Chapter 4

Energy and Energy Sources

Learning Objectives

- Investigate a case study that raises issues of energy science, spirituality, and ethics
- Explain the basic science of energy including the similarities between energy and work
- Understand that energy can exist either as potential or kinetic
- Describe the different types of energy
- Show how energy can be transformed from one form to another
- Understand the importance of the Laws of Thermodynamics in energy transfer
- Differentiate between renewable and non-renewable energy sources
- Describe energy sources that are both renewable and non-renewable as well as the advantages and potential drawbacks each of these energy sources
- font Analyze ethical/ world issues concerning energy availability, access, and use

Case Study

The Deepwater Horizon Oil Spill in the Gulf of Mexico

On 20 April 2010, a deep water oil well in the Gulf of Mexico erupted, and in the three months before the gushing pipe was capped, the spill released nearly 5 million barrels (almost 800,000 cubic meters) of oil into an ecologically diverse region of the Gulf of Mexico in North America. The accident, the worst environmental accident in the history of the United States, had dramatic effects, both in the immediate aftermath and in the years that have followed. Eleven workers died in the accident's fires and explosions, and the release of such a large amount of oil into a fragile ecological zone had significant environmental and economic impacts. There is a large number of oil wells in this ecologically sensitive area. ~~The following map illustrates this.~~ Fig 1

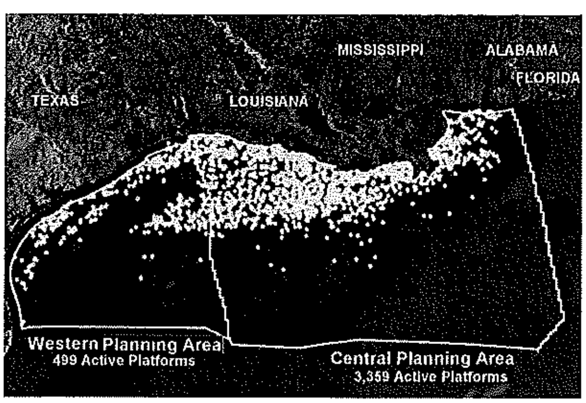


Fig 1 (Map of Gulf of Mexico showing nearly 4000 active oil and gas platforms, ~~site.~~ (http://oceanexplorer.noaa.gov/explorations/06mexico/background/oil/media/platform_600.html)

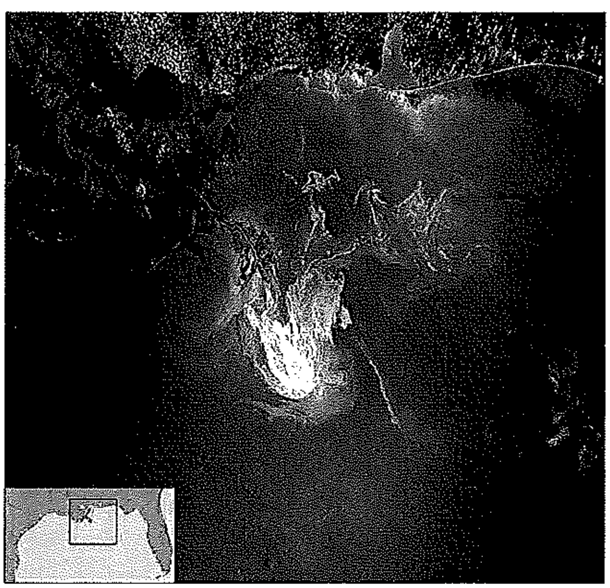
Just before the oil spill, an international team of scientists published the results of a major research project documenting the biodiversity of the Gulf of Mexico, and found that the region of the spill is home to over 8000 species of plants and animals, including more than 200 species of birds and 29 aquatic mammals. While the immediate effects of the accident were significant, resulting in the loss of significant animal life and effects to humans' health, a recent study by the United States' National Oceanic and Atmospheric Administration (NOAA) concluded that the long-term environmental consequences of the spill may be "far more profound than previously thought". Studies of aquatic life in the area show that the health of fish and shrimp has been compromised. One example of this is that prior to the spill, only 1 in 1000 fish had sores or lesions on their bodies, after the spill, almost 20% (200 in 1000) showed these effects. The effects were not limited to the water surface. Recent research has shown that deep sea coral beds were damaged by the plumes of oil rising from the leak site. The oil from this site contained a larger amount of ~~the molecule~~ methane which ~~in these large quantities has the effect of~~ reducing the amount of oxygen in the local environment, ~~This~~ essentially suffocates life. An investigation ~~of the region~~ in early 2013 revealed that the ~~a~~ region 50-80 km around the accident site has a marked reduction in ~~the amount of~~ marine life ~~observed~~.

km

the oil quickly dispersed to the shore which
While

~~The dispersing oil also reached the coastline of the~~ southern United ~~States~~. The oil well was located approximately 50 miles off the Louisiana cost. ~~This~~ lead to oil contamination of beaches and marshlands along the Gulf Coast, ~~This contamination is believed to have caused a~~ significant reduction ~~in~~ the biodiversity of the coastal areas. The effects of this accident extended beyond the environmental. The economy of the region also suffered as many types of businesses, notably the fishing industry and tourist trade were adversely effected. Two years after the spill, estimates for the shrimp and oyster harvest, important to the local economy, were only 1/4 to 1/3 the size of pre-accident harvests. Estimates of losses to the tourism industry suggest a reduction in revenue of over 20% for the three years after the event.

Figure 2
~~The map below~~ show the extent of the oil spill. The green at the top represents the southern coast ~~line~~ of the United States ~~along the coast coast~~. The white color illustrates the surface oil coming out of the leaking well. The picture was taken on May 24, 2010 just a month after the accident. The leaking well in is in the bottom right portion of the bright white oil slick. The map inset shows the area in relation to the southeastern United States. Photo from NASA Terra satellite.



~~But~~ What will be the long term effects of this oil spill? We cannot ~~of course~~ know the complete answer to this ~~now~~, but recent scientific research suggests the effects of this accident will persist for many years. Findings presented in January 2013 suggest that as much as 1/3 of the original oil remains in the Gulf. One of the effects of the remaining oil is to cause solid particles to clump together, and then fall to the bottom of the Gulf in what has been called a "dirty blizzard". Scientists have measured ~~that~~ the rate of particle accumulation on the sea floor ~~is~~ to be ten times greater than the natural *sedimentation* rate in areas of the Gulf unaffected by the spill. (Sedimentation is the process of solid particles settling to the bottom of a body of water.) Many of the fish that are used for human consumption eat creatures that live in the seafloor sediment, thus the concern is that the effects of the oil and its pollutants, including ~~such as~~ high concentrations of mercury, will enter into the food chain for many years come.

Much has ~~Many words have~~ been ~~and continue to be~~ written about the tragic deaths and devastating oil spill following the blowout and explosion of the British Petroleum (BP) drilling ~~rig,~~ Deepwater Horizon, on ~~April 20,~~ 2010. There have been words of deep sadness ~~and loss~~, frustration, anger, explanation, and, of course, blame and threats. ~~Though the containment cap is having some success, the oil is expected to continue flowing into the Gulf until at least the fall.~~ Cleanup and response efforts will go on for years. As the oil flows so will the words we read. As the cleanup continues so will the words we read. We read them on the internet, in newspapers, and in magazines. Books will likely be published. Perhaps all those words will help us understand what happened, describe the devastation and destruction, update us on progress, and assign responsibility. They will keep us informed; but will they help form us? Will they deepen our lives, take us to new levels of consciousness, and strengthen relationships with each other and nature? Probably not. A recent NPR article reported how many people do not see much connection between their lives and what has happened and is continuing to happen in the gulf.

delete

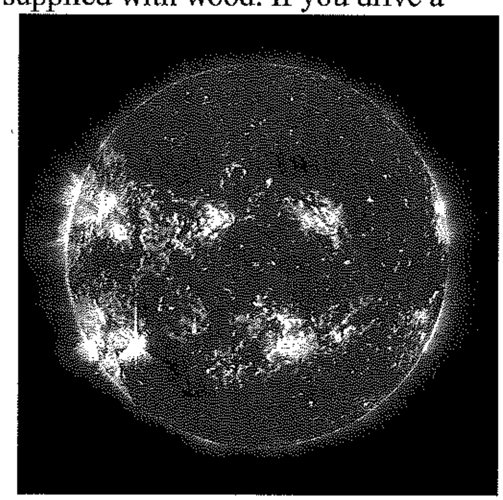
You might be asking now a question like "why would we put oil wells in places like this?". In fact, as Fig. 1 above shows, there are nearly 4000 active gas and oil platforms operating in the Gulf of Mexico alone. So why is there so much effort used in finding and extracting oil and gas? The answer can be summarized in a single word: energy.

develop this to bring in ethics & spirituality

Energy and Science The sun is the source of energy that ultimately fuels nearly all life on the planet.

~~All life activities require a source of energ~~y. That source of energy comes from fuels. Think about a campfire. To sustain a campfire, you need to keep it supplied with wood. If you drive a car, you need to keep gas in ~~your~~ car to reach your destination. As birds fly through the air, they need to utilize the fuel that is stored in their tissues as fat to sustain flight. In each example shown, different types of fuels are used. Wood for the fire, gas for the car, and stored fat for the birds. Each of these sources of fuels comes from the same source—solar energy from the sun that has been converted to and stored as chemical energy. Solar energy originates in the sun from nuclear reactions. Some organisms such as plants are able to trap the solar energy and then use it to make food. This food can then be used by other organisms to fuel activity and growth.

campfires + cars are not "life or living" activities



(illustration of sun http://www.nasa.gov/mission_pages/sunearth/news/News111312-m6flare.html)

This section needs to be reorganized and rewritten.

start w/ chemolithotrophs Archaea, to cyanobacteria + PS, evolution of O_2 and aerobic respiration. Sources of energy for each type of metabolism.

Photosynthesis and the Energy from the Sun

There is a tremendous amount of energy that reaches the Earth from the Sun. There is also a continual loss of energy from the Earth. The Energy from the Earth is lost as heat when it radiates back out from Earth and beyond Earth's atmosphere. The atmosphere of Earth is able to trap in some of the heat. This warms Earth and makes it habitable. Matter on Earth is used over and over as it moves through Earth's four spheres (biosphere, hydrosphere, geosphere, hydrosphere). The nutrients on Earth often change form and may take millions of years to complete their cycle, but matter is not last as it cycles through Earth's four spheres.

I think this ¶ is describing that energy is dissipated, matter is reused.

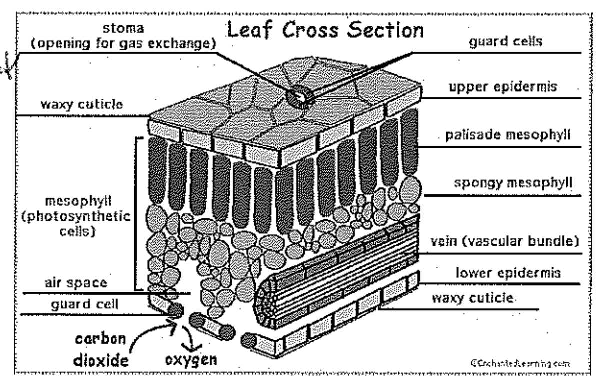
Let's ask ourselves why the conversion of solar energy to chemical energy, in the form of food is so important. There are two main reasons. The first is that the sun will continue to supply the Earth with energy for billions of years to come. The second reason is that many organisms on Earth, like plant life, contain chlorophyll. This allows Earth's biosphere to harvest some of the reliable Energy supply from the Sun.

Why is chlorophyll important? It is key to the process of photosynthesis. Photosynthesis is the process that is critical to life on Earth. Chlorophyll is a pigment that gives leaves their green color. Photosynthesis is the process of "putting something together" with light. How and what does photosynthesis put together with chlorophyll and light? Photosynthesis combines carbon, hydrogen, and oxygen to make sugars, which are the building blocks of life's energy supply. Photosynthesis produces a sugar called glucose.

Describe photosynthesis in more depth w/ more sophistication

Since the sun is the energy source behind all life on Earth, it is important that we understand more about the process of photosynthesis, which is the first step in harnessing the sun's energy. Sugars such as glucose belong to a class of chemical molecules called carbohydrates. Carbohydrates, as the name implies, are made of carbon, oxygen and hydrogen. To make glucose, plant life needs an abundant supply of these three elements. The hydrogen enters the plant from water through the plant roots. Carbon and oxygen are supplied to the plants from carbon dioxide gas, that enters the plants through tiny pores in their leaves called stomata. A diagram of a plant leave is shown in the figure below.

describe PSI, PSII + Calvin cycle



(illustration source: http://www.enchantedlearning.com/subjects/plants/leaf/)

During the process of photosynthesis, chlorophyll in the plant leaves use the energy from the sun to synthesize glucose molecules from water and carbon dioxide. Oxygen is also produced during the process of photosynthesis. The formula that illustrates the process of photosynthesis is shown below.

$$6CO_2 + 6H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

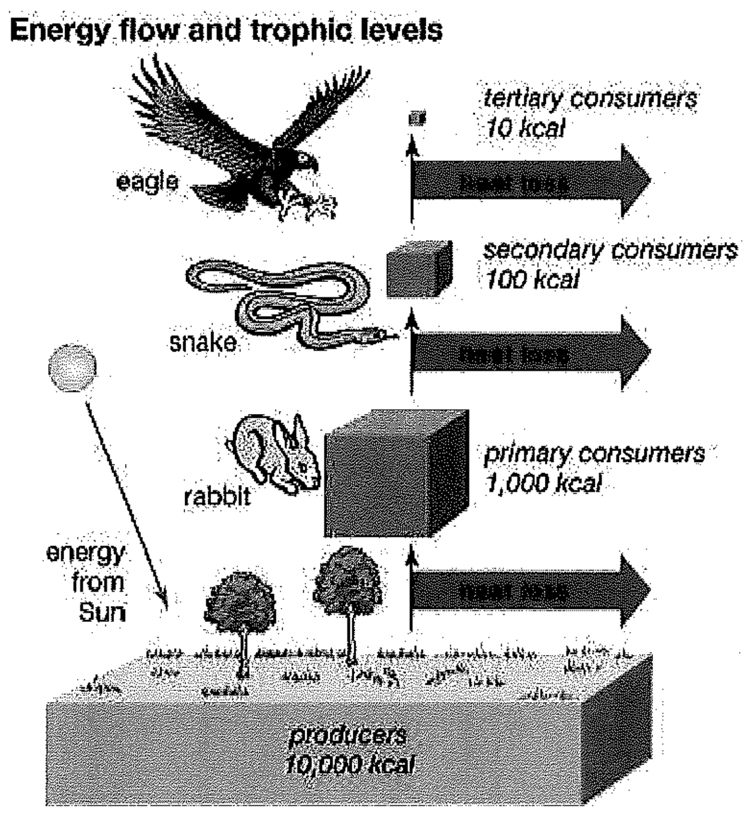
~~nutrients~~ nutrients are not involved in PS

~~Organic compounds~~ glucose

Photosynthesis produces glucose, which is the energy supply that plants, and the organisms that eat them, require for all of their essential activities. In addition, photosynthesis produces oxygen which is continuously added to the atmosphere and which many organisms breathe. Lastly, photosynthesis removes carbon dioxide from the atmosphere. OMG

Trophic Levels and Trophic Efficiency

Matter and energy are transferred between trophic levels within the biosphere. A trophic level is the position that an organism occupies in a food chain. ~~It can also be thought of as a category of organisms that are defined as to how they gain their energy.~~ Primary producers occupy the most basic trophic level. They are organisms that can make their own food, such as plants. On the other hand, consumers are a class of organisms that cannot make their own food. They musts eat other organisms to get the matter and energy they need to live. A food chain can be examined to better understand what is meant by trophic levels. rewrite



~~As can be seen, in this figure,~~ There are four trophic levels in this food chain. The primary producers, the plants, are ~~at~~ the first trophic level. The rabbit, which eats the primary producers, is at the second trophic level, the consumer or herbivore. The snake, which then eats the rabbit, is at the third trophic level. Finally, the eagle, which eats the snake, is at the fourth trophic level. ~~What is interesting about~~ this figure ~~is that it~~ illustrates the principle of "trophic efficiency". ~~If you look at each trophic level in the diagram, you can see heat loss associated with it. Also of interest is the quantity of biomass associated with each level. Biomass is the mass of living cells and tissues that is synthesized by organisms using solar energy.~~

There is only a 10% trophic efficiency between one trophic level and the next. It requires 10,000 kcal of plant energy to produce 1,000 kcal of 1° consumers. This low efficiency is due to the cost of metabolism, & reproduction leaving only 10% for new biomass

~~Examples would be wood, leaves, stems, roots and flowers that contain chemical energy that has been converted from solar energy. All animals also rely on solar energy. Animals eat plants or other animals that eat plants.~~ The trophic efficiency is a measure of how much energy in organisms at one trophic level transfer energy to a higher level. The percentage of energy transferred to a higher trophic level is always less that 100 % because organisms use energy in the biomass that they consume for their life functions (such as moving, maintaining body temperature, etc) and they also produce waste. As a general rule, trophic efficiencies in the biosphere are typically on the order of 10 percent. This is also illustrated in the figure. As can be seen, if we assume a total energy from biomass of 10,000 kcal in the first trophic level, only 1000 kcal (or 10 percent) will be transferred to the rabbit. Of the 1000 kcal that reach the rabbit, only 100 kcal will reach the snake. Of the 100 kcal that reach the snake, only 10 kcal is available to feed the eagle.

Keep this concept but tighten up writing

There are many reasons why there is a decrease in biomass from trophic level to the next. Herbivores may not eat all parts of a plant. They may only eat the bottom portions of the plant or the top portions and leave the roots undisturbed. Also, when biomass is consumed, not everything that is eaten is digested. It leaves the consuming organism as waste. In response to this inefficiency between trophic levels, there are usually less carnivores than herbivores, and less herbivores than plants.

need a transition between the biological use of energy for metabolism & the following physics section

Forms of Energy

Energy comes in two different forms. It is either kinetic or potential. All of the different types of energy that you may be familiar with fall under one of these two categories. Potential energy is stored energy or energy of "position". Think of ways in which energy can be stored. A compressed spring is a good example of potential or stored energy. It has the ability to do work and is therefore considered a form of potential energy. Think also of a piece of wood. When the wood is burned it produces heat and light as a result of energy that was stored in its chemical bonds. The other form of energy is kinetic energy. It is energy of motion. This includes the motion of waves (electromagnetic, sound and water), electrons, atoms, molecules and substances. Think of moving water. One of the earliest ways that early civilizations used kinetic energy to do work was by utilizing the kinetic energy of moving water for transportation or powering simple water mills. We will examine different types of energy relate them to whether the energy is kinetic or potential. It is helpful to question why a certain type of energy is considered kinetic or potential.

There are a number of types of energy that are important in understanding the science of the environment. Let's review these types of energy now.

Radiant Energy (kinetic)

The term 'radiation' refers form of energy can travel through space or vacuum as a wave without the need of a medium to travel through (like sound). Radiant energy from the sun travels through space at the speed of light (3×10^8 m/s). There are various types of electromagnetic (EM) waves. Radio waves have the longest wavelengths and lowest frequency while gamma rays have the shortest wavelengths and highest frequency. The sun emits different amounts of each of these types of EM waves, and each type of EM wave contains a different amount of energy. The longer the wavelength of light, the less energy is contained in the associated form of radiation. Thus, radio waves transmit very little energy, while gamma rays are highly energetic.

As was mentioned earlier, solar radiation is the primary energy source that fuels all life on earth. Plants use the energy from the sun, combined with carbon dioxide and water to make simple sugars in a process called photosynthesis. These simple sugars are then used as building blocks to allow organisms to synthesize carbohydrates, lipids and proteins for structural growth. Animals use the energy from the sun indirectly by consuming and utilizing the chemical energy that was produced by plants. Solar radiation also drives all weather on Earth. This includes local and planetary winds as well as the hydrologic cycle. Low and high-pressure areas on Earth are also the result uneven heating of Earth's surface from solar radiation.

There are other forms of energy that will be defined. One example is thermal energy.
Thermal energy is the the internal energy in a substance due to the vibration and movement of atoms within a substance is thermal energy. Solar radiation transforms to thermal radiation after it makes contact with the atmosphere or surface of the Earth. The thermal radiation causes the atoms that make up the Earth's atmosphere, crust and oceans to vibrate faster and therefore become warmer. This is the energy that warms the Earth. Another example of thermal energy is geothermal energy, which is derived from water that is heated by earth processes deep within the Earth's crust. There is also mechanical energy. Mechanical energy is energy of motion. It relates to the movement of objects from one place to another is motion. A moving substance has the ability to do work and is therefore considered energy. Wind and Hydropower and considered forms of motion energy. Another form of energy is electrical energy.
Electrical energy is the movement of electrons. The movement of electrons can be utilized to power the household items and manufacturing equipment that make our life better. Sound is also a form of energy.

Think how sound is created. It begins with a disturbance in the air molecules around the source. The vibration of the molecules continues out in all directions and is detected by the listener in the air as a vibration of the ear drum. Moving air molecules created by sound is another example of kinetic energy.

Chemical Energy (potential energy)
If you refer back to the chapter on water, you will recall that we spent significant time describing how the molecular structure of water explains many of water's remarkable properties. In particular, recall that water is composed of two hydrogen atoms and one oxygen atom that are bonded together to form a water molecule. The energy stored in these bonds is called *chemical potential energy*, and is the energy that is released when the bonds are broken.

One of the reasons that fossil fuels (oil, gas) are so widely used is that they store large amounts of chemical potential energy. The simplest of these fuels, methane (CH_4) (line drawing of the structure of a methane molecule) consists one a central carbon atom bonded to four hydrogen atoms. When methane is "burned" (in this context, "burned" means to react chemically with oxygen), the carbon-hydrogen bonds are broken and chemical potential energy is released and becomes available to do work. The complete reaction is:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

This chemical reaction is telling us that when 1 molecule of methane reacts with two molecules of oxygen, the atoms in these molecules rearrange themselves into one molecule of carbon dioxide (CO_2) and two molecules of water. In the process, bonds are broken and rearranged and energy is released a result. The energy released is in the form of heat which can be captured and used to produce electricity.

Nuclear Energy

We have known for about a century that all different kinds of atoms have the same basic structure. (line drawing of atomic structure showing electrons orbiting nucleus; radius of electron orbits large compared to size of nucleus; nucleus consists of protons and neutrons). Atoms have a small, dense nucleus composed of protons and neutrons. The charge of each proton is positive and each neutron is neutral. Since like charges "repel", a force is required to hold the protons and neutrons together in close proximity. This force binding nuclear particles together in the nuclei is known as the strong nuclear force. It is one of the strongest forces in the universe, ,and this is the source of nuclear energy. We can extract nuclear energy from nuclei of large atoms (like uranium and plutonium) by splitting them into smaller nuclei in the process called nuclear fission. Fission is the process of splitting a larger nucleus in to two or more smaller atoms. During the process of fission, a portion of the binding energy is released and available as heat. The nuclear fission technique is used in all the operating nuclear power plants in the world. Smaller nuclei like hydrogen and helium can produce nuclear energy by fusion, where two or more nuclei collide at high energy and combine to produce a new, larger nucleus. The sun produces its energy through the process of nuclear fusion deep in the core of the star.

Significant research is underway to learn how to produce energy through controlled nuclear fusion. To date, scientists and engineers have not yet managed to produce energy through controlled nuclear fusion reactions, although each year brings new progress toward this goal.

Gravitational Energy (potential)

Gravitational energy is the energy of position or place. Gravity is a force between two objects as a result of the attraction of their masses. A rock resting on the top of a hill contains gravitational potential energy. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

Energy Transfer and Conversion

Energy can be transferred between substances or through vast space by one of three types of heat transfer. These include: convection, conduction and radiation. **Convection** is the transfer of heat energy in a gas or liquid by movement of currents due to change in density. **Conduction** is the transfer of energy through matter from particle to particle. **Radiation** is the transfer of energy through electromagnetic energy waves. This form of energy transfer does not require a medium to travel through. The combination of convection, conduction and radiation is how our planet is able to keep and moderate temperature. Radiant energy from the sun travels through space as visible light and ultraviolet radiation. When the radiant energy contacts the Earth, the Earth's surface warms. Air that is close to Earth's surface is heated by conduction by contact with the warm Earth surface. As the air is heated, it becomes warmer and lower in density. The resultant lower density air rises and carries with it energy to the upper levels of the atmosphere. The rising energy helps to moderate the temperatures in the Earth's troposphere.

Energy can be converted (transformed or changed) from one form to another. Think about it for a moment. How is your body sustained? The food you eat has potential chemical energy. When you eat it, the bonds between the atoms in the food molecules are broken and the energy is released to your cells. Your body changes the chemical energy to kinetic mechanical energy when you run, jump, write, etc. Finally, your body creates thermal (heat) energy because the molecules in your body are moving. There are also loses associated with waste products of respiration.

Consider another example. Water stored behind a reservoir damn has potential gravitational energy by virtue of its elevation in relation to the land around it. When the water from the reservoir is released to a lower elevation where it can be converted into mechanical kinetic going inside a water turbine. The mechanical kinetic energy can then be converted to electrical energy. The electrical energy can then be used in manufacturing or in households to power equipment! The ability to transform one form of energy into another is remarkable and allows for many types of technologies to capture and utilize energy on Earth.

There are some important limitations on energy transfer that are part of what is called "The Law of Thermodynamics". To gain a better understanding on the limitations of heat transfer, we will examine the energy transfer of a very simple heat engine.

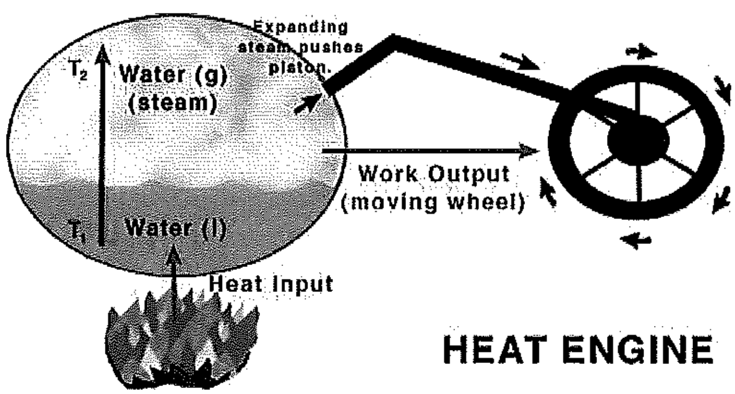


Figure courtesy Washington University of St. Louis (http://www.chemistry.wustl.edu/~edudev/LabTutorials/Thermochem/Fridge.html)

The diagram above depicts a simple device powered by a heat engine. A working fluid, in this and many cases water, is heated until it becomes steam. The steam then pushes on the piston, moving the wheel. In the early days of train travel, this is essentially the design of the heat engines that powered the early steam driven locomotives. The conservation of energy (the First

Law of Thermodynamics) means that the total work output cannot exceed the energy input. However, we can never construct an engine in which the total work output is equal to the total energy input. Some of the input energy will be absorbed by the container holding the water and steam, and then radiate this energy to the outside surroundings. Some of this energy will be lost as friction as the piston moves the wheel. Using the conservation of energy as our guide, we can summarize the energy balance of the engine by writing:

Energy input = work output + energy lost to friction + energy lost to surroundings

There will always be energy lost to the surroundings and energy lost to friction, therefore, it is never possible to obtain as much work output as your energy input. We define the *efficiency* of an engine as the ratio of work output to energy input, or

Efficiency = Work Output/Energy Input

The fact that no real process can ever be completely efficient (the work output must always be less than the energy input) is a result of the **Second Law of Thermodynamics**, which describes how every process converts some of its input energy into waste so that the no process is fully efficient.

History of Energy Sources and Uses

It was not that long ago in human history that essentially all of the energy used by humans for cooking and heating came from renewable energy sources. Until the beginning of the Industrial Revolution in the 1700s, essentially all energy for heating was derived from *biomass*. Biomass is all plant, animal and microbial material in addition to any solid waste generated by animals.

Biomass along with wind power provided almost all of the world's energy needs up until the 1700s. As the Industrial Revolution spread through Europe, the increased demand for biomass energy resulted in cutting down trees more rapidly than they could be grown, leading to an 18th Century energy crisis. In response, Europeans began using a non-renewable source of energy, coal (a fossil fuel), instead of obtaining energy from burning trees.

The diagram below summarizes how global sources of energy have varied over the last 150 years. The amount of energy used is plotted on the vertical axis in the unit of exajoules; one exajoule is the equivalent of 10^{18} joules, or 1,000,000,000,000,000,000 joules. As you can see, it is much more efficient to use scientific notation.

Different types of energy sources are denoted by different colors. For instance, the

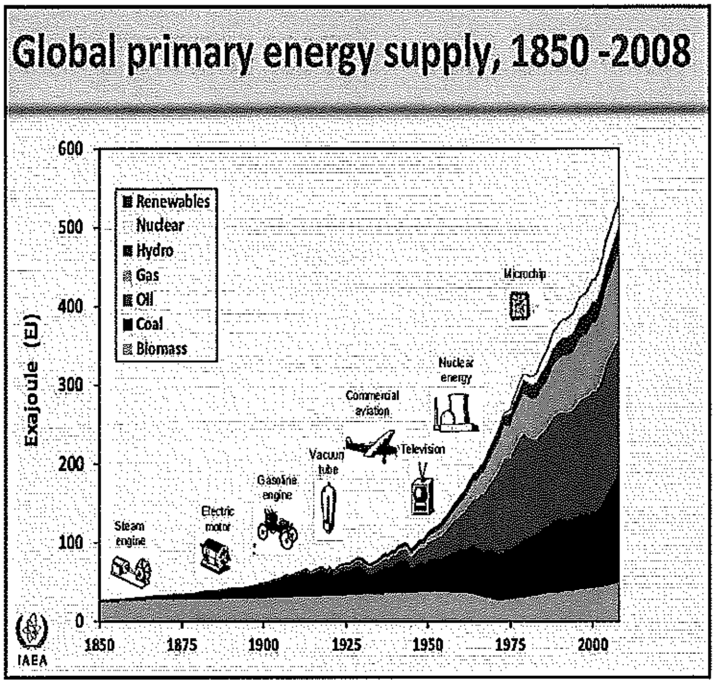


Image Courtesy International Atomic Energy Commission 1

amount of biomass used throughout the world each year is denoted by the green area on the graph, whereas the red region indicates the amount of oil used each year.

There is much we can learn by studying this graph. First of all, and not surprising, is that the total energy usage on the planet has increased dramatically in the last 150 years. We can see from the diagram that the total global energy usage in 2008 was about 20 times greater than the total energy usage in 1850. The current population of the world is approximately 6 times greater than the population of the world in 1850, which means that each person today uses several times more energy compared to our 1850 counterparts.

If we look at how the sources of energy have changed, notice that in 1850 almost all the world's energy supply came from biomass, with very small contributions from coal and an almost imperceptible amount of oil. Biomass is still used in many parts of the world today, especially in rural areas of developing countries.

The graph shows clearly how the use of fossil fuels, in particular the use of oil (shaded in red) dominated global energy usage in the years following World War II. In 2008, approximately 80% of the world's energy was derived from the fossil fuel sources of coal, oil and gas. In the last few decades, other energy sources such as nuclear energy and hydropower energy have become more commonplace, but still represent only a small fraction of the world's total energy consumption. The thin pink strip at the top of the graph represents the amount of energy generated from renewable sources such as wind energy and energy drawn from ocean tides.

As you study this graph, can you make predictions about how the global energy usage will change in the next few years, or during your lifetime? Do you expect the world's population to increase or decrease? Do you expect that people around the world will use more or less energy each day than they do now?

Non-Renewable and Renewable Energy

Many sources provide the energy needed to maintain our lives. Energy sources can be broadly categorized as either "renewable" or "non-renewable". Renewable energy is energy generated from sources which are continually replenished with the passage of time, either through biological reproduction or other naturally recurring processes (Wikipedia 2013). This would include solar (radiant), hydro (kinetic or motion), geothermal (thermal), biomass (chemical), and wind (kinetic or motion) power. Non-renewable energy comes from sources that are finite in supply. Most non-renewable energy sources are fossil fuels. This includes fuels (chemical) such as petroleum, coal, natural gas, tar sands, shale oil and propane. It also includes nuclear power because there is a finite amount of uranium available to power nuclear power plants. We will first examine non-renewable energy sources

Non-Renewable Energy Sources

Fossil Fuels

As mentioned earlier in this chapter, approximately 80% of the world's energy usage comes from fossil fuels (notably coal, oil and gas). In broadest terms, we can think of fossil fuels as the organic (meaning carbon based) remains of plant and animal matter that died many millions of years ago. Figure _ illustrates the formation of fossil fuels. As the carbon rich remains were buried under increasingly thick layers of sediment, the heat and pressure of the overlying material transformed the material into the fossil fuels that we harvest today. Fossil fuels are sometimes referred to as "buried sunshine" since it was the energy of the sun that allowed these plants and microorganisms to grow and survive. While fossil fuel formation is an ongoing process on the Earth, the time required to produce new fossil fuels is much longer than the timescale on which humans are consuming these fuels. Hence, we regard fossil fuels as *non-renewable* sources of energy, because it takes millions of years for the Earth to produce fossil fuel from its original living matter. There are five basic types of fossil fuels that are commonly extracted and used around the world:

Coal is a solid mass of ancient plant life that has been transformed through heat and pressure into the form we call coal. It is a black or brownish rock. There are many types of coal with different chemical composition, but they are alike in that they all originate from the decay of ancient plant life. Pete is the lowest "rank" of coal because it has undergone the least amount of carbonization. It has less carbon content and has a higher amount of impurities. Anthracite is the highest rank of coal. It has the highest carbon content and has the least amount of impurities. Most of the coal mined on Earth today originated over 300 million years ago, although some coal used was formed as recently as a few million years ago. Coal is a reliable energy source, and it is present in great quantities throughout the world, however, its use presents problems and challenges involving it's mining and burning for energy recovery.

Coal mining is accomplished in one of three ways:

1) underground mining
2) strip mining

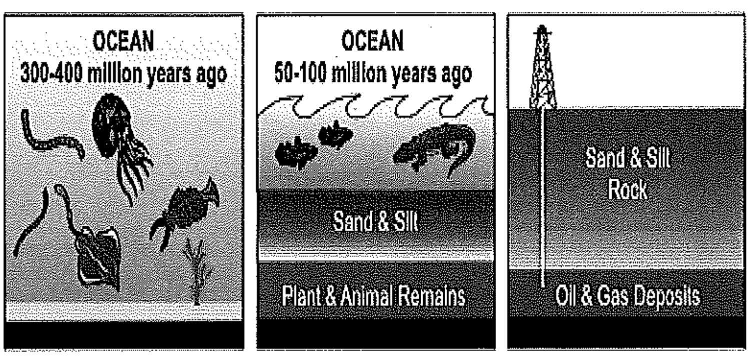
3) mountain top mining

With underground mining, miners are exposed to coal dust, which can create "black lung". Each year, miners are killed in underground mines from mine collapses or explosions from the ignition of released gases such as methane. One of the more controversial types of mining is mountain top mining. With this type of mining, miners literally blast off the tops of mountains to get access to the coal, which lies below them. This forever alters the natural beauty and ecology of large areas. Strip mining involves peeling away the top layer of soil over the coal using massive earth moving machinery. After the cover of dirt and rock is removed, further blasting and digging is required to access the coal seam. Strip mining can also alter the appearance and ecology of larges section of the Earth's landscape.

When coal is burned it can release many toxic pollutants to the atmosphere such as mercury and chemicals that contribute to acid rain production.

Gas (Natural Gas) is gas that is found trapped in underground rocks. Gas may be found alone, or may be found in association with oil deposits. Natural gas consists of many types of chemical compounds, but methane (CH_4) is typically the most abundant type of chemical composing natural gas. It is plentiful in supply and clean burning, however it is a source of green-house gases. In addition, another negative aspect to natural gas is the way in which it is commonly extracted in many parts of the world. A fracturing process called "fracking" utilizes high-pressure water and at times high strength acids to split the underground rocks to release the trapped gases. This process has the potential of injecting pollutants into the underground water supplies with the "fracking" acids that are utilized.

Oil (petroleum) is a viscous (oily) substance that is found in the upper regions of the Earth's crust. Carbon and hydrogen are the predominant elements in oil (molecules formed from carbon and hydrogen are known as *hydrocarbons*). Oil is relatively easy to extract and it is a reliable source of energy. It is the source of gasoline that we use in our cars. When oil is refined it can also make many other types of fuel such as methane, propane, butane and even jet fuel. Burning



Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and gas deposits.

oil in its various forms can be harmful to the environment. As with all fossil fuels, it is the source of greenhouse gases. As you saw in the case study, the recovery of oil from the ground below the deep oceans can present major ecological issues. Oil recovered from deep within the oceans has the potential for leaking in to our oceans and destroying the ecology there. Oil that is refined to release hazardous gases to the atmosphere.

Tar sands are sand or sandstone formations containing a very thick form of hydrocarbon. The technical term for this viscous hydrocarbon is *bitumen*, but it is commonly called tar because of its thickness. In recent decades, significant deposits of tar sands have been discovered. Most of the world's tar sands deposits, over 2/3 of the total, are found in Canada. While tar sands have the potential to increase the world's supply of fossil fuels, one concern is that the tar sands generate more greenhouse gases than other forms of oil products.

Nuclear Energy

Approximately 8% of the world's energy source is from nuclear power. The great benefit to nuclear power is that it does not contribute to greenhouse gases, however the technology to produce nuclear energy is extraordinarily complex. Nuclear power is derived from the energy released from the fission of the U-235 nucleus. The complexities involve the technologies to keep the nuclear power plants running safely and for enriching the uranium to a high percentage of U-235. All nuclear power plants produce radioactive waste material that is difficult to dispose of properly. In addition, the waste products from nuclear power plants are extremely toxic and have the potential of causing cancer, blood diseases, or bone decay for anyone exposed to it.

Renewable Energy

The Renewable 2011 Global Status Report indicated that renewable sources supplied about 16 % of the global final energy consumption. It is estimated that around 8.2 % of this total came from modern renewable energy- counting hydropower, wind, solar, geothermal, biofuels and modern biomass. The traditional biomass, primarily used for cooking and heating in rural areas of developing countries, accounted for approximately 8.5 % of the total final energy. Hydropower supplied about 3.3 % of global final energy consumption (REN 21). The Renewable Global Status Report also indicated that 118 countries implemented Renewable Energy Targets with more than half in developing countries. Investment in renewables has reached $ 257 billion, an increased to 17 % despite a widening sovereign debt crisis in Europe and rapidly falling prices for renewable power equipment (REN 21).

Concerns on climate change, the increasing cost of oil and the increasing government support to renewables are driving increasing renewable energy legislations all over the world, incentives and commercialization of renewable energy technologies (Wikipedia 2013).

Renewable energy technologies are avaialbe to capture and store energy from moving water (hydroelectric), the wind, the sun (solar), the, oceans (tidal and wave) and biomass. We will examine some of benefits as well as the challenges involved with these technologies.

Solar Energy Technology

Solar energy can be captured "actively" or "passively. "Active solar energy uses special technology to capture the sun's rays. The two main types of equipment are photovoltaic cells (also called PV cells or solar cells) and mirrors that focus sunlight in a specific spot. These active solar technologies use sunlight to generate electricity, which we use to power lights, heating systems, computers and televisions. Passive solar energy does not use any equipment. Instead, it gets energy from the way sunlight naturally changes throughout the day. For example, people can build houses so their windows face the path of the sun. This means the house will get more heat from the sun. It will take less energy from other sources to heat the house. Other examples of passive solar technology are green roofs, cool roofs, and radiant barriers. Green roofs are completely covered with plants. Plants can get rid of pollutants in rainwater and air. They help make the local environment cleaner.

(http://education.nationalgeographic.com/education/encyclopedia/renewable-energy/)

There are some drawbacks to solar power. Although photovoltaic cells are reliable, they can be cost prohibitive to install when compared to competing fuels and technologies in a given area. In addition, sunlight over an area is not always predictable due to weather conditions (i.e. blocked by clouds). The intensity of incoming solar radiation (insolation) also varies for different parts of the world based on location, time of year, and time of day. Since sunlight is not available in the evening hours, other sources of energy area required if the solar energy cannot be stored.

Wind Power Technology

As solar radiation penetrates the earth's atmosphere, different regions of the atmosphere warms at differing levels due primarily to the shape (spherical) of the earth—most of the solar rays hit the equator and least at the poles. Since air tends to flow from the warmer to cooler regions, the result is called winds (Moselle *et al, 2010*). A wind turbine is used to harness the power of the wind. A wind turbine is similar to a windmill; it has a tall tower with two or three propeller blades at the top. To produce electricity, wind sweeps the turbine to cause it to rotate and converts kinetic energy (KE) into mechanical energy (UNIDO, 2013). Groups of wind turbines are known as wind farms. Wind farms can be located near farmlands, in mountain passes, and even in the ocean, where there are steadier and stronger winds. Wind turbines anchored in the ocean are called "offshore wind farms." (education.nationalgeographic.com) Wind energy can be very efficient. In wide-open areas and along coastlines, winds can provide a cheap and reliable source of energy. The greatest advantage of wind power (other than that it is a renewable energy source) is that it is a very clean form of energy. During the production of energy from wind power, there are no pollutants released in to the air. There are drawbacks, however. Wind is not always a steady source of energy. Wind speeds can change based on time of day, weather conditions and location. Wind turbines can be also dangerous to birds if they are not aware how fast the turbines are moving.

Geothermal Power Technology

Heat from the Earth's core constantly moving toward the surface. Geothermal energy is powerful enough to melt underground rocks into magma and creates the lava flows we see coming out of volcanoes. Think for a moment of a geyser. In some locations, geothermal energy heats underground water sources of water and forces steam to come out from the surface. In some locations, we can access underground geothermal heat if the heat source is close to the surface. One way of using geothermal energy is with "geothermal heat pumps." A pipe of water loops between a deep underground to the heat source. The water is warmed by the geothermal energy underground and brings the warmth aboveground to building and houses.

(education.nationalgeographic.com). In some locations, water is pumped underground close to geothermal heat sources and turned in to steam. The resultant steam can then be converted into electrical energy through the use of steam turbines.

Hydroelectric Power Technology

Hydroelectric energy is made by flowing water. Most hydroelectric power plants are located on large dams, which control the flow of a river. Dams block the river and create an artificial lake, or reservoir. A controlled amount of water is forced through tunnels in the dam. As water flows through the tunnels, it turns huge turbines and generates electricity. See (education.nationalgeographic.com)

One major advantage of hydroelectric power facilities is that they can often be relatively inexpensive to build and operate. Hydroelectric power plants are also reliable. There are flowing rivers throughout much of the world so this source of energy is available to millions of people. The flow of water through the dam creates the energy flow so energy production from these plants is not affected by weather in the way that solar and wind technologies are. There are, however, drawbacks to hydroelectric power plants. When a river is dammed, the ecology of that river and surrounding land area is forever changed. A large portion of the flowing water essentially becomes a stagnant lake behind the dam. Large sections of land are put deep underwater where the dams are created. This displaces people and animals that were living in that area. The lifetimes of some hydroelectric power plants that utilize a damn can be limited. Silt and debris can build up behind the dam and slows the flow of water.

Ocean Energy Technology (Tidal and Wave)

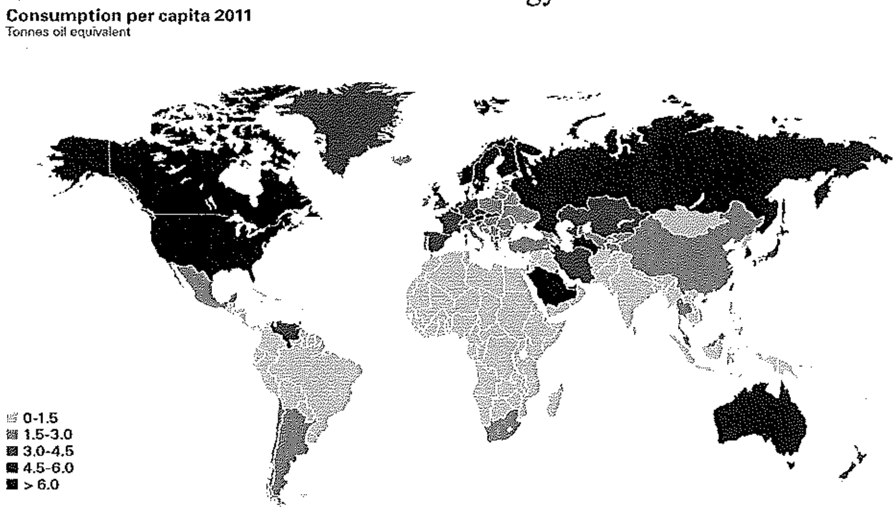
There are a number of different ways in which energy can be harnessed from the oceans. The two most utilized technologies convert the energy from tide and waves into electric power. Some tidal energy projects use the moving tides to turn the blades of a turbine. Other tidal energy power plants use dams to continually fill reservoirs at high tide and slowly release the water (and turn turbines) at low tide. Wave energy takes advantage of the constant kinetic energy available in waves in oceans and even lakes. Wave energy plants can utilize turbines in the same manner as tidal energy facilities. Some wave energy facilities float directly on the water. The movement of water in the waves can be diverted through turbines to create electricity. The major drawback to this type of energy production is the operating costs associated with maintaining the equipment in the harsh ocean environment and the impact that these installations can have on aquatic life in the surrounding oceans.

Biomass Technology (Algae)

Algae fuel is a type of biomass energy that uses the chemicals in seaweed to create a clean and renewable biofuels. Harvested algae, like fossil fuel, release CO_2 when burnt but unlike fossil fuel the CO_2 is taken out of the atmosphere by the growing of algae. Among algal fuels' attractive characteristics: they can be grown with minimal impact on fresh water resources, can be produced using ocean and wastewater, and are biodegradable and relatively harmless to the environment (Wikipedia, 2013). The biggest drawback to algae as a biomass fuel source is cost. At present, it is not economically feasible to process algae into the fuel sources that are in use today.

Energy Use and Sustainability

Although all of us use energy for cooking our food, heating our houses, moving around, or fueling our industries, the amount that we use varies hugely among the different countries. The following figure shows primary energy consumption per capita in 2011. As we can see, the average person in the more developed countries consumes almost 50 times more energy than in the poorer ones. Even within developed countries differences are also large: the US, for example, uses more than twice the amount of energy than most countries in Europe.



Primary energy consumption per capita 2011. BP Statistical Review of World Energy 2012.

This is partly due to the different availability of energy resources: some countries have easy access to modern fuels (such as fossil fuels), some others still need to rely on traditional biomass. Another reason is the climate: colder regions need more energy to heat themselves. But the most important reason for these differences is the degree of development of the country: more developed countries use more energy, partly because of their larger industrial activity, but mostly because of the energy-dependent lifestyle that richer societies follow. Think about it: when people become richer, they tend to have bigger cars, travel more, have bigger houses, more appliances…all this means more energy use. This is the model that most developing countries replicate when they develop.

There is much talk in many places about sustainable energy. However, it is not clear what this is exactly. Some use this for renewable energy, some for cheap energy that supports industrial development, some for "clean" energy, some for "secure" energy. Nuclear, natural gas, wind, solar…even coal supporters use it. It seems that sustainable energy has become a catchword for almost anything. So it may be a good idea to try to define it with a bit more precision.

This is not an easy task: there are many paradigms of sustainability to start with. But here we will propose one for energy that tries to find a consensus view among them. We will consider an energy system, or an energy source, as sustainable when it creates non-decreasing value (this includes not only economic value, but also natural, social or human value), does not run against the limits of our planet, and is justly distributed (see the section on energy usage around the world).

Let us look more in detail at the non-decreasing value part. Energy can create positive or negative impacts. It typically increases economic value by contributing to economic activity, and to satisfying our heating, lighting or transport needs. But it can also decrease the value of our environment when we extract fuels, when we transport them, when we convert them into heat or electricity or movement. The energy production process can possibly release pollutants into the atmosphere, the soil and the water (with the corresponding risk for human health or ecological balance), alter global climate, transforms the landscape, or make places less habitable. All energy sources, even renewable ones can produce negative environmental impacts. The magnitude of the negative impacts will vary: fossil fuels are much more dangerous for the environment than solar or wind energy, for example.

Although these are probably the two most important sources of (positive or negative) value for energy, there are more. The way we use energy, or the energy sources we use, can also affect our social institutions (and therefore, the value we derive from it). Fossil fuels for example are typically associated with something called the "resource curse", the fact that resource-rich countries may turn into failed states because of the (bad) incentives linked with this wealth. Energy has also been associated to wars. Energy can also contribute to human development, to knowledge and innovation, thus creating an additional source of value.

Therefore, in order to know whether an energy source is sustainable, the first thing we need to do is see whether positive and negative value streams compensate each other and result in a net positive value, that is non-decreasing with time. We would like to make it clear that sustainability is not only about the environment, but also about other sources of value.
But then we need to ensure that this creation of value does not run against hard limits, such as those set by the need to support life on Earth. For example, the global warming that is being induced by our use of fossil fuels may threaten the ability to live in some areas of the planet. And finally, we must achieve a fair distribution of energy use. We have already addressed this problem earlier.

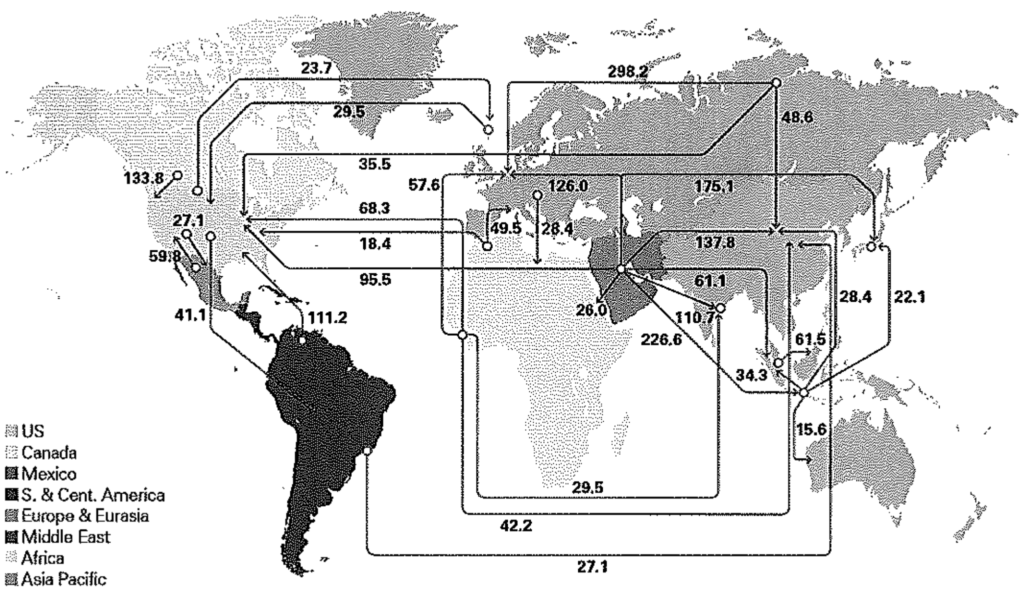
So, with this definition, what can we say about our current energy system? Is it sustainable? On the one hand, energy is typically becoming cheaper thanks to technology advances, although not homogeneously. Modern renewable energy such as wind or solar is greatly reducing its cost, but fossil fuel prices keep an increasing trend. On the other hand, the environmental footprint of our energy use has been increasing, mostly related to the amount of energy we consume. Social and human development issues have not experienced largely positive developments either. Therefore, one might conclude that our current energy system is not sustainable. But there is reason for hope. The development of modern renewable technologies, and more importantly, the growing awareness of the need to save energy (and the potential to do so) makes us think that a sustainable energy system is possible, if we are ready to invest in new technologies, and also to change our behaviors.

Energy and Geopolitics

As mentioned earlier, energy resources and energy used are not evenly distributed in the world. Energy resources, in particular fossil fuel resources such as oil and gas, are concentrated in small regions, which must then supply all countries. In addition, these small regions do not usually coincide with large consumption centers. This creates a need to transport these fuels over long distances, political borders, and geographical accidents, which in turn compromises the security of this supply.

The following figure shows the major trade movements of oil in 2011. Some critical areas may be identified: the strait of Ormuz, the strait of Malacca see a large part of the oil consumed in the world go through them. Some pipelines (e.g, those connecting Russian and Central Asian oil with European consumers) also constitute very sensitive nodes of the network.

Major trade movements 2011
Trade flows worldwide (million tonnes)



BP Statistical Review of World Energy 2012. www.bp.com/statisticalreview

In addition, it may also be seen that many of the oil flows start in countries not characterized by the solidity of their institutions: Saudi Arabia, Iran, Iraq, Venezuela, are some examples. These countries may also use their energy resources as a diplomatic element of persuasion.
It may be seen thus that energy has deep geopolitical implications, and the desire to secure energy supply is a very important element in foreign policy in many countries.