrial	2,312 PJ
Total Transportation	2,373 PJ
Agriculture	211 PJ
Residential	1,250 PJ
Public Administration	128 PJ
Total Demand	7,560 PJ

(Source: Stats Can)

- Total Energy (Canada 2006)

Passenger Road 1,123 PJ (311.9 TWh)
Transportation (Source: NRCan)

Electricity Generation Canada 590.7 TWh

Conversion: 1 PJ = 277.778 GWh

-

Sustainability & Complex Adaptive Systems (CAS)

- The earth, countries, cities, communities, households and individuals
  - all these are CAS that interact non-linearly with and have unpredictable impacts on CAS at other levels.
- What are the characteristics of a CAS?
  - 1.CAS are made up of diverse agents that learn
  - 2.Many relationships among agents in a CAS are non-linear
    - cause and effect are not necessarily proportional (small events can cause large disruptions/ large events can cause small disruptions)
      - e.g. introduce invasive species such as zebra mussels
    - System outcome based on interactions between agents cannot be predicted
    - Efforts to predict and control outcomes may cause more harm than good.
  - 3.Self-organization
    - decentralized process
    - interactions create order (without guidance from form structures)
      - e.g. feeding Manhattan (or ottawa)
    - No formal managers exist to direct/oversee process
  - 4.Emergent properties
    - dynamic characteristics of a system created through agents' interactions over time.
    - Can't be explained through analysis
      - e.g. recycling behaviours, attitudes towards energy conservation, levels of sustainability.
  - 5.Co-evolution and fitness landscapes
    - "agents and systems co-evolve with their environments. as agents in a CAS interact to optimize their positions on the fitness landscape, the landscape changes. As the landscape changes over time, agents must continuously evaluate their decisions and take new action based on these evaluations"
- Consider a city
  - Made up of many organizations and groups and resources
  - each of the organizations and groups is made up of individuals with ranges of education, financial resources, attitudes and values
  - Each element of the city system dynamically interacts with other elements in a continuous cycle of co-evolution. The perpetual co-evolution generates the pattern of movement of the city system across its fitness landscape.

> **"Complexity science and CAS thinking allow us to recognize our inherent inability to predict and control system outcomes because of non-linear relationships, self-organization, emergent properties, and co-evolution. As one accepts the presence of fundamental uncertainty in CAS, attention is freed from attemps at uncertainty avoidance and can subsequently be redirected toward recognizing and embracing uncertainty. If one assumes the core of sustainable development really occurs in the interactions among many CAS at many levels, one must also accept the fact that sustainability is not something that can be achieved through balance. Rather, sustainable development is something toward which we must continuously strive. As we strive toward sustainability, we change the world."**

> **"Traditional approaches to sustainable development focus on the achievement of sustainability and typically assume that once sustainability is reached, the problem is solved. Ideas from complexity science imply that this type of approach will not work. Rather, sustainable development will require dynamic, process-oriented approaches that emphasize the ability of systems to continuously solve and resolve problems."**

- Lake Erie Example
  - in the 1970s there was a problem in Lake Erie
  - Parts of it were dead. that is to say that in those places there was no oxygen in the water
  - The cause was eutrophication (too much nutrient)
    - causes algal and plant growth
    - algae and plants die
    - their decomposition uses up dissolved oxygen.
  - Whole lake experiments were carried out at the Experimental Lakes Area (ELA)
  - These showed that the principle problem material was phosphorus and jurisdictions around Lake Erie undertook to solve the problem. Treatment of wastewater, prevention of runoff from agricultural land, eliminating phosphorus where possible form items such as cleaning products.
  - The diagnosing and remedial actions were successful.
  - But now, with the successful remedial actions in place, the dead zone has reappeared and phosphorus levels are on the rise.
  - The cause is unclear, but it has been attributed by some to the introduction of zebra mussels. When they feed, they re-suspend phosphorus-rich bottom sediments possibly leading to increased phosphorus levels in the water.
  - Sustainability was reached in the Lake Erie CAS, and the problem was solved. But now the Lake Erie CAS must re-solve the problem.

Quiz 1

30 mins to do quiz.
Save answers as you go..
no time limit set, so watch your time.
Available for 2 days.
use firefox!

Risk and Uncertainty

- Both sustainability and sustainable development consider the future
- In sustainable development, for example, the notion of capital bequests to the future leads to the four "types" of sustainability: very weak, weak, strong, and very strong based on how we substitute one form of capital for another
- But we leave something else to the future:risk
- If we leave the future the forms of capital associated with a car culture, for example, we also leave them the risk of death in a car accident
- If we relinquish car culture and go back to the horse (thus possibly gaining environmental capital) we remove death by auto as a risk and introduce the risk of death by horse accident might be greater.
- The one tool we've seen that addresses risk is the precautionary principle
  - When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.
- The principle tool use to deal with risk is risk assessment, a process that the Wingspread folks have singled out as failing to provide the basis for good decision making
- What is risk assessment? how does it related to uncertainty? And, more generally, how does assessment related to how we think about the future?
- Consider Shakespeare's Hamlet who is assessing action in the future.
  -

> **But that the dread of something after death,**
> **The undiscover'd country from whose bourn**
> **No traveller returns, puzzles the will**
> **And makes us rather bear those ills we have**
> **Than fly to others that we know not of?**
> **Thus conscience does make cowards of us all;**
> **And thus the native hue of resolution**
> **Is sicklied o'er with the pale cast of thought,**
> **And enterprises of great pith and moment**
> **With this regard their currents turn awry,**
> **And lose the name of action…** ***Hamlet***

  - Assessing if he should kill himself or not.
  - Here, assessment, "the pale case of thought" leads to inaction "And enterprises of great pith and moment... lost the name of action'
  - On the other hand, in some circumstances we don't let the unknown stand in our way. Instead we embrace it.
- Is there some middle ground between fear and recklessness? Between inaction and action? What is it that we need to control?
  - Captain Kirk and Hannah Arendt quotes in slides. 8 and 9
    - We are no longer concerned with objects but with projects.
    - Our project, if we want to treat the risks we leave to the future requires dealing with uncertainty. Let's see how risk assessment does this.
- The uncertain future presents various hazards (potential sources of danger
  - Infections and degenerative diseases
  - Natural disasters

- Failure of complex technological systems
- Discrete, small-scale accidents
- Low-level, delayed effect hazards
  - radiation exposure
- Sociopolitical disruption
  - Tunisia
- Environmental hazards (human-caused)
  - maybe global warming, if you think its human caused

❖ Associated with each hazard is a risk

- Risk = Probability (P) x Consequence (C)
  - Here the probability is the probability of the occurrence of the hazard where P ranges in value from 0 (certain that something wont happen) to 1 (certain that something will happen)
  - The consequence are some measure of the negative impacts should the hazard occur ($)

❖ Example: Near-Earth Asteroids

- Let's say a big one hits the Earth every 100 million years. The probability that w big one will hit the Earth next year is roughly 1/100 million or 1x10^-8
- Let's say the consequence would be loss of half the earths population (3.5 billion @ 1 million each) and 9/10 of the total world value (1 x 10^15)
- Then the annual risk posed by near-earth asteroids would be roughly 1x10^7 or 10 million.
- It could be argued that it would be reasonable to spend up to 10 million/year on technologies (like nuclear weapons) to manage the risk of near earth asteroids.
- Not surprisingly when treating risk this way there is often disagreement about valuation of consequences (how much a life is worth) and which consequences should be included (value of ants)

❖ Probability is one expression of uncertainty, the uncertainty of when a known hazard might occur.

- However, uncertainty can be more general, as in a case where the hazards are unknown
- this leads to 3 Cases

❖ Three Cases

- 1. Decision-making under Risk (DUR)
  - Know possible outcomes
  - Know their probabilities
  - (Hoek van Holland) place in Holland
  -

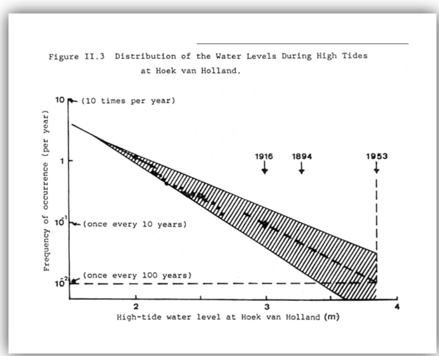


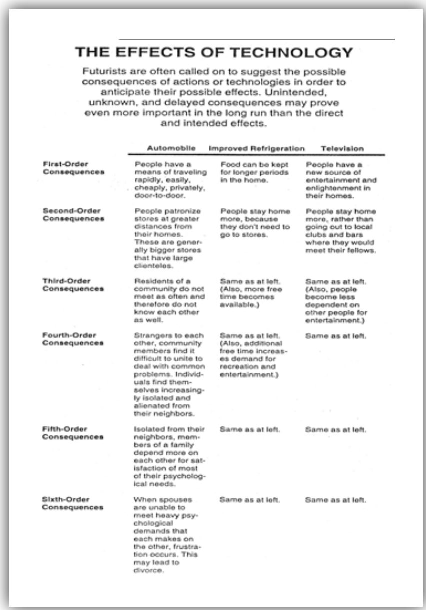
Figure II.3 Distribution of the Water Levels During High Tides at Hoek van Holland.

  - Recording the height of the tides, lots of data available for the tide levels at

Hoek van Holland. Can convert frequency into probability.

- after WWII, holland had a lot of problems, damage to the dykes that were keeping the sea out, did a patch job on the dykes. in 1953 they had the 100 year high tide and a lot of people died due to the water levels. cannot tell from a probability exactly when something will occur.

- 2. Decision-making under Uncertainty (DUU)
  - Know possible outcomes
  - Probabilities unknown or known with insufficient precision
  - (Herbicides/Hillier)
  - **Official drank herbicides to prove safety. Kelowna, B.C. (CP)**
    The former chairman of the B.C. environmental appeal board says he took controlled doses of five different herbicides to prove to himself they were safe.
    Frank Hillier, who resigned in December after eight years with the provincial body, said he had to test them because he felt he had a moral responsibility to ensure herbicides he approved for use were safe.
    "I didn't really do anything brave," Hillier said Wednesday. "I was almost 100 percent sure."
    The 67-year-old mechanical engineer told a board hearing in Kelowna on Tuesday that he became convinced during his years as chairman that most pesticides were not harmful if used in the concentrations recommended by the manufacturers.
    Yet he kept hearing people testifying that they had been adversely affected by the herbicides that the board was making decisions about.
  - Took herbicides to show that they were not hazardous as recommended by the companies
- 3. Decision-making under Unknown Possibilities (DUUP)
  - Possible outcomes unknown
  - Probabilities unknown
  - Risks of car pollution vs. horse pollution
  - Bizarre as the idea might seem these days, there once was a time when the automobile was seen as the perfect answer to urban pollution. That was back at the turn of the century [19th-20th], when horses provided virtually all the motive power for society - and daily deposited some 2.5 million pounds of manure and 60,000 gallons of urine on the streets of New York City alone. Small wonder that turn-of-the-century scientists hailed the development of the auto as a clean, quiet and efficient means of transportation. Some even thought that travel by motor car would be much safer that it was by horse-drawn vehicles - and on this count, surprisingly enough, they were absolutely right. But no one foresaw that the auto would someday create pollution problems much more severe than did the horse it replaced."
    Newsweek, March 6, 1972, p. 57
  - "Ontario Hydro faces financial meltdown," Halifax Chronicle Herald, October 31, 1991, p. C12.
    "The problems mounted last January when the first reactor completed at Darlington was shut down because mysterious cracks were found in cylinders holding the reactor's fuel bundles.
    Hydro still can't say for sure what's causing the cracks–even though it has spent $13 million to find out what's wrong.
    Anderson [Don Anderson, Vice President] concedes it has taken "too damn long" to fix the vibration that appears to be at the heart of the puzzle.
    "We've got all those 350 scientists and engineers up there with stethoscopes listening to this thing trying to find out where this heart murmur is...when we find it, we can fix it, I know we can."
  - Hydro ottawa nuclear reactor problems. was eventually fixed. fluids have to be moved around in the nuclear plant, the pumps vibrate for these fluids and was causing vibrations to amplify in the layout and causing cracking.

- 

THE EFFECTS OF TECHNOLOGY

Futurists are often called on to suggest the possible consequences of actions or technologies in order to anticipate their possible effects. Unintended, unknown, and delayed consequences may prove even more important in the long run than the direct and intended effects.

	Automobile	Improved Refrigeration	Television
First-Order Consequences	People have a means of traveling rapidly, easily, cheaply, privately, door-to-door.	Food can be kept for longer periods in the home.	People have a new source of entertainment and enlightenment in their homes.
Second-Order Consequences	People patronize stores at greater distances from their homes. These are generally bigger stores that have large clienteles.	People stay home more, because they don't need to go to stores.	People stay home more, rather than going out to local clubs and bars where they would meet their fellows.
Third-Order Consequences	Residents of a community do not meet as often and therefore do not know each other as well.	Same as at left. (Also, more free time becomes available.)	Same as at left. (Also, people become less dependent on other people for entertainment.)
Fourth-Order Consequences	Strangers to each other, community members find it difficult to unite to deal with common problems. Individuals find themselves increasingly isolated and alienated from their neighbors.	Same as at left. (Also, additional free time increases demand for recreation and entertainment.)	Same as at left.
Fifth-Order Consequences	Isolated from their neighbors, members of a family depend more on each other for satisfaction of most of their psychological needs.	Same as at left.	Same as at left.
Sixth-Order Consequences	When spouses are unable to meet heavy psychological demands that each makes on the other, frustration occurs. This may lead to divorce.	Same as at left.	Same as at left.

❖ DUU versus DUUP

- Hexachlorophene: It is not generally recognized that many organochlorine compounds are toxic, including some that have been in common use. For example, the substance hexachlorophene was commonly used in soap and patented facial cleansers not too many years ago. It is still used in hospitals as a cleaning emulsion, at 3% concentration of the organochlorine. And yet a baby powder that contained 6.3% of the substance resulted in poisoning of 204 French children with 36 deaths. (Kraft Mill Effluents in Ontario, MISA, 1988)
    - Antibacterial material to help with bed sores.

❖ DUR - Formal methods to evaluate

❖ DUU - can reduce uncertainty? More information, Data quality.

❖ More info?

- In west,
- Infallible, demonstrable knowledge an attainable goal
- Before committing to decisions, maximize information/knowledge
- But, watch quality analysis!
    - better systems to watch water quality, and what's in it.
- Border with ignoring
    - those events which cannot be foreseen
- Must important scientific discovery
- The ultraviolet catastrophe
- Epigenetics
- CAS

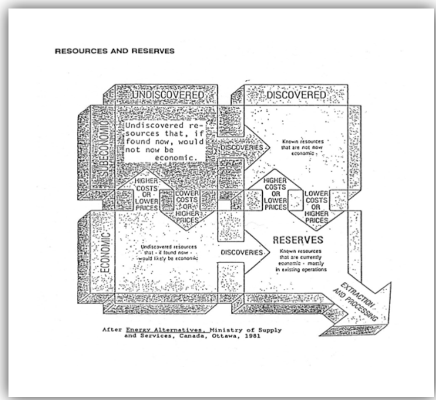
❖ It may be that the will to act on environmental issues is related to the degree of risk presented by those issues. This would seem to agree with the Four Myths of Nature

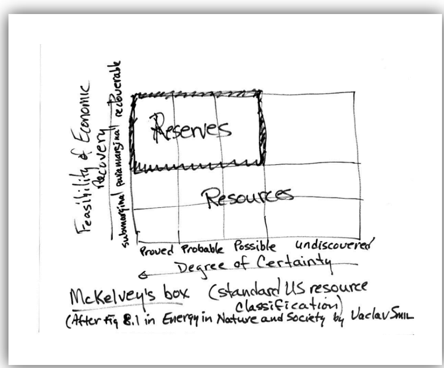
- 1. Nature Benign
    - Individualistic (peoples personalities)
    - Nature robust/resilient/not disturbed easily
    - Low environmental concern, not worried about the environment
    - Regulation threat to autonomy/unacceptable
    - Environmental probs solvable with free markets
    - Technical optimism/opportunities for prosperity

        - Low risk
        - uncertainty unimportant
    - 2. Nature Tolerant
        - Hierarchical
        - Nature moderately vulnerable system
        - Moderate concern
        - Nature resilient up to a point
        - Only experts know nature's limits
        - how many governments work.
        - Environmental problems best handled by regulation based on expert knowledge
        - Moderate risk
        - DUR
    - 3. Nature Ephemeral
        - Egalitarian
        - Nature fragile and precarious system
        - High environmental concern
        - Natural resources limited and depleting
        - Technology major source of environmental problems
        - Solution is radical behavioural change
        - High Risk
        - DUP/DUUP
    - 4. Nature Capricious
        - Fatalistic
        - No coherent view of nature
        - Low environmental concern
        - Life a lottery
        - No particular risk management strategy
        - No preferences/ won't matter
        - Uncertainty irreducible.

❖ Thus, we have:
- Known risk (low, medium, high) and unknown risk
- Those who feel that risk is higher see the need to take "more" action on behalf of the environment.
- So, when we think about sustainability and what we are leaving to the future, we should include those risks that we are creating/ passing on and the risks that we are eliminating
    - Consider smallpox. This was a killer disease that took millions of lives every year for centuries. It's only carrier is humans. In the 20th century a vaccine was developed that protected people in the developed world. This was good, but it was also an ongoing cost since every child needed to be vaccinated.
    - The hope was that some suitable program could be developed that would eliminate the disease. This was achieved toward the end of the 20th century.
    - We no longer vaccinate for smallpox. Is the risk eliminated? Unfortunately no. Smallpox in the general population is gone, but it exists in weaponized form in a handful of countries, a risk left for the future.

Resources and Reserves

- ❖ See Table "Present or Future Near-infinite resources page G2
  - For many materials, possibly a selection on which we could maintain a civilization, there are near-infinite resources having a resource/demand rations in the millions of years
- ❖ Resources vs. Reserves
  - the relationship between resources and reserves is illustrated in figure on G1 coursepack
  - 

  - resource- something that is discovered but not economically viable.
    undiscovered and not economic and not yet discovered.
  - Reserves (what we can use) are discovered, economic resources.
  - This can move around through these different boxes, e.g. extraction process or production could change to make it more viable.
  - horizontal movement is presented as only being one way, cannot undiscover something.
  - note that the boundaries among the categories in the figure G1 are fluid. something that is discovered and uneconomic could be come economic if the costs of production dropped (new technology?) or prices rose (markets). Reserves depend on more than amounts of material but also on social factors (invention/ trade)
  - similarly, something that would be economic but which is undiscovered could be discovered.
  - The figure doesn't show a discovered to undiscovered path. Could there be one?
  - 

- submarginal, paramarginal, recoverable (economic) on vertical axis.

❖ Natural Resources Canada

- **Consider the following data from Natural Resources Canada:**

Substance (Year)	Remaining Reserves	Reserve Life	2007 Amount
Copper (1974)	17.048×10^6t	21 yrs	7.565×10^6t
Lead (1974)	9.31×10^6t	32 yrs	6.82×10^5t
Zinc (1974)	28.274×10^6t	25 yrs	5.98×10^6t
Molybdenum (1974)	3.44×10^5t	25 yrs	2.12×10^5t
Silver (1974)	28,587t	21 yrs	6,588t

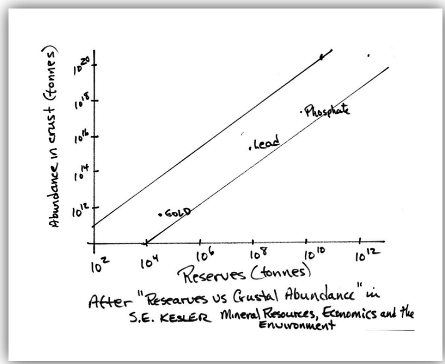
- R/D ratios are fluid, combination of price and technology change.

❖ here you can see that the reserve life based on the amount of a reserve divided by the demand per year in not immutable. several of these substances should have run out before 2000, however there are still reserves.

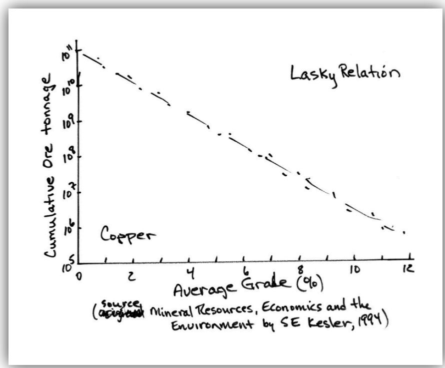
❖ You can also see that the remaining reserves in 2007 are less than in 1974.

❖ High level radioactive waste from nuclear production of energy could be desirable/ marketable to terrorists to make dirty weapons
  - proposals to dispose of the waste by deep burial in the Canadian Shield would leave the material exposed to theft unless protected, and given the radioactive lifetimes and the resultant cost of protection over those lifetimes, some have suggested that the material be buried and "lost"

❖ The graph of reserves versus crustal abundance shows that there were roughly 10^8 more tonnes of crustal resource than there are resources of many substances.
  - the graph of the Lasky relationship shows how there is a logarithmic decrease in ore tonnage as the grade of ore increases arithmetically (for copper)

❖ 

  - tonnes of the reserve on the bottom and the vertical the tonnes of the substance that is assumed to exist in the earths crust. what you find is that the two lines show upper and lower bounds for the data, you can see that on average there is roughly 10^7 to 10^8 more material in the crust than in the reserves. A lot of material that is resource but a lot that cannot be used.

❖ 

- Graph for copper,

❖ The patterns of resource abundance Figure on p G3 of the course pack shows the relationship between concentration of a mineral resource versus volume of resource. Note how the majority of the volume is unrecoverable. Also note that "reserves" is used where we would say "resources"

❖ The grade of a reserve also has a relationship to energy

- the figure on pG3 "energy requirements for metallurgy) shows how the energy required to extract metal from ore increases as the grade of the ore decreases.

❖ The consideration of mineral resources illustrates how materials become non-renewable by change in concentration. Substances such as gold and copper and aluminum are mined, used and dispersed. The amount of gold on the planet remains the same. The amount what we can't use increases.

- The concentration of mineral resources can also affect energy demand.

❖ Helps explain non-renewability.

❖ The final will have 4 essay questions...:l

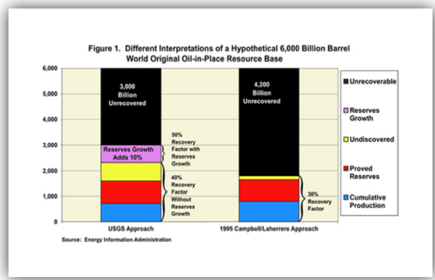
Fossil Fuels

- Forms of Fossil Fuels
  - Coal
  - Crude Oil and Natural Gas Liquids
  - Oil Shale
  - Natural Bitumen and Extra-Heavy Oil
  - Natural Gas
- Coal Types
  - Typically 4 types of coal
  - Anthracite (hardest coal, highest energy content)
  - Bituminous (lower energy content, use in steel and electricity production)
  - Sub-bituminous (softer than bituminous, higher water content, used in electricity production)
  - Lignite (lowest energy content, electricity production sometimes)
- Coal
  - World Coal Reserves (end of 2008)
    - 860 Billion tonnes*
      - 405 billion tonnes bituminous (including anthracite)
      - 260 billion tonnes sub-bituminous
      - 195 billion tonnes lignite
    - * 13 billion tonnes higher than 2003 reserves.
- Coal Energy Densities
  - Anthracite approx 29-31 MJ.kg (~85% Carbon)
  - Bituminous approx 28-29 MJ/kg (~80%C)
  - Lignites approx 8-20 MJ/KG (~65% C)
- Coal Resources and Reserves(Energy)
  - Resources 200ZJ (zeta joule) Reserves (2005) 20ZJ
    - By comparison
      - Total world primary energy consumption
        - (2005) 261.428 Quad (486 EJ) exa joule
        - (2008) 492.587 Quad
      - Canada primary energy consumption
        - (2005) 14.164 Quad (14.9 EJ)
        - (2008) 14.029 Quad
- Coal Combustion Produces
  - Energy (heat, light)
  - CO_2 (carbon dioxide) SO_2 (sulphur oxide)
  - NO_x (NO and NO_2) nitrogen
  - Coal can also be used to produce secondary fuels.
- Solid secondary fuels
  - Coke
    - Made by heating bituminous coal in the absence of air to roughly 1000 Celsius. Coke contains 80-90% C and has a specific energy of about 28 MJ/Kg
  - Coal Dust/Dried lignites

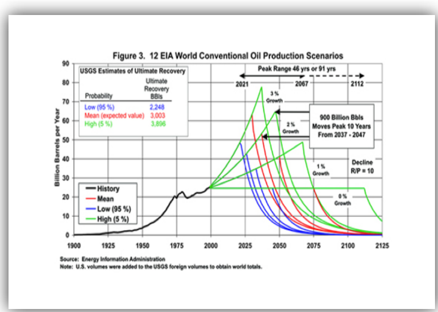
        - Wastes and unwanted fuels can be pressed into briquettes and used for fuel
- Gaseous Fuels
    - Coal can be gasified under various conditions of
        - temperature (600-1400 Celsius)
        - Pressure
        - Amount of oxygen
        - The products of these gasification reactions are called synthetic gas or syngas.
        - Syngas is a variable mixture of carbon monoxide and hydrogen with small amounts of other gases. The composition of the mixture depends on the reactions conditions.
        - Syngas can be used as a fuel. It has an energy density about half that of natural gas.
        - Syngas can be used to make virtually all the products presently obtained from the petroleum industry.
        - It can be used to make synthetic natural gas, and the hydrogen can be used in fuel cells.
        - (a lot of energy goes into making syngas)
- Liquid Fuels
    - Direct Liquification
        - Coal can be dissolved in solvents at high temperature and pressure and then refined.
    - Indirect liquification
        - Convert coal to syngas. Then convert syngas to petroleum and diesel using Fischer-Tropsch chemistry.
        - The syngas followed by Fischer-Tropsch combination can be used to produce a range of other products including
            - other liquid fuels such as methanol
            - synthetic waxes and lubricants
            - chemical feedstocks
            - (note: carbon monoxide /Fischer-Tropsch has been used in the past to produce petroleum. Approx. one quarter of Germany's auto fuel during WWII was prepared this way.
    - The gasification/liquification processes are not limited to coal as the starting material. Biomass, agricultural waste, forestry waste can all be used in the process.
    - There are also studies of using carbon dioxide that is dissolved in sea water as a starting material. This is isolated, converted into carbon monoxide and reacting used Fischer-Tropsch methods to produce fuels.
- Crude Oil
    - Crude oils come in different forms from less dense, less viscous to dense and viscous
    - They are made up primarily of variable amounts of members of three homologous series of hydrocarbons, compounds that contain only carbon and hydrogen. (Alkanes, cycloalkanes and arenes)
    - Products derived from crude oil
        - Motor gasoline
        - Aviation gasoline
        - kerosene - type jet fuel

        - distillate fuel oil (diesel)
        - petrochemical feedstocks
        - lubricants
        - waxes
        - asphalt

- ❖ Crude oil world resources and reserves.
    - Proved Reserves
        - World 1354.182 (Bbbl) Billions of barrels (2008)
        - Canada 175.214 Bbbl (2008)
        - World resources 15 ZJ (zeta joules) more energy in coal
        - World Reserves 7 ZJ
- ❖ World Crude Oil Demand
    - Daily Demand 85.5 mbbl/d (millions of barrel a day) (2010)
    - Forecast consumption growth
        - 1.4 mbbl/d (2011, 1.6%)
        - 1.6 mbbl/d (2012, 1.8%)
    - Annual Demand (based on daily demand)
        - 31.6 Bbbl/y which gives R/D ~ 42 years



- ❖ Ways of looking at the totality of oil, no agreement to what is out there. on the left the USGS approach - believed to be conservative. black part is how much is believed to be unrecoverable. Yellow is undiscovered. Cumulative production - what has been burned.purple part - price change, making more recoverable.
- ❖ But the real problem may not be when we will run out of crude oil but rather when we will reach the peak level of production of crude oil. At that point we will be in a situation where we can't recover crude oil any quicker. but demand for oil will still continue to grow
    - The time at which world oil production peaks is called Peak oil.
- ❖ There is must discussion about when peak oil will occur. Some think that it has already happened. Some think that it will never happen. The following graph from the US energy information agency shows what many feel are good estimates of peak oil under several different circumstances.
    -



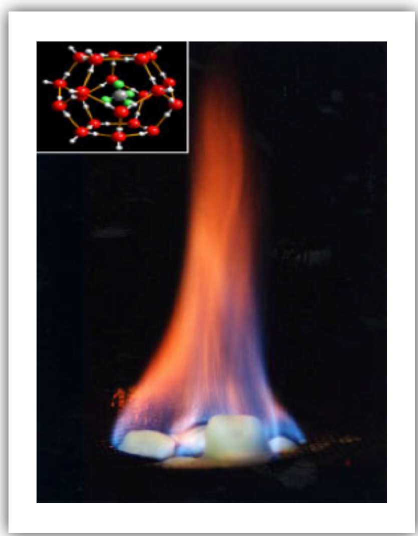
❖ Natural Gas

- Natural gases are mixtures of methane, ethane and propane with methane being the major constituent (> 70%)
- Energy density of methane : 35.5 MJ/m^3
  - Resources: 15 Zk
  - Reserves 7ZJ
- Reserves of Natural Gas
  - World 6.6 QCF (quadrillion cubic feet (0.1868 QCM) quadrillion cubic meter
  - Canada 62 TCF
  - Note: 900-1200 BTU/ft^3

❖ Liquified Natural Gas (LNG)

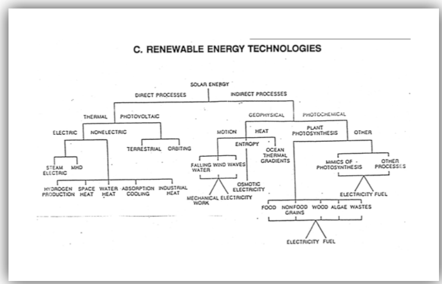
- Natural gas condenses into a liquid when cooled to approximately -160 celsius. This is used since LNG has a volume roughly 600 times smaller than natural gas, and it can be stored and transported while in the liquid state. There is a significant energy cost involved in making and storing LNG, but it offers the possibility of extracting natural gas from deposits that can't economically be connected to a pipeline.

❖ Methane Hydrates

- Methane hydrate chunk with dissociating methane gas.
- 
- The bubbles are the methane, methane hydrate is the chunk
- Methane hydrates have been blamed for the strange events that have occurred in the Bermuda Triangle. Some people believe that sudden large release of methane into the water column reduce the water density to the point where vessels overhead at the surface can no longer float.
- 
- Burning methane hydrate.

- As organic matter decomposes anaerobically at the bottom of deep water bodies, the methane released gets trapped in ice-like structures created when water is subjected to high pressure and low temperature
  - Upper depth limits for the formation of methane hydrates
    - Polar: 100m
    - Oceanis: 300m
    - Warmer oceans :2000m
  - Methane hydrates are one of a type of chemical compound known as a clathrate
  - The world resource is estimated to store greater than 500 ZJ of energy. This is more than combined global coal, oil and natural gas resources.
  - The problem is how to handle the material on a large scale. Methane is a potent greenhouse gas, with a greenhouse gas potential roughly twenty time that of carbon dioxide. While there is much energy contained in methane hydrates, there is a significant risk of releasing large amounts of greenhouse gas if the material is "processed"
  - Even if methane hydrates are never used, clathrates may still e useful. They have been studied as a way to remove carbon dioxide from the atmosphere by locking the carbon dioxide in the clathrate structure.

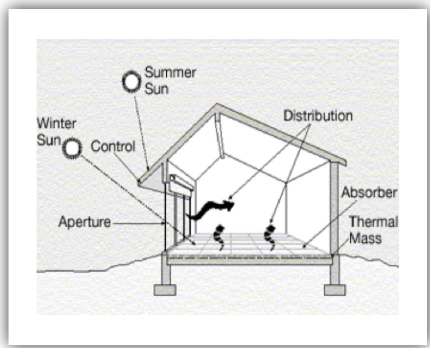
Direct Solar Proceses



- ❖ In this module we will look at three types of direct solar technologies
  - Passive solar
  - Active solar
  - Solar photovolaic
- ❖ Passive solar
  - As a fundamental law, heat moves from warmer materials to cooler ones until there is no longer a temperature different between the two. To distribute heat throughout the living space. a passive solar home design makes use of this law through the following heat-movement and heat-storage mechanisms
    - Conduction
      - is the way heat moves through materials, traveling from molecule to molecule. Heat causes molecules close to the heat source to vibrate vigorously, and these vibrations spread to neighbouring molecules, thus transferring heat energy. For example, a spoon placed into a hot cup of coffee conducts heat through its handle and into the hand that grasps it.
    - Convection
      - Convection is the way heat circulates through liquid and gases. Lighter, warmer fluid rises and cooler, denser fluid sinks. For instance, warm air rises because it is lighter than cold air, which sinks. This is why warmer air accumulates on the second flood of a house, while the basement stays cool. Some passive solar homes use air convection to carry solar heat from a south wall into a buildings interior.
    - Radiation
      - Radiant heat moves through the air from warmer objects to cooler ones. There are two types of radiation important to passive solar design: solar radiation and infrared radiation. When radiation strikes an object, it is absorbed, reflected or transmitted, depending on certain properties of that object.
      - Opaque objects absorb 40-95% of incoming solar radiation from the sun, depending on their colour, darker colours typically absorb a greater percentage then lighter colours. This is why solar-absorbed surfaces tend to be dark coloured, Bright-white materials or objects reflect 90-98% of incoming solar energy.
      - Inside a home, infrared radiation occurs when warmed surfaces radiate heat towards cooler surfaces. For example, your body can radiate infrared

heat to a cold surface, possibly causing you discomfort. These surfaces can include, walls, windows or ceilings in the home

  - Clear glass transmits 80-90% of solar radiation, absorbing or reflecting only 10-20%. After solar radiation is transmitted through the glass and absorbed by the home, it is radiated again from the interior surfaces as infrared radiation. Although glass allows solar radiation to pass through, it absorbs the infrared radiation. The glass then radiates part of that heat back to the home's interior. In this way, glass traps solar heat entering the home.

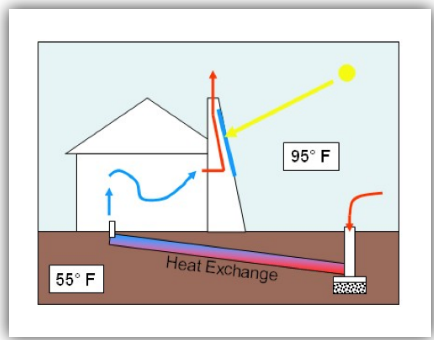
- Thermal capacitance
  - Thermal capacitance refers to the ability of materials to store heat. Thermal mass refers to the materials that store heat. Thermal mass stores heat by changing its temperature, which can be done by storing heat from a warm room or by converting direct solar radiation into heat. The more thermal mass, the more heat can be stored for each degree rise in temperature. Masonry materials, like concrete, stones, brick and tile, are commonly used as thermal mass in passive solar homes. Water also has been successfully used.
  - 

- Complete passive solar design
  - The following five elements constitute a complete passive solar home design. each performs a separate function, but all five must work together for the design to be successful
    - Aperture
    - Absorber
    - Thermal mass
    - Distribution
    - Control
- Aperture (Collector)
  - The large glass (window) are through which sunlight enters the building. Typically, the aperture(s) should face winthin 30 degrees of true south and should not be shaded by other buildings or trees from 9am to 3pm each day during the heating season.
- Absorber
  - The hard, darkened surface of the storage element. This surface - which could be that of a masonry wall, floor or partition (phase change material) or that of a water container. sits in the direct path of sunlight. Sunlight hits the surface and is absorbed as heat.
- Thermal Mass
  - The materials that retain or store the heat produced by sunlight. The difference between the absorber and thermal mass, although they often form the same

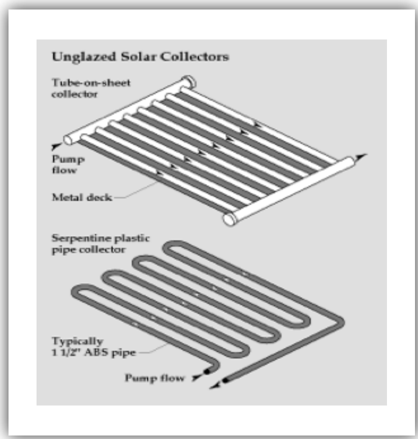
wall or floor, is that the absorbed is an exposed surface whereas thermal mass is the material below or behind that surface.

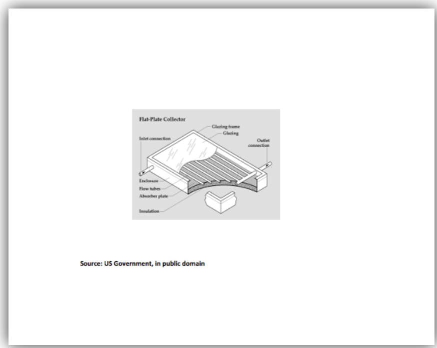
- Distribution
  - The method by which solar heat circulates from the collection and storage points to different areas of the house. A strictly passive design will use the three natural heat transfer modes - conduction, convection and radiation - exclusively. In some applications, however, fans, ducts and blowers may help the distribution of heat through the house.
- Control
  - Roof overhangs can be used to shade the aperture area during summer months. Other elements that control under - and/or overheating include electronic sensing devices, such as a differential thermostat that signals a fan to turn on; operable vents and dampers that allow or restrict heat flow; blinds; and awnings.
- You can also use passive solar design elements together to accomplish passive solar cooling.

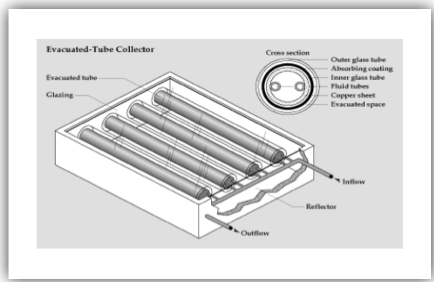
❖ Solar chimney for passive solar cooling

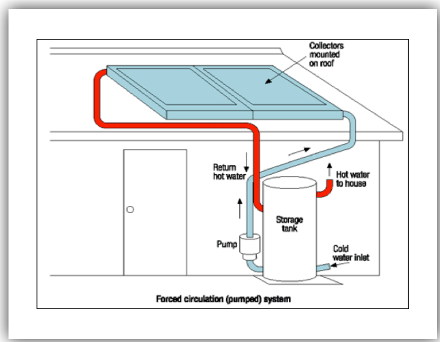
- 

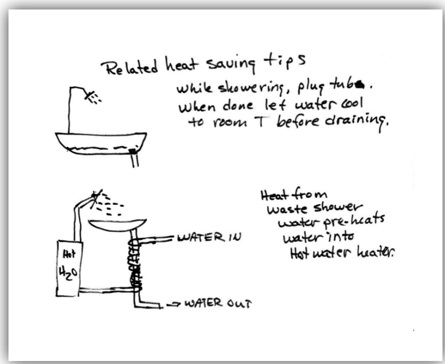
❖ Active Solar

- Active solar uses the same heat transfer principles as passive solar. The different between the two is that active solar incorporates a working fluid to transfer heat from one place to another.
- 

- 

- 

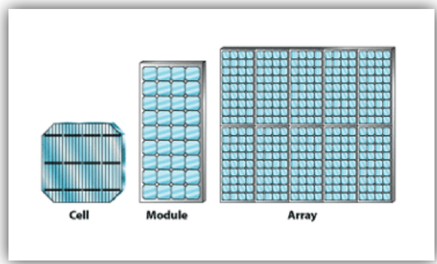
- less heat loss out of tubes.
- Active solar example
- 

- help heat hot water.
- 

- if a pipe with the waste water wrapped around the cold water pipe thats going to the heater to heat it a bit.

❖ Solar Photovoltaic

- Solar cells - the basic building blocks of a PV system - consists of semiconductor materials. When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms. This phenomenon is called the "photoelectric effect". These free electrons then travel into a circuit built into the solar cell to form electrical current... Only sunlight of certain wavelengths will work efficiently to create electricity. PV systems can still produce electricity on cloudy days, but not as much as on a sunny day.

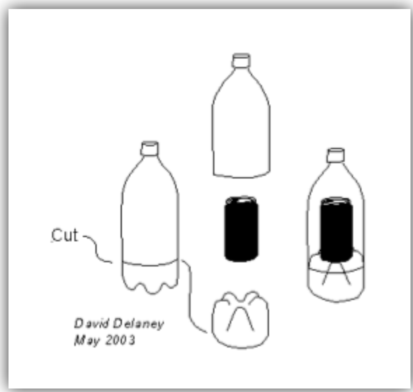
- The basic PV or solar cell typically produces only a small amount of power. To produce more power, solar cells (about 40) can be interconnected to form panels or modules. PV modules range in output from 10 to 300 watts. If more power is needed, several modules can be installed on a building or at ground-level in a rack to form a PV array.
- 

❖ Solar cooker

- "large" area of reflector
- darkened pot
- "greenhouse"
- 
- Parabolic Solar Cooker
  - 

❖ Retained heat cookers

- Women at the workshop were also taught to cup up old sheets and sew them into large pillows, which they could stuff with crumpled newspapers, magazines or bits of styrofoam to make retained heat cookers. The two pillows, which when placed into a cardboard box on top of and underneath a cooking pot filled with hot food, can extend the cooking process for another hour and will keep food piping hot for an additional three hours. By using a retained heat cooker, women can solar cook a pot of food in the afternoon and serve a hot meal in the evening using no fuel at all. A retained heat cooker also allows them to begin cooking over a fire and complete the cooking process in the insulated container, thus dramatically reducing the amount of fuel needed.

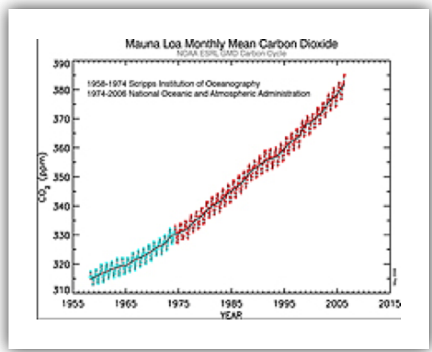
- ❖ Solar pasteurization
  - Uses soda can and plastic soda bottle. Put inside a reflector such as the one on slide 30.
  - 

  - Wapi
    - water pasteurization indicator
    - Uses soy (or other) wax that melts slightly above 65 celsius
    - 
- ❖ This module has shown various applications of direct solar processes such as
  - passive solar heating and cooling
  - active solar
  - solar photovoltaic
  - solar cooking
  - solar cooking combined with retained heat cooking
  - solar pasteurization (using recycled materials)

Quiz 2

Photosynthesis

- ❖ Photosynthesis
  - Water, carbon dioxide, sunlight, enzymes
  - autotroph (organism that makes its own food)
  - produces sugars, oxygen
  - sugars contain some of the sun's energy stored as chemical energy
- ❖ Respiration
  - sugar, oxygen, enzymes
  - releases chemical energy
  - forms carbon dioxide and water
- ❖ How do the carbon dioxide, water and oxygen get into and out of the plants?
  - plants leaves contain small "pores" called stomata
  - Cells surrounding the stomata can get larger or smaller to make the pore size change
  - Carbon dioxide and oxygen enter and exit through the stomata.



atmospheric carbon dioxide in parts per million

in the winter, in the northern hemisphere, there is a lot less photosynthesis.

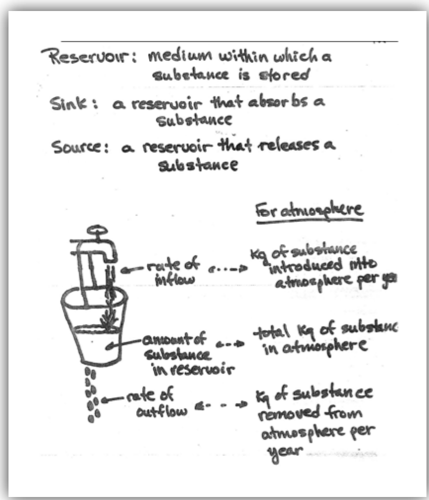
- ❖ Water enters and exits plants by the process of transpiration
  - Water is drawn up into the plant through the roots and exits the plant as water vapor through the stomata. This process also brings dissolved nutrients from the soil into the plant.
- ❖ Transpiration amounts
  - During a growing season, a lead will transpire many times its weight in water
    - 1 acre of corn = 11,500-15,000 l/d (litre a day)
    - Large oak tree = 150,000 l/a (litre annually)
    - Good pumping system
- ❖ Different types of plants carry out photosynthesis in different ways:
  - C3 plants
  - C4 plants
  - CAM plants
- ❖ C3 plants
  - Large majority of plants (95%)
  - Stomata open during the day
  - photosynthesis enzyme also involved in carbon dioxide uptake

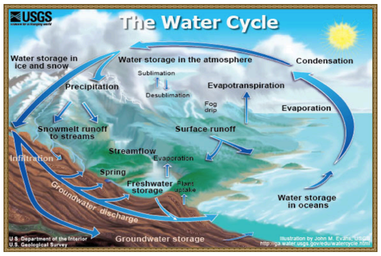
- photosynthesis takes place throughout leaf
- few enzymes, no special anatomy
- most efficient when cool and moist
- Examples of C3 plants
    - wheat, rice, soybeans, oats, barley and potatoes

❖ C4 plants
- stomata open during the day
- different enzymes involved in carbon dioxide uptake and photosynthesis
    - more efficient carbon dioxide uptake
- special anatomy, photosynthesis occurs in inner cells of leaves
- Faster photosynthesis at high light intensities and temperatures
- better water use efficiency
- several thousand species (some food)
- represent about a quarter of terrestrial photosynthesis
    - Examples of C4 plants
        - Corn, sugarcane, sorghum and millet

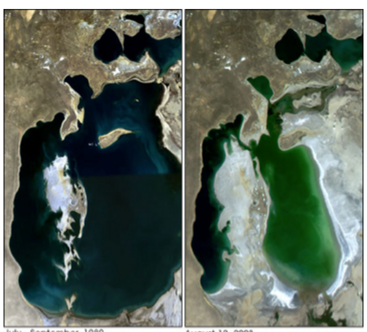
❖ CAM Plants
- stomata open at night, closed during the say; when extremely dry can close day and night (for awhile)
- carbon dioxide converted to intermediate and stored at night
- during day intermediate releases carbon dioxide for photosynthesis
- better water use efficiency when arid
- succulents like cacti

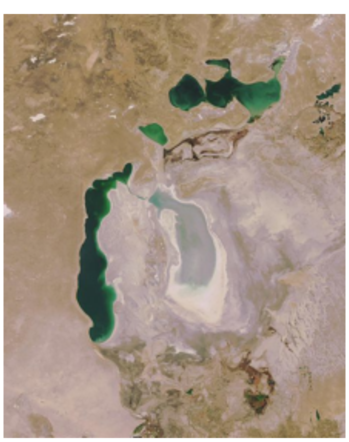
❖ What is interesting from a sustainability point of view is that C3 and C4 and CAM plants have different water use efficiencies (WUE)
- C3 = 400 to 500g water lost / gram C02 fixed
- C4 = 250 to 300g water lost / gram C02 fixed
- CAM = 50 to 100g water lost/ gram C02 fixed

❖ Where does the water from plants come from?
- water comes to plants, ultimately, by way of the hydrologic cycle.
- 

- 

- See water cycle reservoirs and flows in course pack p D1
- 

- Collecting water where there is little rain, fog water collection.
- 

- POorly controlled irrigations water use: the Aral Sea, 1989 and 2003
- 

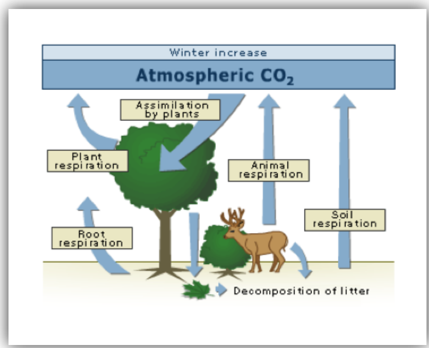
- October 2008

❖ Size of water bodies (surface area in sq mi)

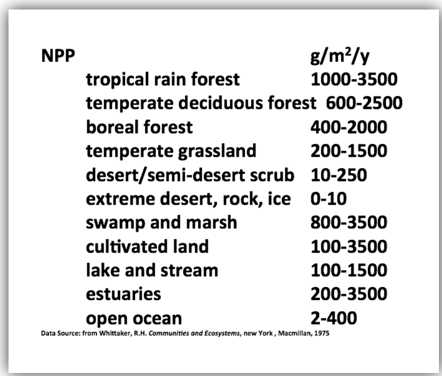
- Lake Superior - 31,800
- Original Aral Sea - 26,000
- Lake Huron - 23.010
- Lake Michigan - 22,400
- Present Aral Sea approx 3,200

❖ How much carbon is fixed by photosynthesis?

- Net Primary Productivity (NPP)
  - measurement of plant growth
  - equals photosynthesis minus respiration
  - grams of carbon per square meter per year
-



- Carbon Cycle (Terrestrial) See carbon cycle details in course pace PI/5
- goes into plants primarily.
-



NPP	$g/m^2/y$
tropical rain forest	1000-3500
temperate deciduous forest	600-2500
boreal forest	400-2000
temperate grassland	200-1500
desert/semi-desert scrub	10-250
extreme desert, rock, ice	0-10
swamp and marsh	800-3500
cultivated land	100-3500
lake and stream	100-1500
estuaries	200-3500
open ocean	2-400

Data Source: from Whittaker, R.H. *Communities and Ecosystems*, new York , Macmillan, 1975

- Photosynthesis might not be able to go above 3,500

❖ Carbon Cycle at Montmorency Forest (North of Quebec City)

- Carbon Reservoir
  - 17.3kg of carbon/m2
  - or 173 t of carbon/ha

❖ Carbon in the forest reservoir

- 7.3 kg in the vegetation
  - 4.5 kg in the wood
  - 1.5 kg in the branches and leaves
  - 1.3 kg in the roots
- 10kg on and within the soil
  - 3kg in humus
  - 7kg in mineral soil

❖ Gross primary productivity of forest is

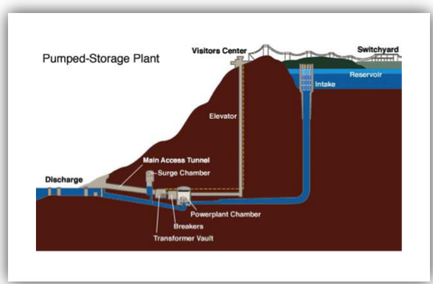
- 1kg of carbon/m2/y
- NPP is 0.5 kg of carbon /m2/y

- How much water?
  - 1kgC/m3/y x1000g /kfx500g water/gC
  - = 500,000 g water /m2/y

❖ Two sustainability issues
- do we have sufficient water?
- Can we produce enough food?
- Is there some way to increase agricultural production above the maximum natural production?

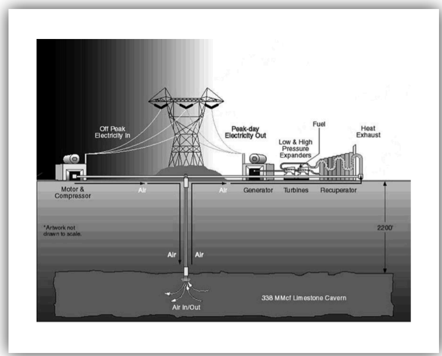
❖ Photosynthesis in an indirect solar proces

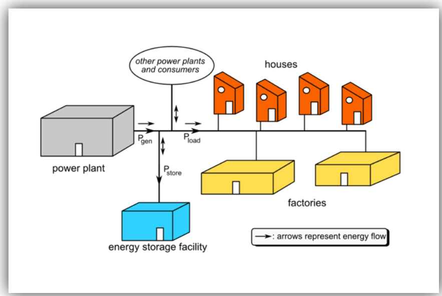
Energy Storage

- ❖ The sun provides most of our energy, but locally it is intermittent. Thus we need ways to store energy so that we can have it even when the sun is not out.
- ❖ Photosynthesis is a very good energy storage process. It is unlike other energy storage processes in the range of time scales over which energy is stores
  - Food crops - weeks to months
  - Biomass - weeks to years
  - Fossil Fuels - geological time
- ❖ There are a variety of energy storage technologies that serve a range of purposes.
  - fluid storage
  - mechanical
  - advanced battery systems
  - transport (electric)
  - hydrogen
  - thermal
- ❖ Fluid energy storage
  - pumped hydroelectric energy storage (PHS)
  - Compressed Air Energy Storage (CAES)
- ❖ Pumped hydroelectric energy storage (PHS)
  - older large scale energy storage technology (late 1800s)
  - most reliable
  - About 90GW (2007) (=3% of world generation capacity)
  - efficiency (70-85%)
  - Short notice (=1min)
  - large costs of construction
  - For PHS there needs to be two water reservoirs separated vertically
    - 

    - During periods of low electricity demand (and cost), water is pumped from lower reservoir. During periods of high demand water is released from the upper reservoir to drive turbines to create electricity.
  - A proposed new variant on PHS
    - 350 meters below sea level
    - 31 meter diameter concrete spheres on ocean floor
    - Floating wind turbines tethered to spheres
    - during low demand periods, pump water out of spheres.
    - during high demand periods, allow water pressure to force water into spheres.
    - turns turbines, creates electricity (5MW)

❖ Compressed Air Energy Storage (CAES)

- here the fluid is air, not water, and the storage containment is an underground chamber rather than two reservoirs.
- A gas (or other) turbine-powered generator provides electricity. During periods of low demand, air is pumped into the underground chamber. During period of high demand, air is released from the chamber to the gas turbine.
- 

- Compressed air has other uses such as the air car, a car that is designed to run on compressed air (or a compressed air hybrid)
  - Advantages - no petroleum, lighter weight, no pollutants from operation
  - Disadvantages - lighter weight, compressing air (pollution)
- 

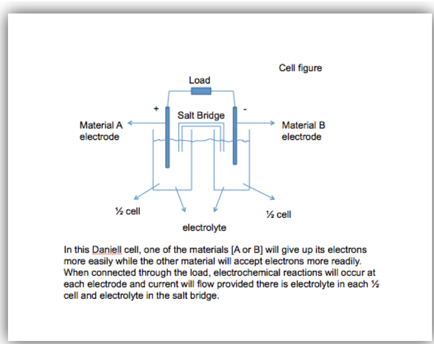
  - Grid energy storage with compressed air. (if the "energy storage facility" was a mobile compressed air electricity generator unit)
- The MDI engine, the heart of one of the first air cars, has been promoted for such use.

❖ Flywheel Energy Storage(FES)

- Input electrical energy and store as rotational kinetic energy
- Components
  - Rotor/bearings
    - bearings can be mechanical or magnetic to reduce friction (20,000 to 50,000rpm)
  - Vacuum system
    - to reduce drag
  - Motor/Generator
    - to add/remove energy
- Rotor material has changed
  - was steel
  - now carbon composite (higher tensile strength, less weight)
  - maximum rotational speed of flywheel determines the maximum E that can be stored
  - maximum rotational speed determined by flywheel disintegration

    - In metal flywheels, explosive decomposition of flywheel can produce 'shrapnel' with velocities like that of bullets
    - So, metal flywheels often shielded, but this adds to weight
    - Flywheel energy efficiencies can be 90%
    - Flywheel specific energy 0.4Mj/kg (compared to lead-acid battery 0.14Mj/kg)
- Some past and present uses of flywheels
    - Gyrobus
        - A flywheel-based bus that was used in Switzerland in the 1950s. Also a 12-vehicle system in the congo
        - Buses could go 6-10km on one 'charge' at 50-60km/h. There would be recharging facilities every few km. Charing took .5 to 3 minutes
    - Porsche 911 Hybrid Test Car uses kinetic energy recovery system (KERS) instead of high-voltage batteries. There is 40,000 rpm flywheel instead of a passenger seat. The flywheel captures energy from breaking. For an energy boost, when passing or coming out of a turn, the drivers presses a button and the flywheel releases its energy to electric motors in the front wheel wells (up to 8 seconds of electricity from flywheel,) To be raced in may.
    - Beacon Power
        - Worlds first 20MW (grid-scale) flywheel energy storage system is being built in Stephentown, NY. The 16,000 rpm composite system will absorb excess energy during periods of low demand. It will provide 10% of NY's overall frequency regulation needs (reduce need for increased E production when demand spikes) note that it does this without additional C emissions

❖ Batteries

- A battery is a device that stores energy in the form of chemical energy. Under the right conditions, this chemical energy can be transformed into electrical energy.
- There are two kinds of batteries; primary cell and secondary cell
    - Primary Cell
        - Non-rechargable
        - can have lower self-discharge rate (the rate at which it uses energy)
        - useful for applications using small current for long times (smoke detectors)
        - also useful for intermittent uses like a flashlight
    - Secondary Cell
        - Rechargable
        - can be used hundreds and possibly thousands of times
        - easily damaged it not recharged properly
        - higher cost, but economical in the long term
        - environmentally harmful if not disposed of properly
    - 

    - In a primary and secondary cell battery, the chemically reactive species are

contained in the half-cells themselves
    - In a flow battery, the chemically reactive species plus electrolyte are contained in external reservoirs, one for each half-cell.

❖ Batteries and Fuel Cells

- In a fuel cell there are two electrodes one at which a fuel and one at which an oxidant undergo electron transfer reactions
- The different between the fuel cell and the battery is that the reactions in the battery are reversible (secondary cell) and the reactants are contained in the cell (closed system) in the fuel cell the fuel is consumed and is introduced from outside the cell (open system)
-

	Energy densities Wh/kg	Power Densities W/kg
Batteries		
Sealed Lead-Acid (Secondary)	18-33	
General	10-300	8-500
Flow Battery	200-2000	6-200
Capacitors	0.01-0.1	900-8x10^6

- Capacitators have a huge power density

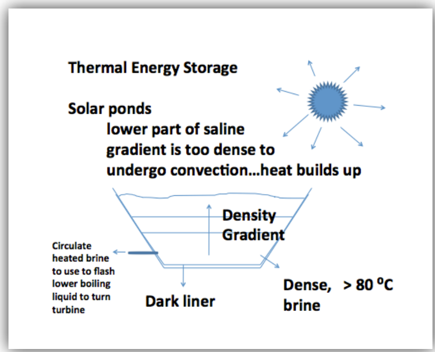
❖ Capacitors

- Rather than storing energy as chemical energy, capacitors store energy in an electrostatic field. (think of the winter when you get a shock from a door handle)
-

Some other comparisons between batteries and capacitors

	cycle life (cycles)	discharge time(s)
Battery	1-10^3	> 1000
Capacitor	10^5-10^6	< 1

    - Capacitors uses
        - Memory backup in cell phones, laptops, regenerative braking systems.
- Superconducting Magnetic Energy Storage (SMES)
    - Based on two concepts
        - direct current moving through a superconducting coil will induce a magnetic field (inductive E storage)
        - Electrical current moves through a superconductor without resistance (thousands of years without degradation)
    - Conventional superconductors run at temperatures between 10 and 1 degree K (<-250 degrees C)COLD
        - Note: MRIs use superconducting coils to produce the magnetic fields. The size of the MRI includes the size of the liquid He refrigeration system (boiling point of liquid He is 4.2K (=-269degrees C)


Thermal Energy Storage
Solar ponds
lower part of saline gradient is too dense to undergo convection...heat builds up
Density Gradient
Circulate heated brine to use to flash lower boiling liquid to turn turbine
Dark liner
Dense, > 80 °C brine

H. Dammen

- ❖ Population Growth
  - capable of producing more than needed to just replace parents
  - every population of organisms is capable of growing
  - Generally 1.4% population growth for humans.
- ❖ Human beings have hit their carrying capacity in the past.
  - about 6billion on earth
  - Since the middle ages we have surpassed the carrying capacity without agriculture (2million)
  - Growth of population in china
    - 1000AD agricultural inovations.
      - increase in population
- ❖ Can we continue to increase the rate in which we produce food
  - whatever has been done to improve land from agriculture, we haven't been able to do better than the natural community, aka rainforest, absolute limit
    - suggests there is a biological limit to how much a meter square of land can do.
    - plants simply cannot do more than 3.5 kg/m2/year
- ❖ 700-1000 g of water for 1g of edible food crop
  - uses a lot of water.
- ❖ Doubling worlds population in the next 50 years (another 4-5 billion)
- ❖ Already pushing the limits of agricultural output.
- ❖ Already at the limits of what irrigation can to do help increase output
- ❖ Plant breading
  - producing crops that are most productive than the ones we have today
  - Sorghum, corn and rice were improved but eventually level off.
- ❖ decrease in the amount of land that is brought into agriculture
- ❖ previous exporters are becoming net importers of food
- ❖ Managing Productivity
  - sustainable yields
  - cannot harvest things like gold or minerals in a sustainable fashion, not renewable.
  - not all renewable resources are used sustainably.

The Tragedy of the Common Fisheries

- Story of Sophocles Oedipus Rex

  - **Oedipus frees the people of Thebes from a pestilence caused by the Sphinx.**

    The people, in gratitude and because their king, Laius, has recently been murdered, make Oedipus the king. He is also given the hand of Jocasta, Laius' queen.

  - **Twelve years later there is another pestilence. Apollo's oracle says that it will stop if Laius' murderer is found and thrown out of the city.**

    A blind seer says that Oedipus is the murderer.

    Oedipus is outraged, and claims it is a plot to take his throne.

  - **Jocasta calms things by pointing out that seers aren't infallible.**

    She had been told by a seer that she would have a son who would murder his father and have kids with her.

    She prevented this by exposing the son in the mountains, and also Laius had been killed by robbers at a crossroads on the road to Delphi.

  - **This makes Oedipus uneasy.**

    He had killed a man at around the same time at the same crossroads when he was fleeing Corinth which he had left to avoid a prophecy that he would kill his father and marry his mother.

    At this point, a messenger arrives from Corinth with the news that King Polybus, Oedipus' father, is dead and that Oedipus has been elected king of Corinth.

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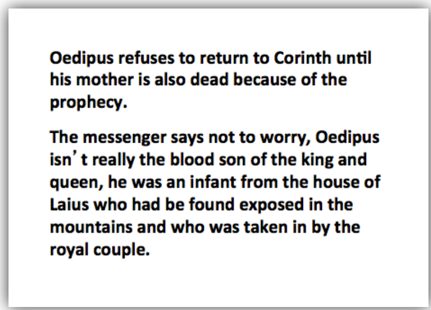

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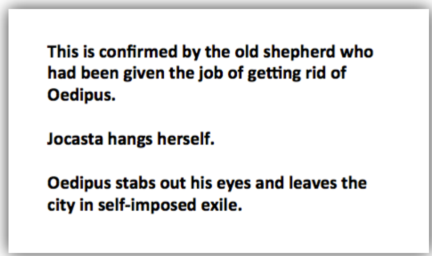


- What does this show us?
  - An early account of an incident of road rage
  - That people can't change their destinies even if they know them
  - Jocasta and Oedipus tried, and failed
  - Tragedy, to the ancient Greeks involved the downfall of a great person due to fate or some tragic flaw. The character's flaw leads to disaster.
  - In this case, both Oedipus and Jocasta have their futures revealed to them, but because of their flaw (pride) believe that they can manipulate things so that their destinies won't happen
  - they took reasonable steps to avoid a situation but fate inexorably gets them. Humans are at the mercy of fate.
  - We don't think this today, as expressed in the DWW.
  - The tragedy of the commons
  - This describes a contemporary phenomenon in which people take reasonable steps to optimize their situations, but in doing so act in such a way that it leads to catastrophe.
  - A commons in previous times was a tract of land that was used by all the people...to graze animals, for example
  - The Tragedy of the Commons was a vier expressed by the ecologist Garrett Hardin.
- Picture a commons
  - Each herder will try to keep as many cattle on the commons as possible.
  - Everything in fine so long as the populations of herders and cattle remain below the carrying capacity.
  - So long as war and disease keep the population under control
  - But then comes peace and health and prosperity
  - At this point the logic of the commons inexorably generates tragedy
  - the rational herder asks "what is the utility to me of adding one more cow to the commons?"
  - The positive result is that the herder receives the full benefit of the added cow...a utility of nearly +1
  - The negative result is the damage caused by one more cow grazing in the

commons. However, this negative utility is shared among al the herders, so the negative utility is a fraction of -1

    - Adding the utilities together causes the rational herder to conclude that the sensible course of action is to add another cow and another and...
    - But each rational herder thinks this way with the result that the commons is destroyed. The quote Hardin " Freedom in a commons brings ruin to all"
  - Today, the commons that are under threat are fisheries
    - In the case of the anchovy fishery in Peru, the rational fishers took more and more anchovies, but then El Nino damaged the population of young anchovies without anyone knowing...and the fishery collapsed.

❖ Sustainability of the GLobal Marine Fishery
  - Half the fish populations in the ocean are fully exploited
  - One quarter of the ocean's fish population are over exploited and will become extinct.
  - 2006 study (science) predicts that all the fish populations that we exploit today will have collapsed by 2048.
  - The total global fisheries catch has increased
    - 1950 < 20 M metric tons
    - 2005 90M metric tons
    - China takes roughly 20% of this catch.
    - Fishing down the food chain.
    - As we take all the desirable big fish species, we turn to smaller, less desirables ones.

❖ Aquaculture
  - accounts for roughly 30% of global fish production
    - Benefits: energy efficient, takes pressure off wild fish
    - drawbacks: need antibiotics to deal with increased disease, waste production

❖ Marine protection areas (MPAs)
  - along the coastlines of developed countries
  - allow fishing or other extractive activities

❖ Marine reserves
  - areas where fishing is prohibited
  - leave ecosystems intact, no human interference
  - improve fisheries; young fish disperse into surrounding areas.

Quiz 3

Electricity Generation

❖ Most electricity is generated by a combination of a turbine and a generator

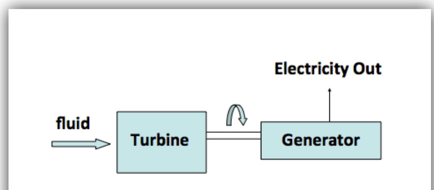
- 

Figure 1

- some of the fluid is turned into rotational mechanical energy,
- The fluid flow is generally linear, but the generator uses a rotary motion, so the turbine serves to extract energy from the fluid and convert some of it to rotary motion of a shaft
- Various fluids can be used
  - water (hydro)
  - air (wind)
  - (steam (h20) or other vaporized liquid
  - gas (gas turbines are used in transportation.
- There are different types of turbines
  - hydropower turbines
  - steam turbines
  - gas turbines
  - wind turbines

❖ Generator

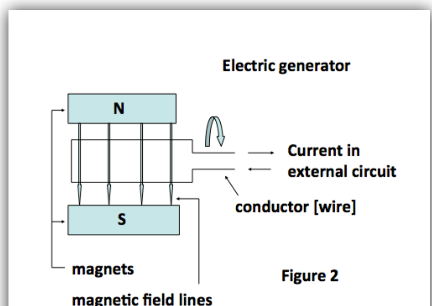
- Electric generators use the phenomenon knows as electromagnetic induction
- If you have a conductor (wire) and a magnetic field (magnets), then whenever the conductor moves relative to the magnetic field a voltage is "induced" in the conductor. If the conductor is connected to an external circuit, then current will flow.
- 

Figure 2

- In this case the rotation of the wire in the magnetic field, caused, for example, by attaching the wire loop to a rotational shaft, will induce a voltage in the wire.
- The rotating shaft is a source of mechanical energy some of which is converted into electrical energy in the wire. The rotation can be the result of connecting the shaft to a turbine.

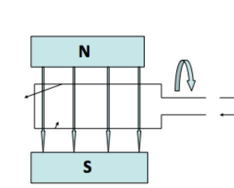
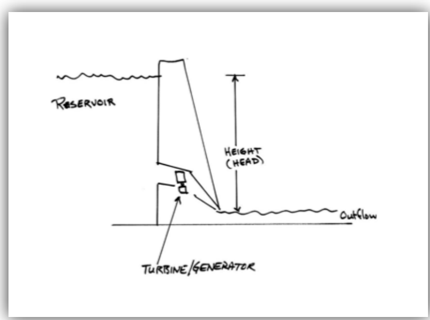
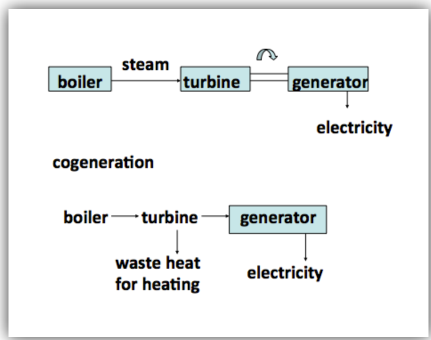
- In Figure 2, the wire loop is depicted as rotating inside the magnetic field. One could just as easily have a stationary wire loop (coil) and a rotating magnetic field by having the magnets attached to a rotating shaft positioned inside a wire loop (coil)
- The carry out the reverse process, conversion of electrical energy into mechanical energy, one uses an electric motor.
- When current is passed through a conductor that interacts with a magnetic field, a force develops on the conductor. In the situation depicted in Figure 3, the force would cause the conductor loop to rotate within the field converting electrical energy into mechanical energy of the rotating shaft to which the loop is connected.
- 

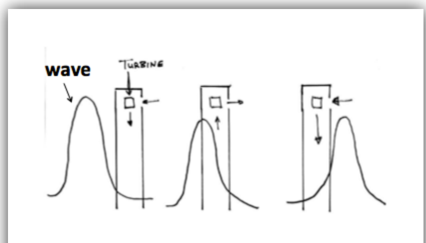
Figure 3
Electric Motor

❖ Some examples: Hydroelectricity
- Canada is the world's larges producer of hydroelectricity (2010) and it generated roughly 60% of its electricity using hydroelectric dams.
- Converts gravitational potential energy of water behind the dam into electrical energy.
- Energy available is determined by the height of the water behind the dam to the height of the downstream outflow.
- Water dropping from the reservoir through a water-driven turbine converts some of this energy into mechanical energy which is fed into a generator to be transformed into electrical energy.
- An alternative to this type of hydro is run-of-river hydro which doesn't use large dams and reservoirs. Instead a different type of turbine is placed in a river or stream. This type of turbines converts the energy of the flowing water into rotational mechanical energy to drive a generator.
- 

❖ Some examples: CHP (combined heat and power) or Cogeneration
- Not so much renewable energy, depends where you get the heat to boil the water
- A boiler is used to boil water and produce steam which is passed through a steam turbine where some of the energy in the steam is converted into rotational mechanical energy to be converted, by a generator, into electrical energy. The boiler can use fossil fuels, nuclear energy, solar energy, etc. to generate the steam.

- Often, the waste thermal energy in the steam is dissipated into the environment.
- In CHP, however, this thermal energy is used for space heating by using it to warm water which is then piped into adjacent buildings or communities.
- 

❖ Some examples: OSW (Oscillating water column)

- This is used in electricity generation from wave energy or tidal energy
- In the case of wave energy, some of the kinetic energy of the changing air column in the turbine housing is converted into rotational mechanical energy by either a bi-directional turbines or a twin uni-directional turbines
    - Twin uni-directional turbines are more efficient.
    - 

      Oscillating Water Column (OWC)
    - the structure has a hole to vent air and the generator is inside of the structure. when the wave is at its minimum height you will have the most air in the structure, when the next wave comes it starts to fill up the space and push the air out. its the movement of the air that pushes the turbine for the generator to create electricity.
    - bi-directional turbines power the turbine both when air is going in and coming out.
    - in a sense it is a wind turbine

❖ Some examples: Wind Turbines

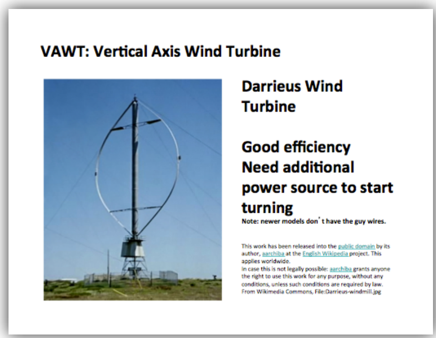
- Types of wind turbines
    - HAWTs(horizontal axis wind turbines)
        - 

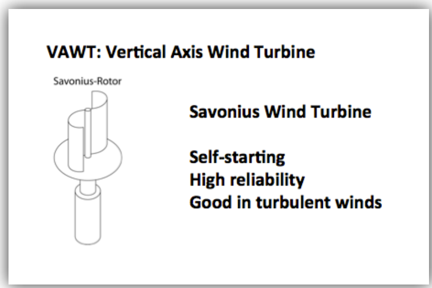
          HAWT

          Horizontal Axis Wind Turbine
        - Advantages to HAWTs
            - Tall tower can access stronger winds

              10m up, 20% stronger winds. = 35% more power
            - Higher efficiency, blades always perpendicular to wind so power

generated through entire rotation.

- Disadvantages to HAWTs
  - Appearance
  - Noise
  - Bird kills (far fewer than windows)
  - Need additional Yaw mechanism to turn turbine into the wind
    wind may change direction, if you want to keep the blades rotating, then there needs to be a way to sense the wind change and move
  - Need braking in high winds.
- VAWTs (vertical axis wind turbines)
  - 

  - 

  - VAWT advantages
    - can be built lower to the ground
    - lower wind start up speeds
    - dont need yaw device
  - VAWT disadvantages
    - decreased efficiency compared to HAWT (due to part of the time turning against the wind) also due to being built closer to the ground.

❖ Some examples: OTEC (Ocean thermal energy conversion)

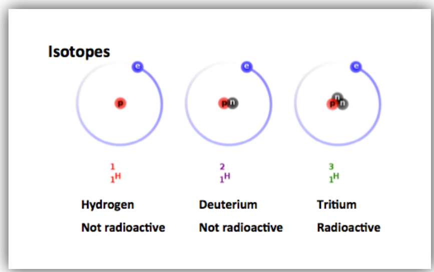
- Potential: the oceans cover a little move than 70 percent of the earths surface. This makes them the world's largest solar energy collector and energy storage system. On an average day, 60 million square kilometers (23 million square miles) of tropical seas absorb an amount of solar radiation equal in heat content to about 250 billion barrels of oil. If less than one-tenth of one percent of this stored solar energy could be converted into electric power, it would supply more than 20 times the total amount of electricity consumed in the United States on any given day.
- OTEC works best when the temperature difference between the warmer, top layer of the ocean and the colder, deep ocean water is about 20 Celsius, (36F). These conditions exist in tropical coastal areas, roughly between the Tropic of Capricorn and the Tropic of Cancer, To bring the cold water to the surface, OTEC plants require an expensive, large diameter intake pipe, which is submerged a mile or more into the ocean;s depths.

- Closed- Cycle OTEC
  - These systems use fluid with a low-boiling point, such as ammonia, to rotate a turbine to generate electricity. Warm surface seawater is pumped through a heat exchanger where the low-boiling point of fluid is vaporized. The expanding vapour turns the turbo-generator. Cold deep-seawater- pumped through a second heat exchanger- condenses the vapour back into a liquid, which is then recycled through the system.
- Open-Cycle OTEC
  - These systems use the tropical oceans warm surface water to make electricity. When warm seawater is placed in a low-pressure container, it boils. Then expanding steam drives a low-pressure turbine attached to an electrical generator. The steam. which has left its salt behind in the low-pressure container, is almost pure fresh water. It is condensed back into a liquid by exposure to a cold temperatures from deep-ocean water.
  - In 1984, the solar energy research institute (now the national renewable energy laboratory) developed a vertical-spout evaporator to convert warm seawater into a low-pressure steam for open-cycle plants. Energy conversion efficiencies as high as 97% were achieved. In may 1993, an open-cycle OTEC plant at Keahole Point, Hawaii, produced 50,000 watts of electricity during a net power-producing experiment.
- OTEC Spin-offs
  - Air conditioning (using spent cooling water)
  - Chilled-soil agriculture(piped in cooling water) grow crops that don't normally grow in Hawaii
  - Cold-water aquaculture (salmon, lobster)
  - Fresh water production (2MW plant could yield 4,300m^3 per day)

Video

Ecological Design - inventing the future

Nuclear Energy

- Atoms are made up of
  - protons (positive charge)
  - neutrons (no charge)
  - electrons (negative charge)
- There are the same number of protons and electrons in an atom, so atoms have no net charge.
- The protons and neutrons are found in the nucleus of the atom, The electrons are outside the nucleus.
- Protons and neutrons have roughly the same size and mass. Electrons are much smaller and less massive
- All the atoms in a sample of an element, say gold, have the same number of protons.
- Atoms of an element can have different numbers of neutrons.
- Atoms with the same number of protons but different numbers of neutrons are called isotopes.
  - 

  - **Note the format:**

    $^{A}_{Z}X$ **(element symbol)**

    X is the element symbol (X = H for hydrogen)

    A is the mass number (protons + neutrons)

    Z is the atomic number (number of protons)
- Some isotopes are stable, they don't want to transform into other isotopes. Such isotopes are not radioactive.
- Some isotopes are unstable, they want to undergo transformation. Such isotopes are radioactive.
- A measure of the stability of a nucleus is its half-life: the time it takes for half the nuclei in a sample to undergo radioactive decay.
  - Half-lives can vary from microseconds to billions of years.
  -

^{238}U	$t_{1/2} = 4.47 \times 10^9$ years
^{131}I	$t_{1/2} = 8.04$ days

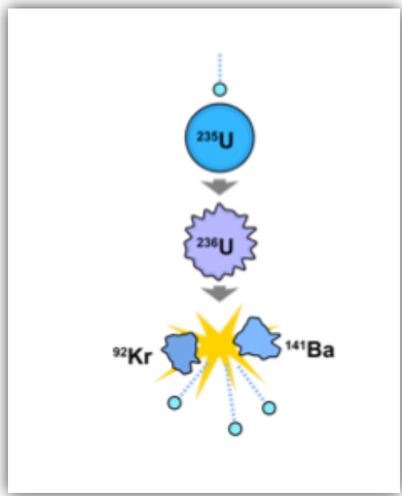
- One can get energy from atomic nuclei by two processes

- Nuclear fission
- Nuclear fusion.

❖ Relative energies are:

- Combustion of 1 kg of gasoline yields 46-47 MJ (4.6 x 10^7J)
- Fission of 1kg of ^235U yields roughy 8 X10^13 J
- 1kg of fusion fuel yields the energy of roughly 10^7kg of fossil fuel or roughly 10^14J
- More fuel out of fusion than fission.

❖ Nuclear Fission

- Isotopes of certain heavy (lots of protons and neutrons) elements can undergo a reaction when bombarded with neutrons. This reaction is called nuclear fission.
- In nuclear fission a nucleus "picks up" a neutron while being bombarded with neutrons.
- This begins with a 3-step process called a chain reaction.
- The 3-steps of the chain reaction are:
  - Initiation - Absorption of a neutron to form ^236U
  - Propagation - This part repeats itself. ^236U splits into fragment nuclei plus more neutrons. These neutrons then go on to form more ^236U
  - Termination - By using up ^235U or neutrons not being captured.
  - 

- Natural uranium contains 0.72% ^235U. More than 99& of natural uranium is ^238U, and does not react the same.
- The fission reaction is a transmutation process in which one element is converted into other elements.
- In the fission process the mass of the products is less than the mass of the starting material. The missing mass has been transformed into energy. (E=mc^2) This violates the energy law of energy not being created or destroy but it is creating energy from the mass.

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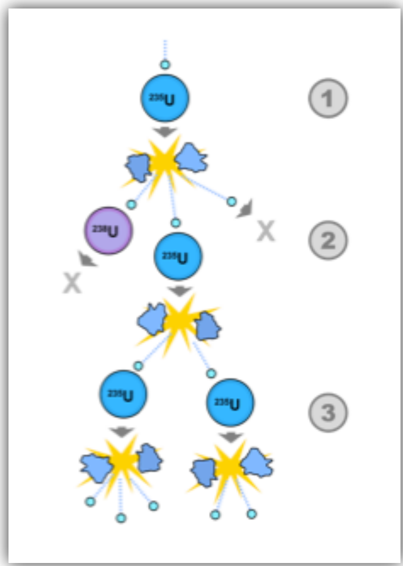
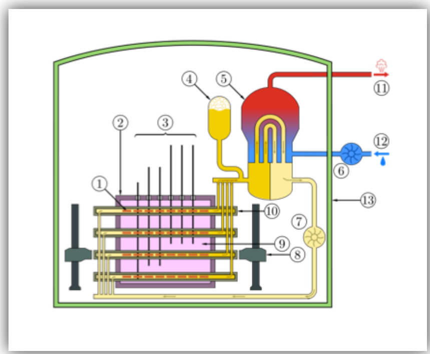




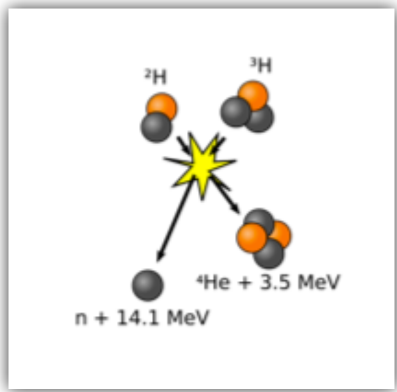
1 nuclear fuel rod
2 calandria (the reactor core/contains heavy water , D_2O)
3 control rods
4 pressurizer
5 steam generator
6 light water condensate pump
7 heavy water pump
8 nuclear fuel loading machine
9 heavy water (moderator)
10 pressure tubes
11 steam
12 water condensate
13 reactor containment building

1 - uranium pellets

Canadian reactors use a special sort of water, that is expensive.

"is a fancy boiler"

- Note: the fission process involves balancing the propagation and termination steps in the chain reaction.
- If there is too much termination, the reaction stops.
- If there is too little termination, the reaction can run out of control.
- Control of the reaction uses control rods made of materials that are good at absorbing neutrons.
- Where does the radioactive waste come from?
- Nuclear fusion
  - In nuclear fusion, small nuclei are forced together to form larger nuclei.
  - Deuterium + tritium forms helium plus a neutron.
  - Fusion reactions produce the sun's energy.

- 

- Advantages of Fusion energy
  - No carbon emissions
  - Abundant fuels
  - Energy efficiency
  - No long-lived radioactive wastes (<100 years)
  - Safe and reliable.

❖ You need four things to make fusion a viable energy source
- 1. Temperature high enough for fusion to occur (1,000,000 Degrees C, 10^6)At this temperature, atoms and molecules don't exist, you have a plasma of unbound nuclei and electrons.
- 2. Containment for long enough for a net release of energy to occur. Energy is released since the product nuclei are less massive than the reactant nuclei (E=mc^2)
- 3. A way to recover the energy.
- 4. Recover more energy than you put in.

❖ In the sun, the plasma is held together by gravity.
- To do this on Earth one can contain the plasma in a strong magnetic field (magnetic confinement)
- A small amount of frozen hydrogen is compressed and irradiated by an intense energy beam such as a laser so that fusion occurs before the atoms separate (Inertial confinement)

❖ Note that in a fusion bomb (H bomb) the fusion fuel is surrounded by the fuel for a fission bomb (A bomb)

❖ The A bomb is detonated, and this forces the fusion fuel together to produce fusion.

❖ ITER
- Joint project of China, EU, India, Japan, Korea, Russi and the US
- World's largest and most advanced nuclear fusion reactor (tokamak/magnetic confinement design)
- Agreement to fund construction in Nov 2006. To be completed by 2018.
- There is ongoing development.

❖ An alternative to this IEC
- Inertia electrostatic confinement fusion reactors
- Low energy (use about as much energy as a computer monitor)
- Low radiation but unfortunately low energy output at present.
- IEC is being researched to solve the problems of low energy yields.
- The ITER system, which can produce MW (mega watts) of energy (more than it uses) for fractions of a second, is being researched to solve the problems it has

producing sustained energy outputs.

- ❖ Cold fusion, it's hot again.
  - Cold fusion was proposed in 1989. It offered the prospect of nearly unlimited energy without radioactive contamination.
  - A flurry of research was carried out with little success, and since the concept was different from traditional views of high temperatures and energies it gradually came to be considered junk science.
  - Cold fusion has resurfaced, however, as LENR-CANR (low energy nuclear reactions- chemically assisted nuclear reactions)
  - Cold fusion was proposed since certain reaction systems seemed to produce more energy than could be accounted for by chemical energy alone.
  - The latest test of the Rossi nickel-light water nuclear reaction in Feb 2011 apparently produced 288kWh of energy over 18 hours (equivalent to the energy of 26kg of gasoline)
- ❖ In this module we have
  - touched on the structure of atoms, protons, neutrons, electrons, isotopes and half-lives
  - Energetics of nuclear reactions
  - Discussed nuclear fission, chain reactions, CANDU reactors
  - Discussed nuclear fusion, steps to viability, processes, TER, IEC, LENR-CANR

Energy Supply and Demand

- ❖ We don't consume energy resources; we consume energy services
  - Heating
  - Cooling
  - Motive power
  - Lighting
  - Communication
  - Entertainment
- ❖ Energy services can be provided by various combiations of
  - Energy supply - supply sources and conversion technologies
  - Energy demand - End-use technologies and efficiencies
- ❖ Motive power(energy service)
  - Energy supply - crude oil /gasoline (delivered)
  - Energy demand - automotive technology (km/l)
- ❖ OR Motive Power (Energy Service)
  - Energy supply - sun/agriculture
  - Energy demand: horses/horsepower
  - Each combination of supply and efficiency has different costs to the consumer and society.
- ❖ A contemporary example
  - Shipping
  - Motive power:
    - Energy Supply: Crude oil/fuel oil
    - Energy Demand: Internal combustion engines
  - Environmental impacts (some)
    - Bilge water (contamination/invasive species)
    - Accidental Spills
    - Air Pollution
- ❖ Return to Wind Power (Energy supply of past)
  - Kites/sails
  - Solar
  - Combination
  - Kites
    - MS Beluga (Germany to Venezuela in 2008
    - Uses kite (160m^2)
    - 100-300 m up
    - Reduce fuel consumption 10-35%
  - Solar
    - Solar SE
      - Solar powered catamarans
      - up to 60 passengers
      - sails on waterways of Berlin
      - Prototype crossed Atlantic 2006/2007
  - Proposed

        - Ships with sails made of solar panels
        - Wind propulsion
        - Stored PV electricity to power vessel processes
        - Stored PV electricity to offload onto grid when docked. (getting paid for this electricity brought in)
- ❖ Conservation as a source of supply
    - Energy service (same or other)
        - Energy supply: surplus supply from reduced demand (but same service)
        - Energy demand: Reduced demand by efficiency
- ❖ In such a case the demand changes become a renewable energy supply
    - Consider the following from a study reported on CNN money in 2006
        - Part of automobile gasoline consumption in the US in 2006 results from an average increase in auto occupant weight due to the change in average weight of Americans since 1960
        - The estimated amount of gasoline is 938 million gallons per year or roughly 3.5 billion litres (3.5 x 10^9 litres)
        - Data from Natural Resources Canada for 2005 show (for gasoline)
        - Number of light vehicle - 17,379,447
        - Light vehicle fuel consumption 29.2 x 10^9 litres
        - By returning Americans to their 1960 average weight, there would be enough gasoline to provide the same energy service from roughly 2 million additional vehicles (of the 2005 Canadian type) without introducing a new energy supply.
        - The energy supply to do this would be renewable conservation energy supply.
- ❖ The point is that to provide new energy services one must either increase energy supply or decrease energy demand (increase conservation supply)
- ❖ How do increasing supply (IS) or increasing conservation supply (ICS) compare?
    - Reserves and Technological Potential
        - IS - Recoverable amount in ground, given technology, electricity production with given technology
        - ICS - amount of energy waste, thermodynamic limits, available technology for saving energy.
    - Cost of production
        - IS - cost of producing, transporting and retailling a unit of energy (Cents/kWh)
        - ICS 0 cost of more efficient end-use technologies, cost of more efficient management and maintenance measures (cents/kWh saved energy)
- ❖ It is usually cheaper to conserve than to consume.
    - Lead times and infrastructure
        - IS - very long (can be a decade or two to build more) involve R&D approvals, construction, well developed infrastructure
        - ICS - generally shorter lead times, constrained by institutional inertia, poor infrastructure, effort required to conserve
    - Employment impacts
        - IS - megaprojects capital intensive but labour poor, jobs concentrated usually around the job site, expensive way to create jobs
        - ICS - conservation generally labour intensive, jobs regionally distributed
    - Person-years of employment /$M invested
        - IS <20
        - ICS > 20

- Environmental Impacts
  - IS - Energy production/conversion is a major source of pollution. Significant environmental impacts at all stages
  - ICS - Provides same environmental service with little or no added environmental impact. Conservation emissions reductions vs supply side treatment
- Energy conservation is the purest form of environmental protection.
- Security Factors
  - IS - Foreign oil supplies, limited transportation routs, concentration, size, high-tech
  - ICS - more dispersed, locally controlled, immune from disruption, diversity, small size, reliable technology, user control

❖ Another example

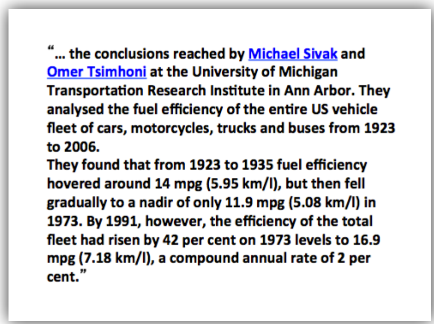
- Residential Appliances   Canada 2008 PJ (10^15)
  - Refridgerator 35.3
  - Freezer 12.2
  - Dishwasher 2.4*
  - Clothes Washer 2.2*
  - Clothes dryer 40.1
  - Range 37.1
  - Other 73.9
  - Other includes televisions, DVD players, radios, computers, toasters
  - * Excludes hot water
- Note: Energy star refrigerator models are 15%more energy efficient than a standard model.
- Total household 13,164,000 Canada
- Total Households 4,555,025 ON 2006 (=35%)
- Refrigerator energy 35.2 PJ Canada
- Refrigerator energy 12.32 PJ ON 2006
- Assuming that all 12.32 PJ is from standard refrigerator models, then energy star substitution would free up 1.85PJ of energy.
- Note - 3.6PJ = 1TWh; 1.85 PJ = 513GWh

❖ Atikokan Generating Station

- Northwestern Ontario
- One coal-fuelled generating uni (211MW max)
- Over past decade electricity production averaged around 750Million kWh/y
- Enough to supply 62,000 homes for a year.
- Ontario Power Generation wants to phase out coal since the Ontario Government has regulated the end of coal for electricity production by 2014.
- What to do about Atikikan?
  - Switch to wood-based biomass fuel with annual production of electricity of 150M kWh (=150 GWh)
- Ontario Power Generation has put out price requests for 90,000 tonnes/y of dried wood pellets
- Forest industry by-products and/or harvested wood (if all harvested <1% of Ontario allowable annual harvest)

❖ Note that is Ontarians substituted half their refrigerators with energy star models, the ICS would be more than enough to allow Atikokan to be shut down.

❖ The problem with Conservation Supply

- CS can support new energy services until it goes to zero (we are back at the original energy supply)
- Consider Canadian Housing:
  - Stock of Canadian Residential Housing
    - Total Housing Stock 2008 - 13,730,000
    - 2006 - 13.327,000
    - 2004 12,918,000
  - Average size of housing unit (m2/house)
  - 2008 - 126
  - 2004 - 124
  - 2002 - 122
- In 2007, 1 in 10 US households used self-storage
- In 1995, 1 in 17
- 65% increase in 12 years
- Fastest growing sector of the US commercial real estate industry over the last 30 years.
- GET SLIDE US vehicle fuel efficiency
- 

"… the conclusions reached by Michael Sivak and Omer Tsimhoni at the University of Michigan Transportation Research Institute in Ann Arbor. They analysed the fuel efficiency of the entire US vehicle fleet of cars, motorcycles, trucks and buses from 1923 to 2006.
They found that from 1923 to 1935 fuel efficiency hovered around 14 mpg (5.95 km/l), but then fell gradually to a nadir of only 11.9 mpg (5.08 km/l) in 1973. By 1991, however, the efficiency of the total fleet had risen by 42 per cent on 1973 levels to 16.9 mpg (7.18 km/l), a compound annual rate of 2 per cent."

- From 1970 to 2000 the fleet increased from roughly 110M to roughly 220M vehicles
- 1973 to 1991 fuel efficiency increases 42% with little shift since 1991.
- Number of vehicles increase 100%

Quiz 4

Japan's Nuclear Reactors

- ❖ Japan's Nuclear Reactors
  - Fuel > Control Rods (slow reaction by absorbing neutrons) >Cooling water needed and is sent to the heat exchanger which leads to external cooling water.
  - In Japan they use light water reactors, using plain h2o as a moderator
    - need more uranium 235. using enriched uranium.
  - CANDU - uses heavy water, d20, moderator so you can use natural uranium

Feminist and Ecological Perspectives

- ❖ Emphasis is always on development
  - Sustainability is thus defined as sustainable development
  - Focus on the environment. Remember other choice paths
  - Make sure technosphere operates in harmony with the biosphere.
- ❖ Focus on two things
  - Household - household technologies
  - Women's bodies: reproductive technologies
  - Historically, women seen as outside modern technology...not officially recognized as insiders in technology
- ❖ Museums of technology only recently mounted exhibits of household technologies
  - 19th century Canadian home:
    - No big distinction between private sphere inside and the public sphere outside, one continuous space
    - Household not strictly a place of consumption, it was a place of work
    - Division of labour, men and older children ranged through bush...women stayed home.
  - But it was more a continuity. Everything connected, men churning butter, women working in the fields
  - All work was essential for survival and well-being
  - The technology itself
    - A lot is hand made, some made of wood, comes from nature, returns to nature as wood ash; come from local blacksmiths. coopers, etc.
  - What is missing is skills. How to do things, make things, use things, how to improvise. Made to disappear.
  - Common of public knowledge. Need to sustain the heritage of such knowledge
  - 19th century women cheese makers in Ontario. Cheese making as commercial industry often attributed to American who came up during Civil War. Before this cheese was made by women on subsistence basis.
  - But women launched cheese-making as a commercial venture long before the American arrived... produced cheese on scale larger than needed for family.
  - Used technology such as vats and other equipment that they constantly refined and had made locally.
  - Their technology didn't count because it wasn't patented.
  - A mix of survival use value and commercial exchange value.
    - Is it relevant today?
  - Ecology
    - Scale and limits to growth
  - household technology not big technology. Scaled to the carrying capacity of the local environment. Not scaled to profit maximization. Geared instead to survival.
  - Simplicity of technology kept it within capacity of local techno-structure: Local blacksmiths. etc.
  - Produced for local market; avoided big market distribution
  - *End user model of technology*: local, freer of large scale commercial property constraints.
  - Consequences of plugging into large scale infrastructures of power and industrial production outside household. Individuals become depended on outside sources.
- ❖ Reproductive technology in context of healthy environment of a woman's body
  - New reproductive technologies:
    - Control over women
    - Dependency
    - Autonomy

- Global scale; population control; contraceptive technologies imposed on 3rd world women by state population control; sex selection.
- In vitro fertilization; remove woman's eggs; fertilize with male's sperm; implant embryo back into women or into another, surrogacy; reproduction as contractual process with rules and penalties.
- Control: in cases of infertility; take required tests; take required drugs; meet criteria
- Technologies of inner space: IVF; genetic engineering
- Are there limits? when do we become more cyborg than human
- Woman and womb becomes an extension of larger techno-medical system
- Are we sustaining life or technological systems?
- Need to conserve natural fertility. To survive in the most basic sense. Need to sense the awe of natural reproduction.
- Ecofeminism
    - Feminism, peace. ecology
    - Goal is to sustain life
    - Key formulations
        - Everything is connected to everything else
        - No such thing as being apart from nature. We are all a part of nature.
        - No real boundaries between private sphere and public sphere; between production and reproduction
        - No real boundaries in the personal and the political. The personal is political.
- Rejects dualisms
    - Culture vs nature; mind over matter;self from otther; nature as other; woman as other; worker as other; etc.
    - Rejects hierarchies of dominations
    - Embraces an ideology of nurturing to sustain life in all its natural creativity
- Take the view from here
- Start with life in all its interconnectedness
- Start from reproduction and the household
- Ecological approach to communication
    - Dominant paradigm is the economics paradigm; mass media/transnational look to price system as major mode of communication; dissatisfaction with transactions where money doesn't change hands
    - Commodity mode lends itself to alienation. Buying and seller exchange something and then go separate ways. Autonomous others.
- Ecosystem model; interdependence; wholes; not isolated individuals
- Need to infuse economics with ecosystem considerations
- But all pressures are toward larger scales; globalization; further commoditization of human relations.
- Need to change our minds. Need to recognize a crisis.

Scenarios, Forecasting and the Future

- ❖ Ways to look at time
  - Perpetual present: things happen to us; we have little control; there are no patterns; thus no plans. thus no future.
  - Notice patterns: seasons; can plan (return of crops); cyclic time; we can have a stake in the future
  - Today: linear time; we see ourselves moving through time toward something new, the future.
- ❖ When you have a future, and a sense that you can exert some control over the future, you can plan; moral standing, futurity, sustainability.
- ❖ Without a path to the future, or some control over the future, you experience apathy...what is there to plan for?
  - WWI - the lost generation
- ❖ But having a future doesn't imply that there is only one plan for it. It doesn't mean that we can even decide what it is. What to do?
  - We project forward; we **forecast**. Sometimes we also **backcast.**
    - use backcasting in forecasting
  - Scenarios are the way we look forward and backward. We build. Scientists, military experts, ecologists, economists, and sci fi writers, all use scenarios to project their ideas onto the future.
    - scenarios opposite of fatalism.
- ❖ Quote from William James " When you need to make a choice and don't make it, that is in itself a choice"
  - Article by Dominic Idier called 'Science Fiction and Technology Scenarios" which looks at both non-fiction scenario techniques as well as the work of Isaac Asimov and William Gibson.
- ❖ Idier notes that technology foresight is not about predicting the future. It is method of assisting people and organizations in the decision-making process.
  - There are times when decisions have to be made, no matter what. I believe you have covered some of this in your discussion of the DUU, DUR, etc. There are sometimes decisions to be made, and you have to make them based on..what? Well, maybe on foresight.
- ❖ Idier claims that foresight is about learning, about preparing ourselves for the unexpected
  - Idier quotes a dictionary definition of scenario that describes a scenario as "an outline of the natural or expected course of events"
  - Other definitions of scenario use "outline" plausible alternative "allows one to move forward"
  - Scenarios are about malleability, possibility.
- ❖ Military uses scenarios all the time. A recent example (from a news article "A Haiti Disaster Relief Scenario was Envisaged by the US Military One Day Before the Earthquake" (2010)
  - US Southern Command (SOUTHCOM) in Miami, one day prior to the earthquake, was in the middle of a scenario about disaster relief after a hurricane in Haiti.
  - The earthquake occurred January 12, 2010
  - On January 13, the day following the earthquake, SOUTHCOM took the decision to implement the system which had been rehearsed in Miami two days earlier.
  - Was US Emergency Aid to Haiti a Military exercise?
- ❖ Another area that makes a lot of use of scenario-style methods is education
  - I'm referring here to an article called "Dreams and Expectations: "Young people's expected and preferred futures and their significance for education" By Richard Exhersley, from the journal FUTURES

- Expected Future/ Preferred Future
  - 1st perspective - pragmatic and personal (expected) deals with getting by/ getting ahead (expected future)
  - 2nd perspective - more universal and philosophical (preferred future)
  - Most public debate is about the first perspective.
- Climate Wars by Gwynne Dyer
  - Look at the title "wars"
  - Remember: this book is meant to be a warning. Warnings aren't usually "cute" or "heartwarming"
  - In a way, a scenario can be dangerous stuff. If someone makes a totally dystopian world view that is inescapable, the population just might give up and say, what's the use?
- The desired result, after all, is not APATHY. We do not want or need another manifestation of a LOST GENERATION.
  - Gwynne Dyer: A former military man, he holds a Ph.D. in War Studies, His speciality is military scenarios and he is seen as a futurist in that field. He turns his attention to global warming, because he sees the problem, and various solutions, as inevitable involving the political and military organizations of the world. You can't separate these things.
- there are several scenarios in this book. All begin with the same general premise, that in the near future the global temperature will rise by around 2 degrees Celsius.
  - This is a speculation. Educated guess or not, as you can to believe, it is a "what if", a speculation. From it, one can build a scenario.
- Each of Dyer's scenarios builds on this roughly 2 degree fact. But what changes are the other parameters - nationalism, famine, protectionism, militarism, etc. Who runs out of food first?
  - *Dyer says that "If the climate modelers will not generate this kind of scenario, who will?*
- The military, of course.
  - In 2007, the US Army War College sponsored a two-day conference on "The National Security Implications of Climate change", in which civilian strategists and active duty and retired officers explored a wide range of climate-related security issues.
- The scenario exercise involved choosing eleven recently retired three and four star generals and admirals from all four services
  - Exposing them to a large number of people working on climate change or related fields,
  - Then writing a study where these military men were asked to comment and elaborate.
  - The study caused a sensation when released.
  - General Anthony C. Zinni, USMC, Ret. Former commander in chief of US Central Command 2007
    - "We will pay for this one way or another. We will pay to reduce greenhouse gas emissions today, and we'll have to take the economic hit of some kind. Or we will pay the price later in military terms. And that will involve human lives. There will be a human toll. There is no way out of this without a human toll"
  - General Gordon R. Sullivan, USA (ret.) former chief of staff of the US ARMY, 2007
    - "People are saying they want to be convinced, perfectly. They want to know the climate science projections with 100 percent certainty. Well, we know a great deal, and even with that, there is still uncertainty. But the trend line is very clear. We nave have 100 percent certainty. We never have it. If you wait till you have 100 percent certainty, something is going to happen on the battlefield. That;s something we know. You have to act with incomplete information.
- All of the scenarios in Dyer's book are thoughtful considerations of possibilities. We could briefly at the one most directly concerning America, Which, as out North American partner, would be sure to have an effect on us (Although all of them do)
  - The premise is a 2 degree celsius increase in temperature worldwide.

- ❖ United States 2029
  - Longer growing season; more productivity
    - Re: the new fence at the US/Mexico Border
    - Interesting parallel to the Iron curtain in USSR (to keep people in) and the US Fence (to keep people out)
  - But by mid-2020, the permanent drought turns farms to dust from Mexico to Costa Rica.
  - 2029- Frontier Fortification. 3,000km long barrier of patrol ships.
  - They create the Big Fence in 2027 due to fear and panic - a death blow to Mexico.
  - Mexico becomes hard to control; armed militias.
- ❖ Another Fear: by 2028, Mexico has withdrawn from NAFTA
  - Mexico cannot afford to buy grain
  - Food Crisis in Mexico City
  - Health problems/epidemics
- ❖ Another fear
  - Cuba: communists have made a comeback (communist coup in August, 2028)
  - Political lobbying
- ❖ Another fear
  - by now Mexican Americans make up about 12% of the population.
- ❖ Border now protected by landmine
  - Brutality. Mexican Americans up in arms (loyalty to new home or to home under siege?)
  - The result? Not democracy
    - "Civil war" Develops.
- ❖ Killing on both sides of the "Fence"
  - Another fear: Mexican-Americans come to see themselves as separate. As they still have a high birth rate, their slice of the American pie continues to grow larger, but they no longer see themselves as of that same group of "Americans"
    - All because of 2 degrees Celcius
  - Fanciful? Maybe
  - Crazy? You could convince people it is
  - Possible? Look around at how we handle things
    - Things get out of hand
- ❖ It is interesting that in all of the scenario projections Dyer makes, at least one of which has Japan withdrawing from its continent, adopted protectionism and turning into Fortress Japan "Bristling with nuclear weapons" because it can feed its people and power its country, not one of the scenarios envisioned what just happened this past week in Japan. So this is the thing.
- ❖ We make scenarios to have some stake in the future, to be part of it. Science fiction writers "try on" various worlds for us to explore. We learn from these things. And we take our best shot, because as William James stays, we have to do something because doing nothing is also a decision
  - But there is still uncertainty. And there is still the unknown.
- ❖ You need to plan. But is there a time when you have to stop planning? Stop making allowance for the unknown, and "Do something?" In Japan, Do you prepare for the "once in a hundred year quake" and build for that, or do you prepare for the less likely (but still possible) "once in 500 year quake" and build for that?
- ❖ Here you encounter **The Planners' Dilemma**
  - As the magnitude of an event such as an earthquake increases, the probability of its occurring decreases.
  - But at the same time, the cost of prevention or mitigation of the event increases as the probability decreases.
  - You must spend more and more to deal with things that are less and less probably. At what point do you stop spending?
- ❖ There is always the element of the uncertain, and it has been portrayed in Dyer's book in pretty negative terms.
  - It is a good thing to remember, though, that the uncertain also works in positive

ways
  - Some unsung, unheralded researcher might be working at this very moment on some fuel source or modification, that levels the playing field, offers alternatives and stabilizes the uncertainty itself.
- ❖ The example of the recent fire at Home Hardware. The students who escaped with nothing. If this were you, where do you start? Your knowns, your unknowns, your total unknowns etc? Will a better place open up?
  - You have to act.
- ❖ So you say:
  - I will position myself in the best possible place, cosmically speaking. And then if the worst of all possibilities comes to pass, I will have been in the best place possible. If the best of all things comes to pass, I will be in the best place possible to experience and take advantage of it.
  - This is what scenarios are all about.

The Power of Community

- ❖ The community Solution - Organization that explores the peak oil crisis
  - Focus - local, community-based solutions that reflect the local values of cooperation, conservation and curtailment.
- ❖ Peak Oil
  - 1949 - M King Hubbert claims that the era of fossil fuel will be short
  - 1956 - Hubbert forecasts oil production in the continental US will peak in 1970. It did
  - Mid 1960s - Oil discovery worldwide peaked.
  - 1980 - Global 2000 Report to the US President : By 2000, half of all oil available in the world will be consumed. Tax credits for alt energy.
  - But then discoveries in Alaska and North Sea, And President Reagan cut budget for alternatives. Nothing for next two decades.
- ❖ In the US today each person uses 26 barrels of crude oil per year: 10 (food), 9 (auto) 7(home)
  - China: 1993 (773,000 cars)
    - 2004 (8,000,000 cars)
- ❖ Cuba: Experienced an artificial Peak Oil crisis and can serve as an example of how to cope with such an event.
  - "The Special Period"
  - The end of the Soviet Union reduced Cuba's oil supply from 13-14M tons/year to 4M tons/year.
    - Immediate consequence: little food. Malnutrition in children under 5 years older, anemia in pregnant women, increase in underweight babies at birth. by 1994 average Cuban had lost 20lbs.
    - Blackouts throughout country (14-16hrs/day)
    - No elevators, fans or air conditioners.
    - Imported 1.5 M (1.2 in video, 1.5 in notes?) bicycles and made 0.5M more.
- ❖ US Embargo (1992): any ship docking in Cuba couldn't dock in US for six months. $750 M of food and medical supplies halted.
  - Embargo tightened: Foreign businesses doing business in Cuba barred from the US. Access to foreign capital is crippled.
  - Cuban government forced to ration food, UN minimum daily amounts.
- ❖ Cuban Agriculture: Before crisis was Green Revolution type, intensive use of natural gas produced fertilizers and oil based pesticides
  - Forced into survival agriculture
  - People grew food in cities/on rooftops
  - Permaculture: Design of human settlements and agriculture systems that is based on principle found in nature.
    - the way of designing places to live and agricultural systems that are modelled after nature.
  - 50% of Havana's vegetable needs are provided by urban agriculture (pop 2+ M)
    - Locals don't need transport
    - Kiosks to sell local produce
    - Farmers are now highest paid workers. Professionals are going back to being farmers.
- ❖ Agriculture: First ethic... take care of the land. crop interplanting, use of oxen (no oil, no soil compaction) worm humus (1 ton= 6 tons of compost)
- ❖ Energy: to be politically independent you must be economically independent; to be economically independent you must be energy independent.
- ❖ Free education and health care. Cuban trained doctors represent 11% of the total number of doctors (scientists) in Latin American. Exports doctors for oil.

❖ Cuba has shown one way in which a culture can survive a significant change in the availability of oil.

Adaptation in the North - A Different Approach

- ❖ Focus of Today
  - A - Adaptation to a changing climate
    - Northern Focus
  - B - Approaches to Adaptation
    - A New Generative Approach
    - What's Different?
  - C - Applying the Theory
- ❖ **Adaptation to a changing climate: Northern Focus**
  - Adaptation does not mean mitigation
- ❖ Climate mitigation
  - any action taken to permanently eliminate or reduce the long-term risk and hazards of climate change to human life, property
    - "An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC)
- ❖ Climate Adaptation
  - ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with consequences.
  - Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC)
- ❖ Climate Change
  - Impacts
  - Vulnerabilities
  - Adaptation
  - (not mitigation)
- ❖ Climate Adaptation - e.g. Flood
  - Adaptation plans for flood impacts
  - Build a levy/berms to prevent water from reaching buildings
  - Move all building out of potential flood zones
  - Build/modify buildings to withstand floods
  - Evacuation plan (ie preplanned or real time)
  - Emergency plan to pay for floor cleanup/rebuild.
- ❖ Why am I focusing on North?
  - An area of my expertise
  - Area of passion
  - Much study has been done of Arctic
  - Unique vulnerabilities and conditions
  - Complexity is evident and exacerbated
  - Worldwide implications
- ❖ Arctic Warming - Worldwide Implications
  - "The arctic is now considered the barometer for the planet; so if you protect the arctic, you save the planet." Shelia Watt-Cloutier.
  - Arctic is warming now - visibily
  - Arctic is warming 2-3 times faster than the rest of the planet
  - Catalyst - Arctic has impact on rest of planet
- ❖ Complexities
  - Vast, diverse, challenging geography (remote, incredible conditions, etc.)
  - Multi-faceted, diverse stakeholders
    - Interests, backgrounds, perspectives
    - FN, Aboriginals, Metis, Northerners, govts (terr/fed/munic/Aboriginal/regional/

hamlets)
    - Youth, women, elders, hunters/trappers
    - Industry, NGOs, academic, researchers
  - Socio-economic conditions
  - Often vulnerable communities and peoples
- ❖ Impacts and Vulnerabilities
  - Coastal communities: Sea levels; wave erosion; storm surges, shipping routes (NW passage)
  - Melting permafrost damaging infrastructure
    - Buildings/pipelines, infrastructure, heave, freeze/thaw
    - Transportation access: ice roads, frozen lakes/tundra
    - Energy: oil and gas exploration, spills, access (fly)
    - Transportation and hunting routes
      - On ice (melting), unpredictable water flow and ice (danger); streams become rivers.
    - Food: changes to diet and food security, high costs, less healthy hunting routes.
  - Loss of culture and history
  - Threats to health, including mental health
  - Decreased availability of water supplies
  - Insect, animal, disease vectors move north
  - Sovereignty
  - Low incomes/ high costs of living
  - Dislocation
  - shift in economic sectors (fisheries, forestry)
- ❖ Infrastructure
  - Transportation: roads, ice roads, airports, sealift "ports"
  - Buildings: houses, municipal buildings, stores, water/wastewater treatment
  - Communications
  - Energy: pipelines, diesel storage, generators, hydroplants, transmission lines, fuel storage.
  - Containment structure: storing waste rock and tailing from mining
  - Industry: wildlife harvesting
- ❖ Northern Infrastructure Uniquely Vulnerable
  - Permafrost (and other ice regines) heavily influence design, construction, maintenance
  - Construction and operating costs high due to distance, isolation, short construction season and extreme cold
  - Deteriorates rapidly in extreme environments
  - Lack of options, redundancies and back ups
  - Reopening after interruption is costly
  - Rapidly changing climate adds challenges
- ❖ Impacts (ACIA, Arctic Climate Impact Assessment, 2004)
  - 1. Arctic Climate is now warming rapidly and must larger changes are projected
  - 2. Artctic warming and its consequences have worldwide implications
  - 3. Arctic vegetation zones are very likely to shift, causing wide-ranging impacts
  - 4. Animal species diversity, ranges and distribution will change
  - 5. Many coastal communities and facilities face increasing exposure to storms
  - 6. Reduced sea ice is very likely to increase marine transport and access to resources
  - 7. Thawing ground will disrupt transportation, buildings, and other infrastructure
  - 8. Indigenous communities are facing major economic and cultural impacts
  - 9. Elevated ultraviolet radiation levels will affect people. plants and animals
  - 10. Multiple influences interact to cause impacts to people and ecosystems.
- ❖ Climate Complexities
  - Models vary widely

- Difficult to predict with accuracy
- Difficult to predict timing
- Difficult to predict local conditions
- Local conditions vary from global

❖ COMPLEX
- Climate change impacts, vulnerabilities, and in particular adaptation is a very complex issue, and is even more complex in the north.

❖ **Thinking and Approach**
- Generative Approach
    - Notice: the alternative approach may seem obvious after the fact, but this is generally not standard practice at the moment (in application)
    - One Generative approach I'll use as a basis for my discussion is: Appreciative Inquiry (AI); however there are many other similar strength based approached.
- Approach to "Change:
    - Status Quo Thinking
        - Change is incremental, linear, and predictable
        - world is controllable and predictable
        - identify/study the problem and then fix it
        - Fixing problem = success
        - Get as much information and facts as possible
        - "must get it right/perfect"
        - Describe reality
    - Generative Thinking
        - Change is complex, subjective, interconnected
        - World is complex, chaotic, and constantly changing
        - Identify and move towards desired future
        - Build on exceptional performance/successes
        - Try it; change as you go
        - Create reality
- Differences in Approach
    - Status Quo Approach
        - Problem based
            - Identify problem
            - Conduct root cause analysis
            - Brainstorm soluations
            - Analyze potential solutions
            - Develop Action plans
            - Implementation (if not stuck)
    - Generative Approach
        - Strength Approach
            - The best of what "is": identify core strengths
            - What might be: wishes/aspirations
            - Design possibilities (bold)
            - Inspired actions towards shared desired future (with collaborations and commitment)
            - Check in/modify as you go

❖ AI Approach Recap
- Focuses on core strengths
- Focuses on the ideal, desired future:
    - What is possible, what is the best, possible outcome, what is the best we can be
- ask questions, uses storytelling
- Uses stories of when things worked best
- Not gaps and problem solving, but creating more exceptional performance
- Builds solutions around what works rather than trying to fix what doesn't

❖ When does AI work best?
- Works in all situations

- In particular useful in systems or situations that are complex and emergent, where both the path and the destination are evolving, and where an iterative approach solidly informs the evolution and the outcomes.
- Innovation.

❖ Results of AI
- accelerates ***transformational change***
- Builds upon existing strengths
- More collaboration and commitment; reflects more diverse perspectives
  - *it's not that the Status Quo approaches don't work, they're just not always as useful for complex and transformation scenarios.

❖ **Applying the Theory**
- Problems
  - Fixing problems does not necessarily equal desired future
    - most common reason marriages fail because of breach in honesty
    - the reason why marriages are great are unconditional positive regard
    - *ideal scenario is not the opposite of the problem
- Questions
  - Questions about details versus questions about experiences, conditions, etc.
  - How we ask a question, already starts the process to transformational change (the question itself is a catalyst)
  - Framing our questions in a generative way, gives different answers - answer that shift us to a desired future.
- Status Quo Approach (Problem based)
  - Identify gaps in research and lit related to adaptation in the north (once we know gaps, then we can figure out where to put out efforts)
  - What are the biggest challengers in planning for adaptation
  - what important elements should we consider
- Generative Approach
  - what conditions are present when adaptive capacity is extraordinary and sustained?
  - What works well already? what could work even better?
  - What is working best in strengthening adaptive capacity in communties?
  - How does your work contribute to increased resilience to climate change?
  - What do you notice when a community is at its best adapting to shifting external stressors?
- Status Quo Approach
  - What role should we play with respect to climate change adaptation and what are your expectations?
    - Provide funding for projects
    - Act as one point of contact for stakeholders
    - make process more user friendly
    - Liaison/ communicate with other stakeholders.
    - *useful but not transformational*
  - Generative Approach
    - Slightly better" what do you value most about our influence on the adaptation file?
      - Always involve community and local stakeholders
      - culture of fairness
      - collaboration and inclusiveness
    - Even better: reflected upon a time when we were fulfilling out purpose of increasing adaptive capacity in the north. what were we doing that made the most positive difference? what positive actions were generated out of this involvement?
  - Status Quo Results
    - Gaps in research and the lit across the north
      - permafrost, sea level rise, infrastructure, food security, disease vectors, all communities, all time frames, all impacts...

- Status Quo Conclusions
  - Focus on :need more data: (may be true, but not transformational)
  - Scarcity/gaps/problems:
    - Not enough info/data; not enough money; not enough research; not for specific community; not for all points in time; not all parameters and conditions could be considered
  - tendency to fill the gap, even if not what is needed
    - Just because gap in food scarcity, doesnt mean it's the priority over permafrost for example
  - Didn't focus at all on desired future.
- Generative Recommendations
  - Systematically adopt practices of:
    - Build upon what exists, what is working well (existing strengths)
    - what worked best/ what could work better
    - solutions evolve and become better over time
    - Seek/integrate multiple perspectives voices
    - Continuous and shared learning
    - Experiential learning (learn by doing)
    - ** Ability to make decisions in uncertainty
      - e.g. parallel with economic uncertainty
    - Formal and information communities of practice
    - Accessible and use-able (existing and new)
    - Create opportunities for co-leadership and influence
    - Meaningful, relevant, and timely action
      - Efforts now more on research and data
      - Try and then adjust (not just study and analyze)

❖ **Summary**

- Overall Conclusions
  - Many issues we manage in the real world are complex, changing, unpredictable
  - Generative change approaches (AI)
    - Identify enablers, conditions of success
    - Is rooted in building solutions and systems around what works, rather than trying to fix what doesnt
    - Rather than starting from a place of gaps and problem solving, it looks at how to create more of the exceptional performance that is occurring when core strengths are aligned.
    - Help move us to transformational change
- Drawbacks
  - It's not yet widely known, understood, or practiced (business/ political world is set in linear short-term approaches)
  - Many organizations are not ready yet
  - It's a longer planning process and many existing systems, organizations and processes are set up to do piecemeal, one-off, inexpensive assessments without the continuity needed to see real change happen.
- Still Hope
  - After an organization has been able to truly see the results, they do support it
  - Possible to make small shifts in the approach until client is ready
  - Growing # practitioners using these methods
  - Complements other growing professions like coaching
  - Remember my mandate: help others define and achieve their best future
    - My coaching and AI work are very complementary
-

Quiz 5

Gardens of Destiny Video

- ❖ Salt Spring Island, BC
- ❖ Seed and Plant Sanctuary for Canada
- ❖ Ganges Market, homemade items, or grown organic foods
- ❖ Seed banks - keep growing seeds that are adapting to the world
- ❖ Living gene bank
- ❖ believes he is optimistic, small scale agriculture, being aware of where your food comes from. Hard to do in the city other than some small scale rooftop gardens and other green space
- ❖ Taste?
  - Many believe organic tastes better than commercial
- ❖ Diversity?
  - Genetic diversity
  - if a fungus comes in, less will be taken out with diversity.
  - Genetic diversity is limited in commercial use, especially through the use of mechanical harvesting. everything has to be the same height.
  - 90% of biodiversity has disappeared.
  - Indonesia loosing rice varieties. (had 100,000 to a million varieties of rice) Green revolution wiped out most of the indigenous rice crops, gave them only a few varieties. Disease hit and devastated rice crops. Had seed banks. Got up to about 10 commercial varieties of rice.
- ❖ Moving to the countryside?
  - need wide spread commercial organic foods
- ❖ Water?
  - not a lot of water is needed
  - use a lot of mulch to use less water.
- ❖ Medicinal plants
  - milk weed seeds for stomach
- ❖ non organic, non local farming is one of the biggest contributors to greenhouse gas
- ❖ using biofuels is one of the biggest contributors of the world food crisis
- ❖ Productivity?
  - whole planet should go organic to have enough food and nutrience
  - commercial moves food around too much
- ❖ Pollution?
  - use of nitrogen to great in commercial farming
  - creating dead zones.
  - can kill 99% of pests with pesticides but that 1% will become resistant and breed
- ❖ GMO?
  - putting medications into foods?
  - GMO can destroy cells in the guts
- ❖ Salvestrols
  - available in grapes and organic foods
  - helps fight cancer cells
- ❖ organic food has more antioxidants - they go after cancer too
- ❖ it is difficult to send seeds into the USA
- ❖ Terminator seeds?
  - plant the seed and it will germinate but the seeds produced from this cannot be planted as they will be sterile.
  - if terminator gene cross pollinates with other seeds nearby, they could become contaminated with the terminator seed.
- ❖ need an acre of land for one man to grow his food for a year.
- ❖ it is illegal for farmers to use the vast majority of organic plants available in

Green Building and Green Rating Systems

- Trevor Freeman
- Engineer, was with Engineers without Borders
  - 4 years with EWB in Zambia.
  - Working with Sustainability
- Successful vs. Significant
- Why Green? Why Now?
  - Resource problems? population boom.
  - Glacial Retreat
- Sustainability? - creating balance with ecological systems
  - Concept
    - big picture - what needs to be aimed for is a closed loop system
      - have an open loop system now
      - Water - Energy - Resources - no consumption
      - The market is not yet ready for sustainability, so the focus is on green.
        moving the yardsticks towards sustainability
    - Triple bottom line
      - People, Planet and prosperity
- Energy Reduction
  - Energy reduction through sustainable design of the built environment
    - New Building Design
    - Existing Building Design
    - Community Design
  - Energy Use
    - Building energy can be broken down into three categories
      - the relative size of each pie slice varies by building type and use
    - Building Operations
      - how the building is run
      - maintenance has a large impact on how efficiently energy is used.
      - in the past, buildings have been run to make occupants happy.
      - Retro-commissioning is used to evaluate energy savings opportunities in building operatios
        optimizing operation of the building, which results in reduced energy use and increased occupant comfort
    - Building Systems
      - The physical components of a system
        boilers, chillers, pumps, fans, lighting
      - Traditionally, most efforts to reduce building energy use have been focused on upgrading systems.
      - Energy audits are used to evaluate energy savings opportunities in building systems
        Mechanical, electrical, etc.
    - Occupant Use
      - occupant use constitutes a large portion of buildings total energy use, typically 25-50% in a commercial office building.
      - the opportunities for realizing savings here are significant.
      - Energy costs typically low portions of overall tenants costs
      - spend about 3$ per indiv on energy, about 30$ for the building costs and 300$ on people costs e.g. health care. sick days.
- Green Designing Consumes less (Green communities)
  - 70% water savings
  - 70% solid waste reductions

- energy savings
- CO_2 reduction
- Focus on Water Demand
  - Water efficient fixtures
  - grey water reuse
  - native landscaping.
- Stormwater (runoff)
  - bio-swales
  - permeable pavements
  - green roofs
- Public Transportation
  - Land use planning
  - Large upfront costs
    - huge return on investment
- Active Transportation
  - Cycling
  - Walking

❖ Rating Systems for Green Building

❖ BOMA Best
- For existing buildings
- Offices, light industrial, enclosed shopping centres
- Four levels of BOMA
- 5 Main categories of sustainability
  - energy management, water management, waste reduction, emissions and indoor environment
- Third party verification
  - valid for 3 years

❖ LEED
- top 25% of buildings.
- Certified, silver, gold and platinum levels
- Leadership in Energy and Environmental Design
- Focus on
  - Sustainable sites
  - Water efficiency
  - Energy and atmosphere
  - Materials and resources
  - Indoor environmental quality
- Prerequisites - minimum eligibility requirements
- Credits - amount of points available.
- Available for new buildings, commercial interiors, core and shell, existing buildings, homes, neighbourhood developments

❖ LEED for new construction and core and shell
- focus on design prerequisites and credits
  - site, water use reduction, minimum energy performance, durable building, thermal comfort
- Construction prerequisites and credits.
  - pollution prevention, recycled products.
- Using an integrated approach
- Project process and roles
  - each credit has a credit owner, among the design and construction team
  - Credit owners are responsible for understanding and implementing requirements

❖ LEED for existing buildings
- operate a building that does perform.
  - commuting, energy, procurement, maintenance.
- Focuses on two categories

    - Operational plans, programs and policies
    - Physical building requirements
  - Valid for 5 years
- ❖ TO being it all together
  - green needs to happen now
  - sustainability needs to happen soon
  - the perception is that technology and systems upgrades is the answer but so much more can be done
  - Behaviour change is key.
- ❖ Two other pieces of wisdom
  - VOTE! it's important
  - Successful vs. Significant

Semester Summary

- In the beginning:
  - A quick survey of the class indicating that sustainability was important for anthropocentric reasons
  - The worldview module
    - Discusses the DWW, HEP and NEP (something from worldviews will be on final)
    - corollaries to DWW
    - Carrying capacity
    -
- Why Energy and Sustainability Module
  - Primary and delivered energy
  - energy services
  - peak oil
  - US GDP vs. primary energy use
    - if US GPD grows, so does primary energy use
    - everyone wants use GDP to grow, or youre in a recession. that means energy always has to grow. Maybe we should try to unlink these.
  - Ontario primary E demand vs. GDP
- Renewable and Non-Renewable Resources Module
  - Renewable
  - Non-renewable (abiotic)
  - Non-renewable renewable (biotic)
  - Non-renewable: concentration, composition, amount
  - Non-renewable renewable: population structure (exponential/logistic growth) community structure, ecosystem structure.
- Sustainability Module
  - 5 Views of sustainability
  - Basiago's 4 principles of Sustainability
  - Sustainability as methodology
- Sustainable Development Module
  - Brundtland definition of SED
  - Inter- and intra- generational equity
  - Needs, limits
  - compensating future
  - 3 types of capital
  - 4 types of sustainability
  - precautionary principle
  - core principles of sustainable developmentt
  - techno and eco centrism
- Futurity Module
  - Moral standing
  - anthropocentrism
  - 4 reasons for giving moral standing to future generations

- Aamjiwnaang (more females than males birth rate.)

❖ Sustainability and CAS Module
  - Complex Adaptive Systems (CAS)
  - 5 Characteristics of CAS
  - Example of city
  - Lake Erie
  - ELA

❖ Renewable Energy Module
  - Inexhaustible, exhaustible, flux limited E
  - Natural energy flow
  - atmosphere and EM radiation
  - EM radiation
  - Radiative cooling
  - Renewable energy technology

❖ Energetics Module
  - Energy(E)/power(P)
  - Forms of E
  - 1st and 2nd Law
  - Potential E, Kinetic E, Thermal E
  - Mass-energy relationship
  - Energy intensity / power density
  - exergy/anergy
  - Energy flow in biosphere
  - various energy units

❖ Resources and Reserves Module
  - Near infinite resources of minerals
  - Resource/demand ratios
  - Resources and reserves definitions
  - McKelvey's Box
    - picture that describes what resources and reserves are
  - Reserves vs crustal abundance
  - Lasky Relationship
  - Relationship of grade to energy

❖ Non-Renewable Energy (Fossil Fuels) Module
  - Types of fossil fuels
  - Coal:Types, resources, reserves, energies
  - Coal combustion: solid, liquid. gas
  - Crude oil: USGS peak Oil
  - Natural Gas
  - Methane Hydrates

❖ Renewable Energy Direct Solar Processes Module
  - Passive, active, solar photovoltaic
  - Conduction, convection, radiation
  - Complete passive solar design components
  - Passive solar cooling
  - solar cookers

❖ Risk and Uncertainty Module
  - Leave risks for future

- Types of Hazards
- R=PxC
- 3 cases: DUR, DUU, DUUP
- Higher-order consequences
- Risk and views of nature
- 4 myths of nature

❖ Energy Storage Module
- Energy storage technologies
- Fluid E Storage (PHS, CAES)
- FES
- Batteries (primary cell, secondary cell)
- Fuel cell
- Capacitors
- SMES
- Thermal E Storage

❖ Photosynthesis Module
- Photosynthesis process
- Respiration
- Transpiration
- 3 types of Plants
- Reservoirs, resources, and sinks
- Water (hydrologic) Cycle
- Aral Sea
- NPP
- Carbon cycle

❖ H. Damman Video Lectures
- Agriculture: Irrigation, pesticides
- New crop species
- Limits to productivity
- Biotic resource management
- Peruvian Anchovy Fishery
    - collapsed in 1970s because of El Nino

❖ Tragedy of the Commons Module: Fisheries
- Tragedy
- Tragedy of the Commons (TOC)
- Tragedy of the Commons cause
- Fisheries as examples of TO
- Aquaculture
- Marine Protected areas

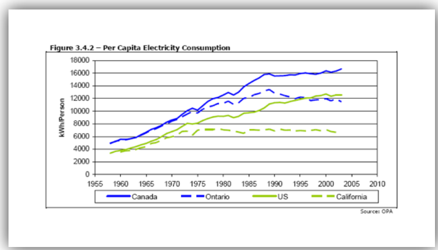
❖ Ecological Design Video
- Buckminster Fuller
- Jay Baldwin
- John Todd
- Stewart Brand
- Amory Lovins
- Paolo Soleri etc
- Dymaxion house and car
- Living Machines

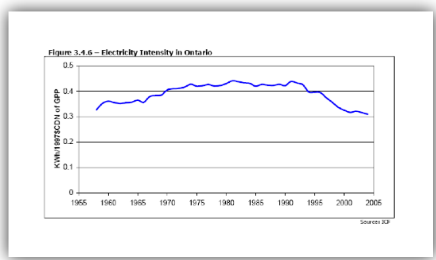
- ❖ Electricity Generation Module
  - Turbine/ Generator pair
  - Types of Fluids/types of turbines
  - Electromagnetic induction
  - Electric generator/ electric motor
  - Hydroelecticity
  - Fossil Fuel (CHP/cogeneration)
  - OWC
  - Wind: HAWT, VAWT
  - OTEP: types and spin-offs
- ❖ Nuclear Energy Module
  - Atomic structure/isotopes
  - Half lives
  - Fission (used for energy) .Fusion
  - Fission chain reaction/ CANDU
  - Fusion
  - 4 things you need for fusion
  - ITER (tokomak). IEC, LENR-CANR
- ❖ Supply and Demand Module
  - Energy services
  - Conservation as a source of supply
  - Increasing supply vs increasing conservation supply
  - Atikokan Generating Station refit
  - Examples
- ❖ Power of Community Video
  - Peak Oil
  - Cuba's Oil Crisis /US Embargo
  - Consequences of Oil Crisis and Embargo
  - Green agriculture
  - Survival Agriculture
  - Permaculture
  - Health Care and Education
- ❖ H. Menzies Video
  - Focus on household and women's bodies
  - Household technology
  - New reproductive technology
  - Ecofeminism
  - Ecological Approach to communication
- ❖ R.Donovan Lecture: Scenarios
  - Ways to look at time
  - Foresight
  - Expected future/preferred future
  - The Climate Wars
  - The planner's Dilemma
  - Apathy, planning, action
- ❖ M. Creede Lecture
  - Adaptation not mitigation
  - The North and Climate Change

- AI: generative approach
- AI vs. status quo approach

❖ T. Freeman Lecture
- Successful vs. significant
- Go Green not sustainable (yet)
- Rating systems for green buildings

❖ Some end comments
- There are signs of progress:
  - The electronic Journal of Sustainable Development (2008)1(2) "Sustainability of Fisheries" Rognvaldue Hannesson*
- 1990s saw the collapse of the Northern Cod fishery off Newfoundland. The fishery has yet to recover.
- 1970s saw a collapse of the Peruvian Anchovy fishery as a result of poor resource management and an El Nino event. This fishery had recovered by the mid 1990s, but then in 1997 another El Nino event occurred (people decided not to fish that year to save the fishery, losing one year of fishing over many years, sign of improvement). This time the fishery was curtailed and the stock recovered after one year.

❖ CDM (Conversation and Demand Management)
- programs in ontario are also informed by the trend in electricity intensity. Demand for electricity in Ontario has grown since 1990. However, this growth has been accompanied by a striking improvement (decrease) in electricity intensity that started in 1990) This means that Ontario's economic output has grown significantly faster than the demand for electricity. Electricity intensity is the ratio of electricity output (kWh) to economic output measured by the Gross Provincial Product (GPP) This trend is expected to continue in the future.
- 

- 

- Decoupling of GDP and power use in recent years.

❖ A similar trend in energy intensity was observed in the EU in 2007
- It is unclear if this means that sustainability is on the way, but it is encouraging that in some places positive change is occurring.