INTRODUCTION TO RENEWABLE ENERGY (0611341)

مقدمة في الطاقة المتجددة

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Chapter 1: Introduction

Any change that takes place in the universe is accompanied by a change in a quantity that we name energy. Energy comes in many forms, such as: electrical energy, chemical energy, or mechanical energy, and it can be used to realize many forms of change, such as movement, heating, or chemical change.

Any activity, and human activity as well, requires energy.

Human beings need it to move their bodies, to cook, to heat and light houses, or to drive vehicles. An active young man needs about 2500 kcal (2.9 kWh) per day to fulfil his daily energy requirements. This means the energy of about 1060 kWh per year. The present global energy consumption is around 19 000 kWh per inhabitant per year. It means that on average a man consumes about 19 times more energy than is needed for his survival and satisfactory health.

Energy

energy is never produced but always converted from one form to another.

The form of energy may change in time, but the total amount does not change. The law of conservation of energy: **states that there is a certain quantity, which we call energy that does not change in the manifold changes which nature undergoes**. It is a mathematical principle; it says that there is a numerical quantity which does not change when something happens.

We will now state some basic physical connections between the three very important physical quantities of: ***Force : Energy: Power,*** These connections are taken from classical mechanics but generally valid.

Force

We **start with the force F, which is any influence on an object that changes its motion.** According to Newton's second law, the force F is related to the acceleration **(a)** of a body via:

$$\mathbf{F} = m*\mathbf{a}:$$

where m is the mass of the body. The bold characters denote that **F** and **a** are vectors. The unit of force is **Newton (N). It is defined as the force required to accelerate the mass of 1 kg at an acceleration rate of 1 m/s^2**, hence 1 N = 1 kg m/s^2

Energy

In mechanics, **energy E, is given as the product of force times distance,**

$$E = \int F(s)\,\mathrm{d}s$$

where s denotes distance. **Energy is usually measured in the unit of Joule (J), which it defined as the amount of work required applying the force of 1 Newton through the distance of 1 m,**

1 J = 1 N m.

Power

Another important physical quantity is the **power P**, which tells us **the rate of doing work**, or, which is equivalent, **the amount of energy consumed per time unit**. It is related to energy via:

$$E = \int P(t)\,\mathrm{d}t$$

$P(t) = E / t$ where t denotes the time. **The power is usually measured in Watt (W).**

1 W is defined as one Joule per second, 1 W = 1 J/s and 1 J = 1 W s.

1 J is a very small amount of energy compared to the human energy consumption. Therefore, in the energy markets, such as the electricity market, often the unit Kilowatt hour (kWh) is used. kWh is what you get charged for using electricity It is given as:

$$1\,\text{kWh} = 1000\,\text{Wh} \times 3600\,\frac{\text{s}}{\text{h}} = 3\,600\,000\,\text{Ws}$$

__**EX1:**__ A 5kW electric motor which runs 2h, consume,
5kWx2h=10kWh of energy.

__**EX2:**__ Eight 100W light bulbs that are left on all day will consume,
8x100x24=19200Wh=19.2kWh of energy.

Different Units of Energy: force x distance units = Joules

__**Calorie (Cal)**__

1cal= amount of energy required to raise the temperature of 1 gram of water by one degree Celsius.

Energy in food: Calories

1Calorie=1000 calories

__**Btu (British Thermal Units).**__

Is heat energy needed. 1Btu = amount of heat energy required to raise temperature of one pound of water by one degree Fahrenheit.

Burning of one wooden match releases 1Btu.

1Btu=252 Cal

1 Joule = 2.78×10^{-7} kWh

= 9.49×10^{-4} Btu

= 0.2392 Cal

__**electrical energy = qV**__

The amounts of energy in solid state physics, the branch of physics that we will use to explain how solar cells work, is very small. Therefore, we will use the unit of **electron volt (eV), which is the energy a body with a charge of one elementary charge (e = 1.602×10^{-19} C) gains or losses when it is moved across electric potential difference of 1 Volt (V).**

__**E (in electron volt) = Q * V,**__

where Q is the electronic charge (1.602×10^{-19} C) and V is the voltage

1 electron volt is equal to 1.602×10^{-19} Joule.

Conversions..

	joule	watt hour	electronvolt	calorie
1 J = 1 kg·m^2 s^{-2} =	1	2.778×10^{-4}	6.241×10^{18}	0.239
1 W·h =	3600	1	2.247×10^{22}	859.8
1 eV =	1.602×10^{-19}	4.45×10^{-23}	1	3.827×10^{-20}
1 cal =	4.1868	1.163×10^{-3}	2.613×10^{19}	1

Some factors

Factor	Name	Symbo
10^{-12}	Pico	*P*
10^{-9}	Nano	n
10^{-6}	Micro	µ
10^{-3}	Mille	m
10^{3}	Kilo	K
10^{6}	Mega	M
10^{9}	Giga	G
10^{12}	Tera	T
10^{15}	Peta	P
10^{18}	Exa	E

Forms of Energy

Energy has a large number of different forms, and there is a formula for each one. These are:

gravitational energy,
kinetic energy, Potential energy
Heat (thermal) energy.
elastic energy,
electrical energy,
chemical energy (coal, oil, natural gas)
radiant energy, Electromagnetic radiation
nuclear energy, mass energy, mass energy .

Energy may be transformed from one type to another. If we total up the formulas for each of these contributions, it will not change except for energy going in and out. The consequence of doing work on an object is to give the object **energy.**

Energy can be **kinetic** **(associated with motion)**

Kinetic energy is the energy available in the motion of particles, for example wind or moving particles. Objects in motion can do work, therefore they possess **Kinetic energy:** $E_K = (0.5mv^2)$.m is the mass of object and v is the speed.

EX3: A car with a mass of 1000 Kg moving at 10m/sec has kinetic energy
$E_k = (0.5) x 1000 x 10^2 = 50000$ **Joule.**

Energy can be **potential** (ability to do work stored in some form):

Potential energy is the energy available because the position between particles for example water in stored dam, energy coiled spring. Because objects interact (e.g by gravity) then due to their relative position thy can do work or have a potential energy (P_E).

P_E = mass x g x height = m x g x h (Joules)

g represent the gravitational field strength (9.8 N/Kg)

<u>EX4</u>: To raise a 10 Kg mass a height of 2 m while standing on the earth surface require a potential energy is:

P_E ***= mass x g x height = m x g x h*** =10 x 9.8 x 2 = 200 Joules.

<u>Mass energy</u>

When nucleons come together, the mass of the product is less than the sum of the masses of individual nucleons.

Energy = (change in mass) c^2, where c is the speed of light.

Nuclear energy depends on the conversion of mass into energy:

<u>$E = \Delta m * c^2$</u>

<u>Ex5:</u> Grain of sand (0.001g), if converted to energy, would provide 100,000,000,000 (100 billion joules, or about 25,000 kWh) of energy. Average family uses about 1,000 kWh of electricity per month. One grain of sand would supply their needs for two years!

But, that is not how it works… It is not that simple… Why?

$E / m = c^2 = (299,792,458)^2$ m/s = 89,875,517,873,681,764 J/kg

= (˜9.0×10^{16} joules per kilogram)

So one **gram of mass is equivalent to the following amounts of energy:** 89.9×10^{12}joules. Or 0.001 gram of mass is 89.9×10^9joules

Conversion tables: 1 joule = 2.78×10^{-7}kWh

89.9×10^9 joules x 2.78×10^{-7}

1kWh/J = 25,000 kilowatt-hours

= 85.2 million BTUs

<u>Methods of Energy Conversion</u>

As we mentioned already above, **energy is never produced but always converted from one form to another**. The form of energy may change in time, but the total amount does not change. If we want to utilize energy to work for us, we usually convert it from one form to another more useable form. **An example is the electric motor, in which we convert electrical energy to mechanical energy.**

Figure 2 shows different energy sources and the ways we utilize them. We see that usually the **chemical energy stored in fossil** fuels is converted to usable forms of energy via heat by burning, with an efficiency of about 90%. Using heat engines, **thermal energy** can be converted into **mechanical energy**. Heat engines have a conversion efficiency of up to 60%. The far majority of the current cars and trucks work on this principle. With the heat steam is generated that drives a steam turbine and subsequently an electric generator just as in most fossil fuel power plants.

Mechanical energy can be converted into electricity using electric generators with an efficiency of up to 90%. Most of the World's electricity is generated with a **turbo generator that is connected to a steam turbine,** where the **coal** is the major energy source. Along all the process steps of making electricity out of fossil fuels, at least 50% of the initial available chemical energy is lost in the various conversion steps.

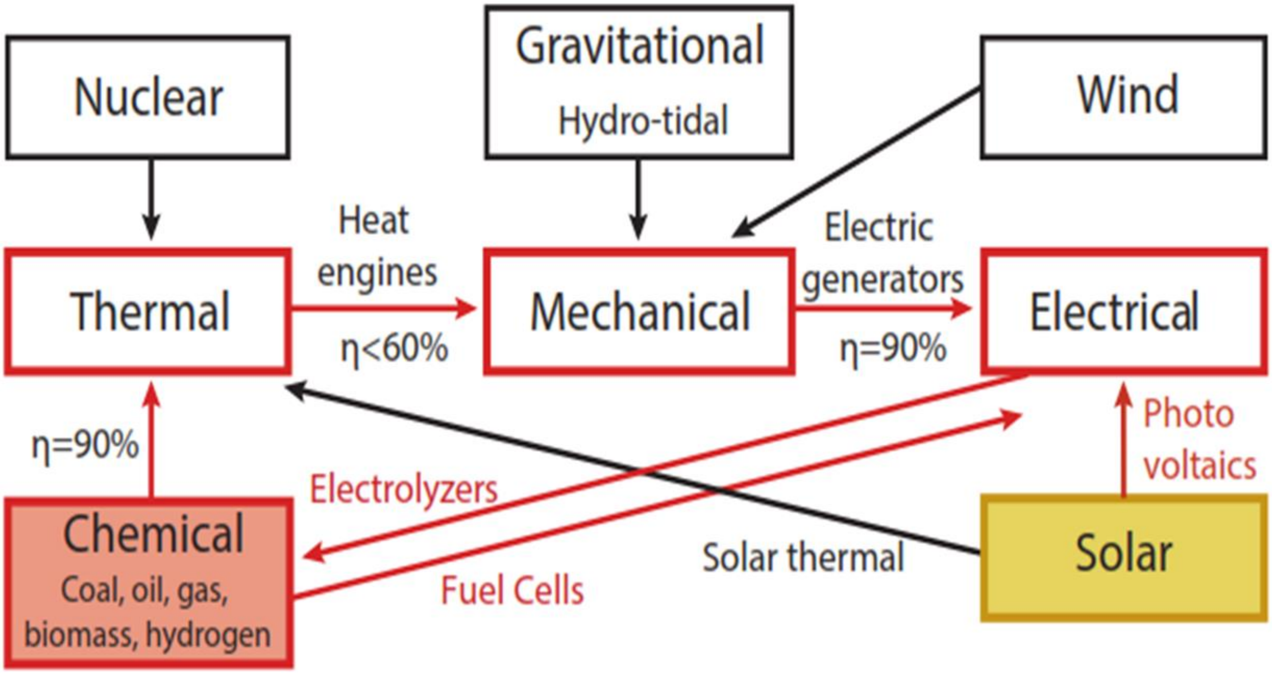


Figure 2 shows different energy sources and the ways we utilize them.

Chemical energy can be directly converted into electricity using a fuel cell. The most common fuel used in fuel cell technology is **hydrogen**. **Typical conversion efficiencies of fuel cells are 60%.** A regenerative fuel cell can operate in both directions and also convert electrical energy into chemical energy. Such an operation is called electrolysis; typical conversion efficiencies of hydrogen electrolysis of 50-80% have been reported.

In nuclear power plants,

energy is released as heat during nuclear fission reactions.

With the heat steam is generated that drives a steam turbine and subsequently an electric generator just as in most fossil fuel power plants

Energy Sources

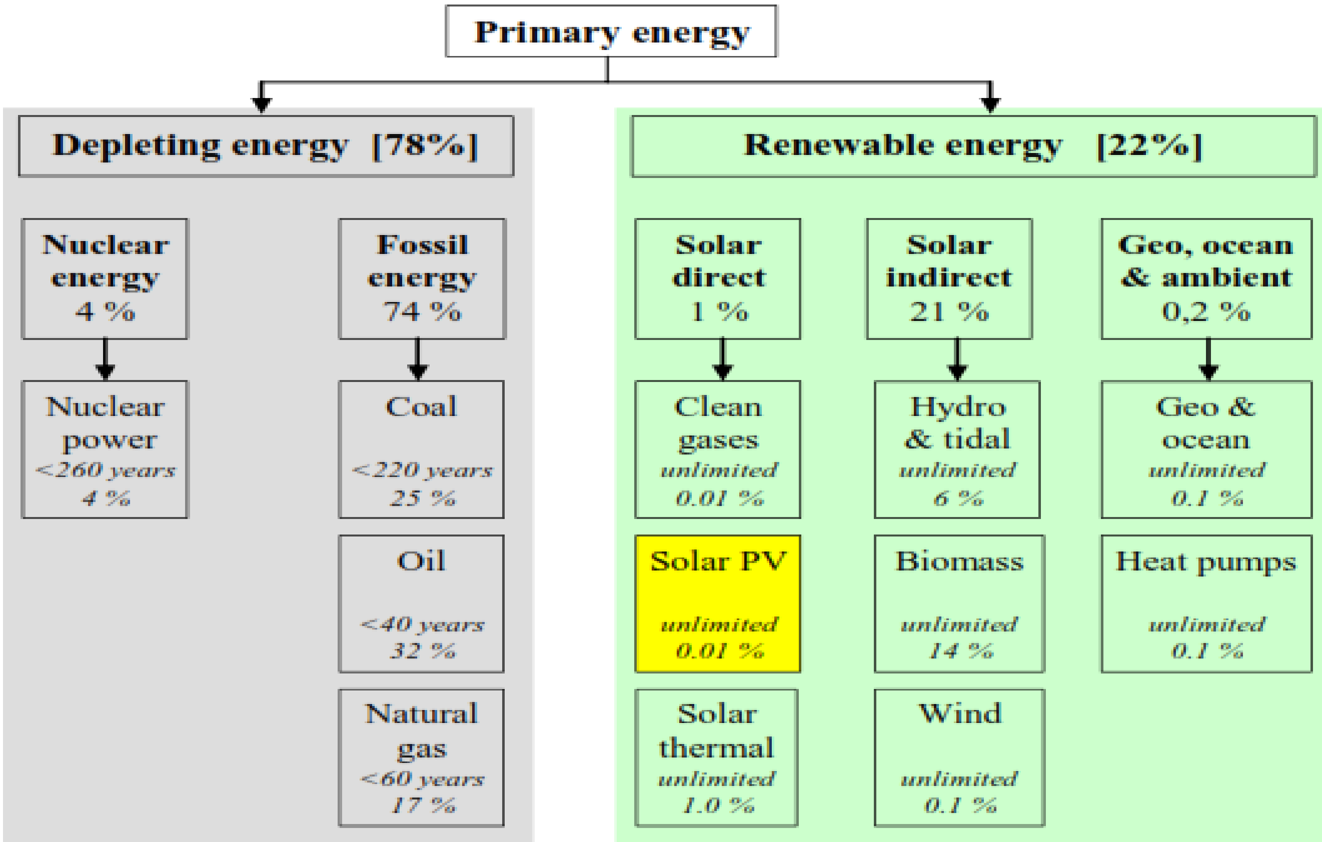
There is a growing need for energy in the world and since the traditional energy sources based on the **fossil fuels** are limited and will be exhausted in future, and it is destroying ecology.

Renewable energy is considered a promising energy source candidate.

By renewable energy we understand energy that is obtained from the continuing flows of energy occurring in the natural environment, such as **solar energy, Wind energy, hydropower and energy from biomass.**

Primary energy sources

Figure 4 below presents an overview of the present primary energy sources



The primary energy sources can be divided in two groups. **<u>depleting energy sources and Renewable energy sources:</u>**
The first group includes those energy sources that will be exhausted by exploiting them. These energy sources are called the depleting energy sources and they are the fossil fuels and nuclear energy. The fossil fuels and nuclear power are the main source of energy in today's energy system and they supply 78% of the energy demand. Under the assumption that the population of mankind does not change drastically and it consumes energy at the current level:
The fossil fuel reserves will be exhausted within 320 years and the nuclear energy within 260 years. This can seem a very long time for us. However, when we compare this period of time to the time span of existence of the Earth or the human civilization, it is a negligible fraction of time. We have to be aware that the reserves of fossil fuels on the Earth are limited and will be exhausted.
Furthermore when we want to take the concept of sustainable development into account, we have to look for no depleted and environmentally friendly energy sources. These sources are known as **<u>renewable or sustainable energy sources. The renewable energy sources</u>** form the second group of the primary energy sources and today they contribute with 22% to the total energy production.

<u>Fossil Fuels</u>
At the end of the 19th century coal was the main source of energy. In this period electricity was introduced in the industrialized countries as a new and elegant form of energy. The widespread

growth of electricity use led to construction of hydroelectric plants and hydropower became an important source of energy in the first half of the 20th century. **Oil and gas** started to play an important role as energy sources in the second half of the 20th century. **Coal, oil, and gas** form today dominant sources of energy. These three energy sources, also known as **fossil fuels**, are called the **traditional energy sources**. In this period **nuclear energy** was introduced as a new source of energy. Increasing and more efficient mass production resulted in the low price of many household products. The consumption of the products grew enormously. It has been recognized that a massive consumption of fossil fuels in order to fulfil the present energy demands has a **negative impacts and challenges.**

A first **challenge** that we are facing is related to the fact that our energy infrastructure heavily depends on fossil fuels like oil, coal and gas. Since the beginning of the industrial revolution, mankind is heavily dependent on fossil fuels. Within a few centuries, we are using solar energy that was incident on Earth for hundreds of millions of years, converted in to chemical energy by the photosynthetic process and stored in the form of gas, coal and oil. **Fossil fuels are millions and millions of years of solar energy stored in the form of chemical energy.** The problem is that humans deplete these fossil fuels much faster than they are generated through the photosynthetic process in nature. Therefore fossil fuels are not a sustainable energy source. The more fossil fuels we consume, the less easily available gas and oil resources will be available.

A second challenge is that by burning fossil fuels we produce the so-called greenhouse gases like carbon dioxide (CO_2). About 75% of the primary energy is generated using fossil fuels, where **coal** is the dominant contributor. As coal emits about twice as much CO_2 per generated kWh as natural gas. Thus **Coal power plants are a major contributor to global warming.** It has been recognized that a massive consumption of fossil fuels has a negative impact on the environment. Gases such as CO_2 and SO_X and NOx are produced as the byproducts during burning of the fossil fuels. Enormous quantities of these gases are emitted into the atmosphere, where they change the natural concentrations. The ecological problems, such as the **greenhouse effect (global warming), acid rains and Ozone damage** are caused by the increase of these gases in the atmosphere.

The greenhouse effect is linked to the increase of CO_2 in the atmosphere. The CO_2 molecules are transparent to solar radiation but are opaque to heat, which is the radiation in the infrared wavelength region. The concentration of CO_2 in the atmosphere has increased in the 20th century from 280 ppm to 350 ppm as shown in figure below. Scientists expect that when this trend continues, the temperature will rise from **3 ºC to 5 ºC in 2030-2050**.

Hence, it seems very clear that the increase in carbon dioxide is responsible for the global warming and climate change, which can have drastic consequences of the habitats of many people. In order to avoid this situation, in which the climate change, known also as the global warning, can lead to undesired ecological changes a reduction in CO_2 emission is essential.

These gases (CO2 and SOX and Nox) cause environmental and health concerns because they can spread easily via air pollution and **acid rains. Acid rain** has many ecological effects, especially on lakes, streams, wetlands, and other aquatic environments, it is also damage forests, especially those at higher elevations.

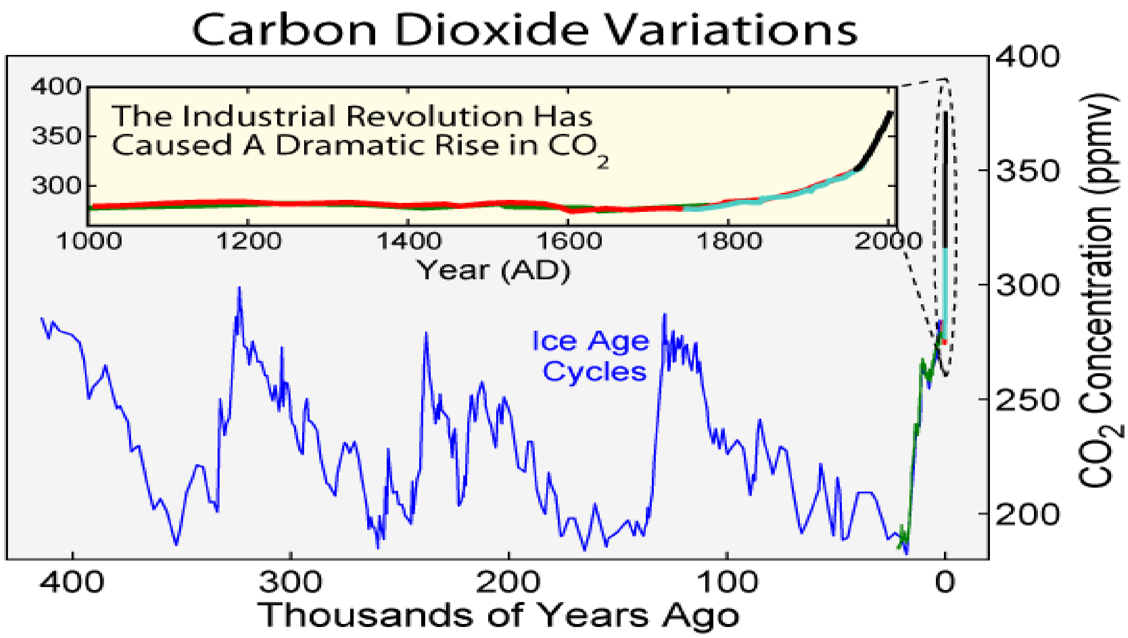


Figure 5, shows the increase in carbon dioxide concentration in the Earth's atmosphere up to 2000.

Ozone layer prevent the ultraviolet (UV) radiation that reaches Earth's surface. **Ozone depletion**, is a gradual thinning of Earth's ozone layer in the upper atmosphere caused by the release of chemical compounds containing gaseous chlorine or bromine from industry and fossil fuels. The thinning is most pronounced in the polar regions, especially over Antarctica.

Ozone depletion is a major environmental problem because it increases the amount of ultraviolet (UV) radiation that reaches Earth's surface, which increases the rate of ***skin cancer, eye cataracts, and genetic and immune system damage.***

Sustainability

The deterioration of environment is a clear warning that the present realization of human progress has its limitations was formulated in a concept of a sustainable human progress. The sustainable human progress is defined as: "**to ensure that sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs".** A new challenge has emerged at the end of the 20^{th} century that represents a search for and a utilization of new and sustainable energy sources.

Renewable Energy

The urge of this challenge is underlined by limited resources of the fossil fuels on the Earth and increasing demand for energy production. This is the reason why the attention is turning to the **renewable energy sources.** In contrast, **renewable energy sources are energy sources that are replenished by natural processes at a rate comparable or faster than its rate of consumption by humans.**

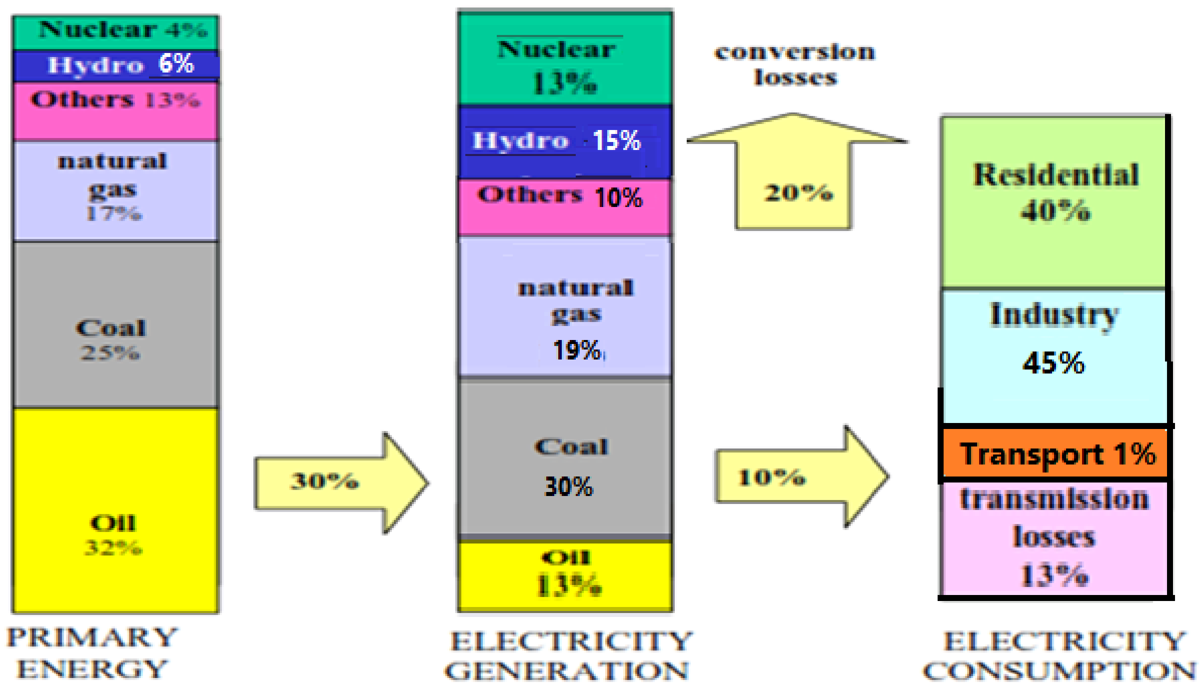
Consequently, **hydro, wind and solar energy are renewable energy sources. wood and biomass also could be considered as a renewable energy sources.**

Before the industrial revolution, the main source of energy was **wood** and biomass, which is a secondary form of solar energy**.** The energy source was replenished in the same characteristic time as the energy being consumed. However, also back then the way we consumed energy was not fully sustainable. For example, deforestation due to increasing population density was already playing a role at the end of the first millennium.

Electricity

It is important to realize that without electricity modern society as we know it would not be possible. Despite this importance of electricity, in 2019 still about 800 million people had no access to electricity. About one third of the primary energy is used to generate electric power. The electrical energy represents about 12% of all energy consumed worldwide.

Figure 7 below shows the present distribution of primary energy sources, their contribution to the production of electricity, and the use of electricity.



Nuclear is responsible for 16% of the World's electricity generation. With **19%, hydroelectricity is by far the largest contributor among the renewable energy sources which are included in others**.

Of all the generated electricity, **40% is used for residential purposes, 45% is used by industry** and **13% is lost in transmission**. **Transport did not play** a significant role in the electricity consumption. However, this is expected to change as electric cars are becoming more and more important.

Renewable energy carriers

Renewable energy carriers are energy carriers that are replenished by natural processes at a rate comparable or faster than its rate of consumption by humans. Renewable resources include:

solar energy, wind, falling water, the heat of the earth (geothermal), plant materials (biomass), waves, ocean currents, temperature differences in the oceans and the energy of the tides.

Renewable energy technologies produce power, heat or mechanical energy by converting those resources either to electricity or to motive power.

Hydroelectricity is an example of an energy conversion technology that is not based on heat generated by fossil or nuclear fuels. The potential energy of rain falling in mountainous areas or elevated plateaus is converted into electrical energy via a water turbine. With tidal pools the potential energy stored in the tides can also be converted to mechanical energy and subsequently electricity.

The kinetic energy of wind can be converted into mechanical energy using wind mills.

Finally, the energy contained in **sunlight, called solar energy,** can be converted into electricity. If this energy is converted into electricity directly using devices based on semiconductor materials, we call it **photovoltaics (PV)**. **Solar light can also be converted into heat.** This application is called **solar thermal energy**. Examples are the heating of water flow through a black absorber material that is heated in the sunlight.

Next to generating heat and electricity, solar energy can be converted in to **chemical energy** as well. This is what we refer to as **solar fuels.** For producing solar fuels, **photovoltaics and regenerative fuel cells can be combined**. In addition, sunlight can also be directly converted into fuels using **photo electrochemical devices.**

<u>What are the renewable energy applications?</u>

Renewable energy applications generally break down into two categories or applications, "on-grid" and "off-grid". A **<u>"grid"</u>** may be defined as an integrated generation, transmission, and distribution system serving numerous customers. Characteristically, a grid is a portfolio of generating units operating under the control of a central dispatch center. Grids may be national, regional or local (in the latter case they are typically referred to as "mini-grids").

<u>Renewable resources are environmentally benign.</u>

Renewable energy facilities generally have a very modest impact on their surrounding environment. The discharges of unwanted or unhealthy substances into the air, ground or water commonly associated with other forms of generation can be reduced significantly by deploying renewables. Clean technologies can also produce significant indirect economic benefits. For example, unlike fossil-fuel facilities, renewable facilities will not need to be fitted with scrubbing technology to mitigate air pollution, nor will a country need to expend resources in cleaning up polluted rivers or the earth around sites contaminated with fossil-fuel by-products. Furthermore, they provide greenhouse gas reduction benefits and should a worldwide market for air emission.

<u>Renewable resources promote energy diversification.</u>

Development of a diverse portfolio of generation assets reduces both a country's dependence on any one particular form of technology or fuel and its vulnerability to supply disruption and price increases. The primary long-term benefit of renewable technologies is that once a renewable project has been constructed, and fully depredated, it becomes a permanent, environmentally dean, and low cost component of a country's energy system. In effect, the construction of a renewable energy project provides future generations a low cost, energy facility that produces power with little or no environmental degradation.

<u>Renewable resources are sustainable.</u>

Renewable technologies are designed to run on a virtually inexhaustible or replenishable supply of natural "fuels." Expanding a nation's electricity supply by attracting investment to renewable energy projects is, by definition, a strategy for sustainable growth, since operation of the facilities does not deplete the earth's finite resources.

Renewable energy facilities enhance the value of the overall resource base of a country by using the country's indigenous resources for electricity generation. Moreover, since these facilities operate on "fuels" that are both indigenous and renewable (as distinguished from imported fossil fuels), they may reduce balance-of-payment problems. Reduced dependence on fuel imports reduces exposure to currency fluctuations and fuel price volatility. The construction and operation of renewable projects normally generate significant local economic activity, often in previously “resource poor” areas of a country. Renewable energy projects thus act as engines for regional economic development. In the case of large scale, on-grid projects, easements will need to be purchased and local workers hired to construct and operate the facility. Frequently, a local industry such as a sugar mill or a paper mill (when biomass technology is employed) will be associated with the development, enhancing the opportunities for joint ventures between local landowners and private investors who may supply technological expertise. Smaller scale facilities often attract local private sector involvement. Local involvement, in turn, stimulates new economic activity in a multiplier effect and adds value to the local tax base.

Does renewable energy generate affordable power?

On a total cost basis, a new, renewable energy, generating facility is often cost competitive with a conventional fuel facility provided that the cost calculation considers long-term fuel costs - and even more so when one considers environmental costs and benefits. Since this generalization is not true in every situation confronting the policy planner, the policy planner will need to apply cost-effectiveness criteria adapted to each situation.

Advantages of renewable energy

The advantages of renewable energy are:

1. Sustainable (non depletable),
2. Ubiquitous (found everywhere across the world in contrast to fossil fuels and minerals), Essentially non-polluting.
3. Note that wind turbines and photovoltaic panels do not need water for the generation of electricity, in contrast to steam plants fired by fossil fuels and nuclear power.

Disadvantages of renewable energy

The disadvantages of renewable energy are:

1. Variability and low density, which in general results in higher initial cost.
2. Visual pollution, odor from biomass, avian and bat mortality with wind turbines, and brine from geothermal.
3. Wherever a large renewable facility is to be located, there will be perceived and real problems to the local people.
4. For conventional power plants using fossil fuels, for nuclear energy, and even for renewable energy, there is the problem of not in my backyard.