Pearson BTEC Levels 5 Higher Nationals in Engineering (RQF)

Unit 44: Industrial Power, Electronics and Storage

Unit Workbook 1

in a series of 4 for this unit

Learning Outcome 1

Energy Demand and its Influence on the Technology and Methods of Energy Production

4. ENERGY DEMAND

4.1 Introduction

Energy has always been among the most fundamental elements for the survival, reproduction and evolution of human society. The sun is the ultimate source of energy. Non-renewable fossil fuels are formed by solar energy that has been captured over extremely long geological periods. What is more, renewable energy sources are directly (photovoltaic systems) and indirectly (wind, water, etc.) interrelated with the sun. Inevitably, almost all organisms rely, either directly or indirectly, on solar energy for their survival and maintenance. Life on earth would be impossible without the photosynthetic conversion of solar energy into plant biomass. The sun provides approximately 1366 watts per square meter per second ($Wm^{-2}s^{-1}$), hence, about 170,000 terawatts ($TWm^{-2}s^{-1}$) on the Earth's surface. In the food chain, solar energy flows are captured and converted through the complex process of photosynthesis. Part of this energy is used by organisms, while a great proportion is lost as heat and a small portion is passed down the food chain as one organism digests another. Apart from the food chain, intelligent human systems utilize the solar energy embodied in fossil fuels and the renewable energy sources as the essential power, the "engine" of modern civilization. This WorkBook concentrates on electrical energy, its collection, its storage, its delivery, its application by human societies, and on the power electronic devices which are utilised in these endeavours.

Please bear in mind that with the continued introduction of renewable energy sources and the retirement or moth-balling of existing energy sources, some of the statistics provided in this Workbook may appear some years out of date. However, where statistics are provided, year of derivation and source are usually referenced. Remember that when you research answers to the assignment questions you will face the same problem. This makes it especially important that all reference material is cited correctly.

4.2 Historical Energy Production

Throughout recorded history, humans have searched for ways of putting energy to work for them. They found ways of growing food instead of foraging for it out in the wild. Instead of walking, they ride in cars they have built for getting from one place to another. Humans even learned how to send messages electronically instead of using a messenger or a postal service. This quest for faster, easier, and more efficient ways of meeting the needs of a growing human population has led to increasingly high energy demands. But the resources currently used for generating energy are running out. The pollution created by the use of these resources is also causing significant damage to the planet's natural systems. For these reasons, people are beginning to turn to alternative energy sources to reduce pollution while meeting their energy needs.

4.3 The Organic Energy Economy

The sun is by far the oldest source of energy. It has provided heat and light for millions of years and is directly responsible for sustaining all life on earth. Energy, in almost all its forms, starts with the sun. For example, wind is created by temperature changes caused by the sun. Plants and trees, which provide energy in numerous ways, gain their nourishment from the sun. Streams and rivers, providing energy by the force of their downhill flow, are formed from rain and snow. Rain and snow fall at high elevations after being evaporated from lakes and oceans by the sun. The variety of life-forms depending on the sun's energy in one manner or another is impressive.

Although the sun provides vast quantities of energy in many forms, humans could not control it, and so they began to explore other sources of energy. For example, humans discovered a way to generate their own energy from wood, somewhere between five hundred thousand and seven hundred thousand years ago, by most scientists' estimates. The very first milestone of mankind's utilisation of energy was the mastery of fire. The utilisation of fire for cooking and heating, using biomass (mainly wood) as fuel, dates back at least 4–500,000 years (Ref 1). At first, wood was burned for warmth, security, light, and for preparing food. The burning of wood and other forms of biomass eventually led to the discovery of ovens which, besides cooking, permitted the early forms of crafting. Ovens made it possible to produce pottery and to refine metals from ore. Early humans lived a largely nomadic existence, closely in synchrony with the change of seasons and periodic plant growth.

The next milestone of mankind was the Agricultural Revolution (Ref 2). The introduction of agriculture increased the amount of available food, permitting the first permanent human settlements, which caused a substantial increase of human population. Water and wind power were the next essential steps in the evolution of the human conquest of energy. The watermill was invented about 2500 years ago (Ref 3). Using both the water and the windmills, humans managed to master the water and air power necessary to meet their needs for crushing grain (wheat, etc.) in order to produce flour, crushing olives for olive oil production, tanning leather, smelting iron, sawing wood, and so on (Ref 4). However, despite the improvements in energy use and the exploitation of several energy resources, the rapid growth of population in Europe about a thousand years ago, as a result of this progress, led to dramatic pressures on land for cultivation, and forests were being encroached upon to provide more land (Ref 5 and Ref 6).

As the human population increased over time, so did humanity's dependence on fire. This increase in population led to severe shortages of wood in some areas of the world. By the sixteenth century, for instance, Great Britain had so few trees left because of overcutting that people had to search for new sources of fuel. This first era of mankind's quest for new energy resources, from the early discovery of fire to the agricultural (and farming) revolution, could be briefly described as the Organic Energy Economy (Ref 7). This solar-based energy economy was intimately based on intensive land use and biomass consumption. Inevitably, the organic energy economy was limited to the consumption of energy at the rate that solar energy can be converted into useful goods and services. In this context, population growth and the limited land availability imposed crucial restrictions upon further economic growth and gradually forced a transition towards a new energy regime, the era of fossil fuels (Ref 7 and Ref 8).

4.4 Transition to the Fossil Fuel Economy

The milestone that determined the transition from the organic economy to the fossil fuel (because they are extracted from fossilized plant and animal material from deep under the ground) economy, was the invention that characterized the Industrial Revolution era, was the steam engine. The unique process that the steam engine initiated was the conversion of chemical energy (heat) into mechanical energy (motion) (Ref 9). The biomass energy stocks accumulated in the earth's crust for hundreds of millions of years were now available to serve human needs for the first time in mankind's history, to such an extent that the dawn of the fossil fuel era was about to begin. While the early steam engine was mainly used for pumping water out of coal mines, it soon became, thanks to the efficiency improvements made by James Watt, a Scottish inventor and mechanical engineer, a valuable tool which increased human muscle and animal power for extracting more coal, drove the manufacturing industry, moved ships and trains, and laid the foundation for today's complex and energy intensive human (economic) systems (Ref 7).

Although coal had been used in different parts of the world since the second millennium BC, its potential uses had not been fully explored. During the 18th century, many industries had already substituted wood-fuels with coal, while heating services made the transition from organic biomass to fossil fuels by the beginning of the 19th century. Specifically, between 1650 and 1740, the real prices of wood-fuel increased substantially, which encouraged its progressive substitution with coal (Ref 10 and Ref 7). The timing of this substitution was absolutely essential, given the fact that during the second half of the 17th century the harvesting of forest trees had to be regulated, even restricted, in England and elsewhere in Europe (Ref 5). It has been suggested that, by 1800, had the British economy been dependent on wood-fuel, a surface area equivalent to the whole of Britain would have had to be coppiced every year in order to supply the energy demands of the economy. In 1800, wind and water power provided only one-tenth of the total power of the British economy (Ref 6). By 1900, steam engines provided two-thirds of all power services and the expansion of the railway network provided more than 90 % of goods transportation on land, while steam ships were carrying about 80 % of all freight cargos at sea.

Once coal replaced wood as a fuel, inventors found many ways that coal could be used as a source of energy. The Industrial Revolution marked a big change for people of the world. Many of the agricultural societies that used human muscle power and animals to do work quickly became industrialized and began using machines to do work. When the coal-burning steam engine was invented, a race began to create and build bigger, better, and faster machines. The machines were used to provide transportation and to do the work formerly done by people and animals. Coal continued to be used in great quantities until the twentieth century. Then came the invention of the internal combustion engine and the automobile, which used oil and gas instead of coal. Over the years automobiles were modified to use oil and gas more efficiently and with less pollution, but the sheer numbers of automobiles that have come into use over the years have offset the potentially positive impact of these changes. Oil and gas also came into use in other areas, such as for manufacturing and power production, and remain in high use today.

Ever since the Industrial Revolution, humans have sought to generate power from a variety of energy sources. This remains true today, especially as some energy sources are being used up. Current power needs are continuing to climb while the resources of the planet are steadily being depleted. Technology that operates on electricity, including everything from the typical refrigerator in the kitchen to street lights, is now a part of the lives of most people in industrialised nations. Much of that electricity is generated in power plants, which use large quantities of fossil fuels.

The process that created fossil fuels is a natural process of the earth's systems. The remains of plants and animals that died millions of years ago were slowly buried under sediment from the earth and compressed by the weight of the sediment. Over the course of millions of years, the pressure of being compressed by the sediment turned the dead plants and animals into oil, coal, and natural gas. The earth took 500 million years to produce these fuels. Humans have severely depleted them in just over one hundred years, a rate that is 50 million times greater than the rate at which they are formed.

There are three primary types of fossil fuels: coal, oil, and natural gas. Coal is responsible for providing much of the energy for producing electricity.

For most purposes, oil can be considered as liquid coal. Oil is usually found underground in dome-shaped spaces directly above coal deposits. Much of the oil extracted each year is used in transportation as either lubricant or fuel.

Natural gas is highly flammable and is made up mostly of methane, created from large amounts of plant material that did not become coal. Natural gas will usually flow from a drilled well under its own pressure. Natural gas is used primarily for heating purposes and for powering industrial production, especially in manufacturing.

4.5 Nuclear Energy

While fossil fuels are the main source of energy, another of today's energy sources is nuclear power, which utilises the heat generated from nuclear fission to generate electricity. A major drawback to nuclear power plants is that they rely upon unstable atoms such as U_{235} to generate electricity. Unstable atoms are used because they are the easiest to break apart. After U_{235} undergoes nuclear fission, however, it becomes a highly radioactive waste material that is extremely difficult to dispose of safely.

When nuclear power became a usable source of energy for producing electricity in the 1950s it was thought that it would be the new power for the future. However, due to the threat of nuclear accidents and the difficulty and costs associated with the disposal of the toxic waste by-products, nuclear power has not become the primary source of power production it was once thought it would become.

By way of comparison Figure 1 shows the growth of worldwide energy consumption per capita and the relative contribution from each type of fuel since the early 19th century.

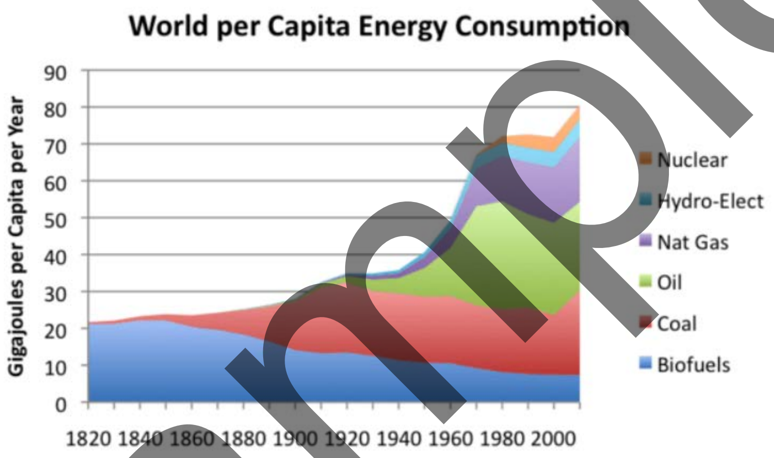

Figure 1 World Energy Consumption Per Capita

4.6 The Environmental Impact of Modern Power Consumption

Weighing the benefits and drawbacks of one power source versus another is a complicated process. There are many factors to consider, including everything from understanding the environmental effects of a particular type of power production and consumption, to addressing the power needs of the people and finding methods for delivering the power. Throughout this process, decision makers rely upon scientists to supply the necessary data to make informed decisions. What forms the basis of this science includes the knowledge that carbon dioxide, which is released into the atmosphere when fossil fuels are burned, is creating a lot of harm to the planet and its systems.

Gases that form the atmosphere completely surround the planet. A part of the atmosphere called the ozone layer acts as a sort of shield from the sun, filtering out harmful radiations. Today, human activities release about 433,000 metric tons of nitrous oxide into the atmosphere each year. Nearly 40 percent of the world's nitrous oxide emissions come from burning fossil fuels. The atmosphere has a certain amount of nitrous oxide naturally, but too much nitrous oxide causes a depletion of the ozone layer. Over the last decade scientists have reported that the hole in the ozone layer is growing rapidly.

Carbon dioxide is another harmful gas released into the atmosphere. It comes back to the surface as acid rain, poisoning water supplies, killing plants and animals, and eroding and blackening buildings. In addition, carbon dioxide reflects light and heat back to the planet's surface. As the carbon dioxide levels increase in the atmosphere, more heat from the sun is held in, changing the climate of the entire planet by making it warmer. This is called the greenhouse effect and is considered a form of pollution.

Earth operates on delicate systems of natural balance and scientists believe warming the atmosphere by even a few degrees could cause enormous changes to the environment. It is also believed that an increase in the temperature of the planet, brought on by the greenhouse effect, will lead to more weather-related natural disasters such as tornadoes, floods, droughts, and hurricanes. Scientists also predict a significant rise in sea levels, which will reduce land size. Considering that half of the human population lives near a coastline, the effects could be dramatic.

4.7 Fossil Fuel Supplies Depleted

Not only are these high levels of consumption causing equally high levels of pollution, but the world's fossil fuel supplies are quickly being depleted. For example, today's total oil supply is estimated at between 2,000 and 2,800 billion barrels. About 900 billion barrels of oil have already been consumed, 28 million barrels of that just in the year 2000. Addressing resource depletion is not an easy task.

The future of energy production will certainly determine what the overall health of the planet will be. Most scientists agree that the choices that support fossil fuel use will only worsen the environmental damage that has already occurred. Instead, choosing to look to renewable energy sources and energy conservation techniques offers the potential to improve the health of the planet.

4.8 Renewable Energy

Because energy is usable power, the form that the energy is in can be used up. When a combustion engine car runs out of fuel, it loses its power and can no longer operate until more fuel is put into the system. If a power plant that generates electricity by burning coal runs out of coal, then it can no longer generate electricity until more coal is put into the power plant burners.

Renewable energy, on the other hand, is energy that is replaced at the same rate that it is used. Renewable energy is replaced through natural processes or through sound management practices, and so it is a source of power that does not run out. A perfect example of renewable energy is energy from the sun, which comes in an abundant supply every day.

Other examples of renewable sources of energy include the wind, the waves and tides, the gravitational pull of the earth, the heat at the earth's core (geothermal energy), landfill gases, and, to a limited degree, trees and plant material (biomass). Many of these renewable sources of energy can be used in their raw form. They are natural forces that create energy without the help of humans. All that is needed is for someone to decide how that energy can be used. Building a sail for a boat makes use of the wind. Building a waterwheel on a river makes use of the flowing water that is pulled downhill by the earth's gravity. Building a house out of glass—a greenhouse—traps the heat from sunlight inside, providing warmth and allowing plants to grow where they might not otherwise grow.

4.9 The Case for Renewable Energy

Renewable energy, also called "green energy," or "clean energy," does not deplete natural resources and creates little, or no pollution, when it is generated. Throughout history, renewable sources of energy have been used by various peoples to supply power for their specific needs, but always on a small scale. The unique challenge of today is finding a way to supply renewable energy to entire populations. Large-scale energy production requires specialized equipment such as energy storage and transmission facilities. The technology for generating the power must also be efficient and cost-effective to produce and operate.

In the face of big-oil-company interests and the politics of government, it has taken a long time for renewable energy options to even be considered on a large scale. The scientific and technological development of solar power, for example, looked promising when in 1977 the USA President, Jimmy Carter, initiated a plan to develop solar energy and other alternative fuels. His goal for the USA was to have 20 percent of its power coming from solar power generation by the year 2000, and he started by putting solar panels on the White House. By the late 1970s, however, big oil companies had bought up most of the patents for the solar technologies being developed. The Reagan administration took the solar panels off of the White House and spent billions of dollars on the military, foreign aid, and for research and production of atomic weapons instead of on renewable energy.

Since that time, government support for the research and development of renewable energy has not been easy to get, and the technology has been slow to come into its own. Despite these setbacks, independent companies are now making renewable energy products that, while still costly to purchase, offer cheap, clean, renewable energy to the consumer. Modern science and engineering technology have made renewable energy much more efficient, convenient, and economical. In fact, one of the myths surrounding clean energy is that it is not ready to do the job. Renewables are ready—the technical barriers are almost entirely removed. Because renewables do not use fossil fuels (most are entirely fuel-free) they are largely immune to the threat of future oil or gas shortages and fossil fuel price hikes. For the same reason, because most renewable technologies require no combustion, they are far kinder to the environment than coal, oil, and natural gas.

In addition to being virtually non-polluting, renewable energy is considered to be cheaper for producers and consumers. As the human population continues to increase and the energy needs of the world climb, renewable energy is seen more and more as the only alternative.

4.10 Energy Consumption

4.10.1 Overview

World energy consumption is the total energy used by the entire human civilization. Typically measured per year, it involves all energy harnessed from every energy source applied towards humanity's endeavours in every country across every single industrial and technological sector. It does not include energy from food, and the extent to which direct biomass burning has been accounted for is poorly documented. Being the power source metric of civilization, World Energy Consumption has deep implications for humanity's socio-economic-political sphere.

Institutions such as the International Energy Agency (IEA), the U.S. Energy Information Administration (EIA), and the European Environment Agency record and publish energy data periodically. Improved data and understanding of World Energy Consumption may reveal systemic trends and patterns, which could help frame current energy issues and encourage movement towards collectively useful solutions.

Closely related to energy consumption is the concept of total primary energy supply (TPES), which, on a global level, is the sum of energy production minus storage changes. Since changes of energy storage over the year are minor, TPES values can be used as an estimator for energy consumption. However, TPES ignores conversion efficiency, overstating forms of energy with poor conversion efficiency (e.g. coal, gas and nuclear) and understating forms already accounted for in converted forms (e.g. photovoltaic or hydroelectricity). The IEA estimates that, in 2013, total primary energy supply (TPES) was 1.575×10^{17} Wh (= 157.5 PWh, 5.67×10^{20} joules, or 13,541 Mtoe) (Ref 11). From 2000–2012 coal was the source of energy with the largest growth. The use of oil and natural gas also had considerable growth, followed by hydropower and renewable energy. Renewable energy grew at a rate faster than any other time in history during this period. The demand for nuclear energy decreased, in part due to nuclear disasters (e.g. Three

Mile Island 1979, Chernobyl 1986, and Fukushima 2011) (Ref 12 and Ref 13). These trends are illustrated in Figure 2

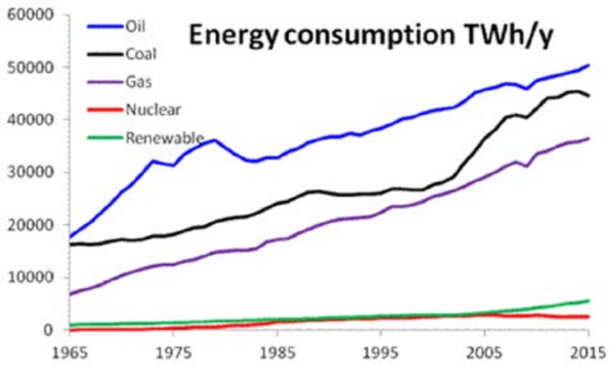

Figure 2 The World's energy consumption (2015 data)

In 2011, expenditures on energy totalled over 6 trillion USD, or about 10% of the world gross domestic product (GDP). Europe spends close to one-quarter of the world's energy expenditures, North America close to 20%, and Japan 6% (Ref 14).

4.10.2 Energy supply, consumption and electricity

World total primary energy supply (TPES), or "primary energy" differs from the world final energy consumption because much of the energy that is acquired by humans is lost as other forms of energy during the process of its refinement into usable forms of energy and its transport from its initial place of supply to consumers. For instance, when oil is extracted from the ground it must be refined into petrol, so that it can be used in a car, and transported over long distances to petrol stations where it can be used by consumers. World final energy consumption refers to the fraction of the world's primary energy that is used in its final form by humanity.

In 2014, world primary energy supply amounted to 155,481 terawatt-hour (TWh) or 13,541 Mtoe, while the world final energy consumption was 109,613 TWh or about 29.5% less than the total supply (Ref 15) World final energy consumption includes products as lubricants, asphalt and petrochemicals which have chemical energy content but are not used as fuel. This non-energy use amounted to 9,404 TWh (809 Mtoe) in 2012 (Ref 16).

The United States Energy Information Administration regularly publishes a report on world consumption for most types of primary energy resources. For 2013, estimated world energy consumption was 5.67 × 10^{20} joules, or 157,481 TWh. According to the IEA the total world energy consumption in past years was;

- 143,851 TWh in 2008,
- 133,602 TWh in 2005,
- 117,687 TWh in 2000,
- 102,569 TWh in 1990.

In 2012 approximately 22% of world energy was consumed in North America, 5% was consumed South and Central America, 23% was consumed in Europe and Eurasia, 3% was consumed in Africa, and 40% was consumed in the Asia Pacific region.

The total amount of electricity consumed worldwide was

- 19,504 TWh in 2013,

- 16,503 TWh in 2008,
- 15,105 TWh in 2005,
- 12,116 TWh in 2000.

By the end of 2014, the total installed electricity generating capacity worldwide was nearly 6.142 TW (million MW) which only includes generation connected to local electricity grids (Ref 17). In addition, there is an unknown amount of heat and electricity consumed off-grid by isolated villages and industries. In 2014, the share of world energy consumption for electricity generation by source was coal at 40.8%, natural gas at 21.6%, nuclear at 10.6%, hydro at 16.4%, other sources (solar, wind, geothermal, biomass, etc.) at 6.3% and oil at 4.3%. Coal and natural gas were the most used energy fuels for generating electricity. The world's electricity consumption was 18,608 TWh in 2012. This figure is about 18% smaller than the generated electricity, due to grid losses, storage losses, and self-consumption from power plants (gross generation). Cogeneration (Combined Heat and Power - CHP) power stations use some of the heat that is otherwise wasted for use in buildings or in industrial processes.

In 2016 while total world energy came from 80% fossil fuels, 10% biofuels, 5% nuclear and 5% renewable (hydro, wind, solar, geothermal), only 18% of that total world energy was in the form of electricity (Ref 18). Most of the other 82% was used for heat and transportation.

Recently there has been a large increase in international agreements and national Energy Action Plans, such as the EU 2009 Renewable Energy Directive, to increase the use of renewable energy due to the growing concerns about pollution from energy sources that come from fossil fuels such as oil, coal, and natural gas (Ref 13 and Ref 19). One such initiative was the United Nations Development Programme's World Energy Assessment in 2000 that highlighted many challenges humanity would have to overcome in order to shift from fossil fuels to renewable energy sources (Ref 13). From 2000–2012 renewable energy grew at a rate higher than any other point in history, with a consumption increase equivalent of 176.5 million tonnes of oil. During this period, oil, coal, and natural gas continued to grow with increases that were much higher than the increase in renewable energy.

4.10.3 Trends

The energy consumption growth among the G20 nations (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States and the European Union) slowed down to 2% in 2011, after the strong increase of 2010. This was largely due to the economic crisis, but for the world at large, energy demand is characterized by the bullish Chinese and Indian markets, while developed countries struggle with stagnant economies, high oil prices, resulting in stable or decreasing energy consumption.

According to IEA data from 1990 to 2008, the average energy use per person increased 10% while world population increased by 27%. Regional energy use also grew during 1990 to 2008: Middle East by 170%, China by 146%, India by 91%, Africa by 70%, Latin America by 66%, the USA by 20%, the EU-27 block by 7%, and the world overall by 39%.

In 2008, total worldwide primary energy consumption was 132,000 terawatt-hours (TWh) or 474 exajoules (EJ). In 2012, primary energy demand increased to 158,000 TWh (567 EJ).

Energy consumption in the G20 increased by more than 5% in 2010 after a slight decline of 2009. In 2009, world energy consumption decreased for the first time in 30 years by 1.1%, or about 130 million tonnes of oil equivalent (Mtoe), as a result of the financial and economic crisis, which reduced world GDP by 0.6% in 2009.

This evolution is the result of two contrasting trends: Energy consumption growth remained vigorous in several developing countries, specifically in Asia (+4%). Conversely, in the OECD, consumption was severely cut by 4.7% in 2009 and was thus almost down to its 2000 levels. In North America, Europe and the CIS (Commonwealth of Independent States), consumptions shrank by 4.5%, 5% and 8.5% respectively due to the slowdown in economic activity. China became the world's largest energy consumer (18% of the total) since its consumption surged by 8% during 2009 (up from 4% in 2008). Oil remained the largest energy source (33%) despite the fact that its share has been decreasing over time. Coal posted a growing role in the world's energy consumption: in 2009, it accounted for 27% of the total.

Most energy is used in the country of origin, since it is cheaper to transport final products than raw materials. In 2008, the share export of the total energy production by fuel was: oil 50% (1,952/3,941 Mt), gas 25% (800/3,149 bcm – billion cubic metres) and hard coal 14% (793/5,845 Mt).

Most of the world's high energy resources are from the conversion of the sun's rays to other energy forms after being incident upon the planet. Some of that energy has been preserved as fossil energy, some is directly or indirectly usable; for example, via solar PV/thermal, wind, hydro- or wave power. The total solar irradiance is measured by satellite to be roughly 1361 watts per square meter (see solar constant), though it fluctuates by about 6.9% during the year due to the Earth's varying distance from the sun. This value, after multiplication by the cross-sectional area intercepted by the Earth, is the total rate of solar energy received by the planet and about half, (89,000 TW), reaches the Earth's surface.

The estimates of remaining non-renewable worldwide energy resources vary, with the remaining fossil fuels totalling an estimated 0.4 yottajoule (YJ) or 4×10^{23} joules, and the available nuclear fuel such as uranium exceeding 2.5 YJ. Fossil fuels range from 0.6 to 3 YJ if estimates of reserves of methane clathrates are accurate and become technically extractable. The total power flux from the sun intercepting the Earth is 5.5 YJ per year, though not all of this is available for human consumption. The IEA estimates for the world to meet global energy demand for the two decades from 2015 to 2035 it will require investment of 48 trillion American dollars and "credible policy frameworks" (Ref 20).

According to IEA (2012) the goal of limiting warming to 2 °C is becoming more difficult and costly with each year that passes. If action is not taken before 2017, CO_2 emissions would be locked-in by energy infrastructure existing in 2017. Fossil fuels are dominant in the global energy mix, supported by 523 billion American dollars-worth of subsidies in 2011, up almost 30% on 2010 and six times more than subsidies to renewables. (Ref 21).

4.10.4 Emissions

Global warming emissions resulting from energy production are an environmental problem. Efforts to resolve this include the Kyoto Protocol, which is a UN agreement aiming to reduce harmful climate impacts, which a number of nations have signed. Limiting global temperature increase to 2 degrees Celsius, thought to be a risk by the Stockholm Environment Institute (SEI), is now doubtful.

To limit global temperature to a hypothetical 2 degrees Celsius rise would demand a 75% decline in carbon emissions in industrial countries by 2050, assuming that the population is 10 billion in 2050 (Ref 22). Across 40 years, this averages to a 2% decrease year on year. In 2011, the emissions of energy production continued rising regardless of the consensus on the fundamental problem. Hypothetically, according to Robert Engelman of the Worldwatch institute, in order to prevent collapse (in 2009), human civilization would have to stop increasing emissions within a decade regardless of the economy or population. (Ref 23).

Greenhouse gases (GHGs) are not the only emissions of energy production and consumption. Large amounts of pollutants such as sulphurous oxides (SOx), nitrous oxides (NOx), and particulate matter (PM) are produced from the combustion of fossil fuels and biomass; the World Health Organisation estimates that 7 million premature deaths are caused each year by air pollution. Biomass combustion is a major contributor. In addition to producing air pollution like fossil fuel combustion, most biomass has high CO_2 emissions.

4.10.5 The effect on the environment

Anytime the natural environment is altered, there are impacts. All energy sources require the setting up of some form of power generation plant and this activity has initial financial and environmental costs. All energy sources also have continuing environmental impacts. Some energy sources have greater up-front costs while others have greater or lesser continuing costs and impacts.

Fossil fuels are acquired by mining non-renewable resources. There are usually large exploration, mining and drilling costs and impacts. Furthermore, the burning of fossil fuels to generate energy adds additional and very major environmental impacts.

Using renewable energy sources generally has much less environmental impacts. Developing renewable resources have various up-front financial and environmental costs. All renewable energy sources impact the environment in at least some small way.

4.11 Solar Energy

The factors needed to determine the ideal location of a solar power plant include lots of open flat areas, lots of sunshine, and no shadowing trees or buildings. The infrastructure (basic building facilities and installations) required to develop solar energy is a solar power plant to make power and the electrical grid for power distribution.

Advantages of Solar Energy

Solar energy is widely available and unlimited. No air or water pollution is given off when solar panels are used for energy production. It does not require transport of fuels or disposal of waste products. Solar energy produces electricity very quietly, so it can be used in residential areas without creating noise pollution. Solar panels can be installed on top of many rooftops. Therefore, large amounts of open areas are not required for typical household use. Solar panels do not require a direct connection to the grid.

Solar energy has the ability to make electricity in remote locations that are not linked to the grid. This is more cost efficient than running long sets of wires into remote locations.

Disadvantages of Solar Energy

The initial cost of solar cells can be quite expensive, and it is only able to generate electricity during day light hours. Energy must be stored for later use in battery systems. Weather or smog may also limit the efficiency of solar energy, however new technologies are being developed to overcome this obstacle.

Large area solar farms can create heat islands or cause ecological damage such as habitat loss. Solar farms also require a large area (up to thousands of acres) and therefore have a large land footprint. However, the sunniest areas such as arid environments are not heavily vegetated, and habitat disruption is less than it would be in forested regions. Residential applications do not result in large-scale ecological damage; however, some habitat loss is experienced due to tree removal designed to improve sun exposure for rooftop panels.

4.12 Wind Energy

The factor needed to determine the ideal location of a wind farm is the availability of enough sustained winds. The infrastructure (basic building facilities and installations) required to develop wind energy is wind turbines to make power and the electrical grid for power distribution.

Advantages of Wind Energy

Wind is available nearly everywhere and is generally plentiful. Wind produces no air, water, or thermal pollution and does not require transport of fuels or disposal of waste products. The technology for harnessing the wind energy is well developed. Wind power may also be used to provide electricity to individual homes or buildings without a direct connection to the grid. Wind can also generate power for large numbers of people using larger turbines connected to the grid.

Given the amount of energy wind turbines capture, both the material and energy requirements for their manufacture are impressively low. If well-designed wind machines are placed at good wind power sites, electricity can be generated very cheaply.

Disadvantages of Wind Energy

In order to harness sustained winds greater than 7 mph, larger wind farms are often located on coastlines or on mountain ridges. Some people feel that placing turbines in such places destroys the natural beauty of that location. Wind farms also require a large area and therefore have a large land footprint. Flying animals such as birds or bats can be killed when flying near windmills. Other possible damages to the environment include habitat destruction in the form of tree removal or changing a hillside to in order to build a turbine.

Some turbines produce noise pollution. In some locations the vibrations caused by the rotation of windmill blades has been shown to interfere with TV and mobile phone reception.

4.13 Tidal Energy

The factors needed to determine the ideal shore location of a tidal power plant include a large tidal range and a funnel shaped shoreline pointing inland. The infrastructure (basic building facilities and installations) required to develop tidal energy is a tidal power plant to produce the power and the electrical grid for power distribution.

Advantages of Tidal Energy

Tidal energy does not create air, water, or thermal pollution. Once a dam, barrage or tidal fence is built, the energy production is free since tidal power harnesses the natural power of tides. It does not require the transport of fuels or disposal of waste products.

Energy output from tidal power generators is predictable since we can accurately predict when tides occur. This makes tidal energy reliable and easy to integrate with the grid. It is also sustainable because its energy comes from the lunar and solar cycle.

Disadvantages of Tidal Energy

There are a limited number of locations worldwide that have tidal ranges large enough to make tidal power cost-effective. Tidal power systems are currently expensive to develop, and they cannot be built in any location. Tidal energy systems that use dams may restrict fish migration. These dams may also cause silt to build up along the dam. This build up affects a tidal basin ecosystem in negative ways, causing habitat changes for aquatic life as well as for birds that may rely on low tides to unearth mud flats that are used as feeding areas.