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SOLAR ENERGY

Renewable technologies represent an important opportunity, but not a panacea for the U.S. energy economy. Their long-term contribution is predicated on overcoming remaining technical and cost barriers, mainly through intensified R&D. The National Energy Strategy's renewable energy initiatives are based on these conclusions and on a clear understanding of the contributions that renewable energy can and cannot be expected to make. For example, given policies to address existing regulatory barriers and market imperfections, solar thermal or photovoltaic electricity technologies can compete today to provide electricity generation in remote locations and for peaking purposes.

(*National Energy Strategy, Executive Summary*, 1991/1992)

The Administration supports fundamental and applied research that helps the renewable industry develop technologically advanced products. [...] Applied research into thin reflective membrane deposition, airfoil design, and solar module fabrication has reduced costs and increased productivity from solar thermal power plants, wind turbines, and flat plate photovoltaic arrays.

[...]

Programs supporting renewable electric supply will contribute 0.6 quads of primary energy in the year 2000, saving $4 billion in annual fuel costs and reducing 7 million metric tons of carbon-equivalent emissions.

(*Sustainable Energy Strategy*, 1995)

we discussed the following nondepletable energy sources: geothermal, wind, tidal, wave, hydroelectric and biomass energy. We saw that they *will not* solve the world's energy problems. But they are, they can be and they will be important on a local scale. In Chapter 14 we discussed nuclear fusion; it *could* solve all our energy problems, but many technical problems need to be overcome before it can be harnessed and commercialized. The production of electricity using fusion must go through the 'bottleneck' of thermal-to-mechanical energy conversion, which is inherently inefficient. The last energy source that we need to discuss, direct solar energy, *will* solve all society's energy problems, but not yet. Its efficient large-scale utilization is expected to become a reality some time in the 21st century (probably in the second half). Its greatest virtue – apart from being free, inexhaustible, universally available and pollution-free – is that it can be converted directly into electricity, unlike any other energy source. Its potential, its current status and the challenges lying ahead are discussed next.

Solar Energy Balance

More than 99.9% of the energy flow on the earth's surface is due to incoming solar radiation. The rest is from geothermal, gravitational (tidal) and nuclear sources. The sun is an average-size star, with a diameter of 864,000 miles and 93 million miles away from our planet. It is a giant nuclear fusion reactor whose interior and surface temperatures are 35,000,000 and 10,000 °F, respectively. Each second 657 million tons of hydrogen isotopes are converted into 653 million tons of helium. The residual mass of 4 million tons is converted to energy, according to the Einstein equation, $E = mc^2$:

$$\text{Power from the sun} = \left(4\times10^{9}\ \frac{\text{kg}}{\text{s}}\right)\left(3\times10^{8}\ \frac{\text{m}}{\text{s}}\right)^2 = 3.6\times10^{26}\ \text{W}$$

To place this number into perspective, if gasoline were pouring from Niagara Falls, at a rate of 5 billion gallons per hour, and if we had begun collecting it 3.5 million years ago, the combustion of all this accumulated gasoline would liberate the amount of energy equivalent to one minute of the sun's production. The reader is urged to verify this.

Being quite far away from the sun, the earth receives only about half a billionth of this radiation. But it receives it more or less continuously. About 30% of this energy does not reach the surface of the earth because it is reflected from the atmosphere (as ultraviolet radiation, see Figures 3-1 and 11-7). Still, the radiation that does reach the surface is four orders of magnitude larger than the total world's energy consumption (see Illustration 5-1 and Figure 5-2). In fact, only 40 minutes of sunshine would be sufficient – if available in adequate forms – to supply the entire annual energy demand on earth.

The *if* mentioned in the previous sentence is a big one, however. Because solar energy spreads out more or less evenly through space, it reaches the surface of the earth in quite diluted form, at a rate of about 220 W/m^2 (see Figure 3-1). In other words, if one square meter were available for conversion of solar energy to electricity (at 100% efficiency), the energy produced would be sufficient for just two or three light bulbs. The challenge of solar energy utilization is to concentrate it. Practical ways to achieve this are discussed below. They include direct solar heating, indirect production of electricity and direct production of electricity.

Direct Solar Heating

The use of solar rays to achieve effective heating has been practiced since ancient times. In 213 B.C., the Greek savant Archimedes used mirrors to direct sunlight onto the fleet of Marcellus, the Roman general who tried to capture Syracuse (Sicily), and set his ships on fire. Today's devices are not necessarily more sophisticated than the ones used by Archimedes. They are called *collectors.* A collector is thus a device that collects solar radiation and converts it to thermal energy.

Figure 17-1 shows the statistics of most recent shipments of solar collectors in the U.S. The low-temperature collectors are used primarily for less demanding residential consumption (to heat swimming pools, for example); it is good to see that their sales are up again. The medium-temperature collectors are used primarily for residential hot water. Both kinds became popular in the decade of the oil crises (1970s). However, consumer interest in them decreased sharply when the price of oil decreased in the 1980s (see Chapter 20) and when Federal solar energy tax credits expired in 1985.

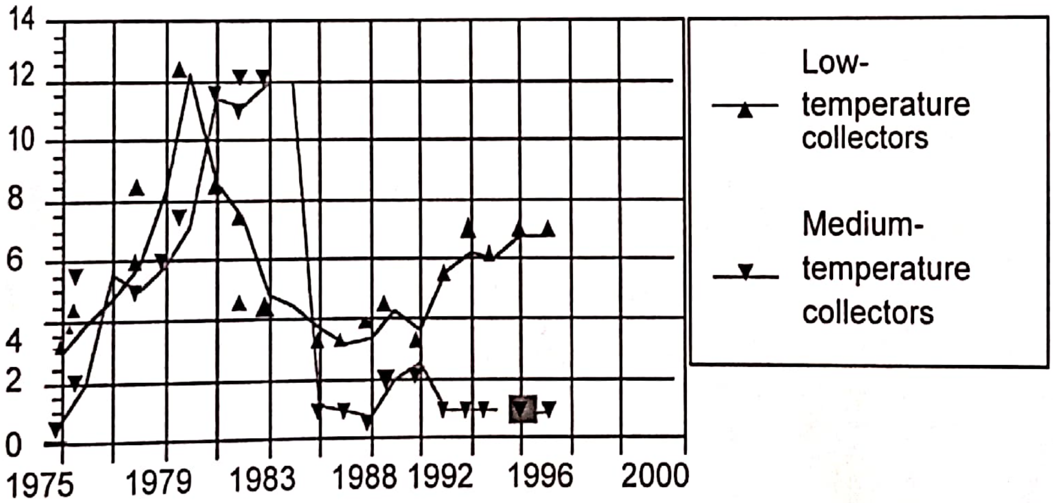

FIGURE 17-1. Shipment of solar collectors in the U.S.
[Source: Energy Information Administration.]
FIGURE 17-1. Shipment of solar collectors in the U.S.
[Source: Energy Information Administration.]
Figure 17-2 is a schematic representation of a typical flat-plate collector used for domestic heating. A "working fluid" (such as air, water, oil or antifreeze) circulates through the tubes. The enclosure, with its black metal surface between the tubes and insulation at the bottom, is designed to maximize the absorption of solar radiation and its conversion to heat: the glass cover provides the greenhouse effect. The efficiency of conversion of solar radiation to heat stored in the working fluid is a complex issue; it is quite dependent on collector design. Man-made collectors are much less efficient than "natural collectors," that is, animal furs. The fur of polar bears, for example, has been reported to have an efficiency of about 95%; no wonder they enjoy swimming in the icy Arctic waters! The most sophisticated, and most expensive, solar collectors have maximum efficiencies in the 65-70% range. Typical values on a cold winter day, when they are most used, are around 20%.

FIGURE 17-2. Schematic representation of a flat-plate collector.
[From "Energy and Problems of a Technical Society," by J.J. Kraushaar and R.A. Ristinen. Copyright © 1988 by John Wiley & Sons. Reproduced with permission.]
In addition to the collector and the working fluid, a complete *active solar system* must have an energy storage facility and/or a backup system, because the sun does not shine all the time and it may not shine every day. Such a system is illustrated in Figure 17-3. The hot working fluid (such as antifreeze) exchanges heat with water in the primary loop, similar to the primary loop of a pressurized water nuclear reactor (see Figure 13-8). In the secondary loop, this hot water is used to heat the storage tank, from which the hot water is distributed to the various consumers (for example, a shower in a home or a dishwasher). The size of the storage system depends on the amount of solar energy incident on the collector and on the efficiency of the collector. This is shown in Illustration 17-1, based on the information given in Table 17-1.

In addition to the active solar energy system, *passive* solar heating system can be used effectively to reduce the heating (and cooling) requirements of houses and buildings. A passive system contains no active components, such as collectors and pumps; it relies on both regular and special features of building design. Walls, ceilings and floors constitute both the collection and the storage system. Heat is distributed by natural convection. Building design is optimized to let the sun in and keep it in in the winter, and to do the opposite in the summer. There are two ways to accomplish this: using the so-called *direct gain* and *indirect gain.*

FIGURE 17-3. Schematic representation of a solar energy storage system.
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Illustration 17-1. A home in Phoenix (Arizona) requires 62 kWh of heat on a winter day to maintain a constant indoor temperature of 20 °C. (a) How much collector surface area does it need for an all-solar heating system that has a 20% efficiency? (b) How large does the storage tank have to be to provide this much energy?

Solution.
Phoenix is located at about 33 °N, so we can use the data for 32 °N given in Table 17-1. The average solar radiation in winter is about 6.5 $kWh/m^2/day$. Hence, the daily quantity of thermal energy obtained using collectors will be:

$$\text{Thermal energy} = 6.5\ [\text{kWh (solar)}]\ [0.20\ \text{kWh (thermal)}] = 1.3\ \text{kWh}$$

m^2 day [1 kWh (solar)] m^2 day

This means that for every square meter of collector surface area, 1.3 kWh of heat are produced every day. Therefore, the required collector surface area is obtained as follows:

$$\text{Collector surface area} = \frac{62 \frac{\text{kWh}}{\text{day}}}{1.3 \frac{\text{kWh}}{\text{m}^2\,\text{day}}} = 48\ \text{m}^2$$

So a collector 6 m long and 8 m wide would do the job. Obviously, it can be placed on the roof. The size of the storage tank can be obtained by remembering the quantitative definition of heat (Chapter 3):

Heat = [Mass] [Heat capacity] [Temperature difference]

Here the mass is that of the storage medium, water, which needs to be determined. The heat capacity of water is 1 kcal/kg/°C (see Table 3-2), and the temperature difference is that between the hot fluid in the secondary loop and the cold water going into the storage tank (say, 60 – 20 = 40 °C); see Figure 17-4. Therefore, the required mass of water for a day's worth of heat is obtained as follows:

$$\text{Mass} = \frac{\text{Heat}}{[\text{Heat capacity}]\,[\text{Temperature difference}]} =$$

$$= \frac{62\ \text{kWh}}{\left(1\ \frac{\text{kcal}}{\text{kg}\ ^\circ\text{C}}\right)(40\ ^\circ\text{C})\left(\frac{1.16\times10^{-3}\ \text{kWh}}{1\ \text{kcal}}\right)} = 1336\ \text{kg}\ H_2O$$

This is equivalent to a volume of 1336 liters (or about 350 gallons), because the density of water is 1 kg/L.

TABLE 17-1

Variation of solar radiation (in W h/m^2) with time and latitude

Date	Perpendicular	Horizontal	Vertical South	60° South
October 21				
32°N	8,498	5,213		
40°N	7,735	4,249	5,212	6,536
48°N	6,789	3,221		
November 21				
32°N	7,584	4,035		
40°N	6,707	2,969	5,314	6,013
48°N	5,257	1,879		
December 21				
32 °N	7,401	3,581		
40 °N	6,235	2,465	5,188	5,660
48 °N	4,551	1,406		
January 21				
32 °N	7,748	4,060		
40 °N	6,878	2,988	5,440	6,127
48 °N	5,390	1,879		

February 21				
32 °N	9,053	5,434		
40 °N	8,321	4,457	5,452	6,858
48 °N	7,344	3,404		
March 21				
32 °N	9,494	6,569		
40 °N	9,191	5,838	4,677	6,852
48 °N	8,763	4,974		

[Sources: Kraushaar and Ristinen, op. cit.; A.W. Culp, Jr., "Principles of Energy Conversion," McGraw-Hill, 1991.]

Direct gain refers to systems that admit sunlight directly into the space requiring heat. The maximum reception of sunlight is obtained through windows facing south, as shown in Figure 17-4 (see also Table 17-1). The sunlight received during the day – while it lasts – must be absorbed by a high-heat-capacity material on the floor or the walls. As shown in Table 3-2, dense substances such as concrete, brick, stone, adobe and water can store relatively large quantities of heat in a reasonable amount of space. When the sun ceases to shine, the warm floor and walls transfer the accumulated heat to the cold space in the house.

Indirect-gain passive systems are those that also absorb solar radiation in a high-heat-capacity material, such as an outside concrete wall. The accumulated thermal energy is then transferred to the space needing heat. The south-facing *Trombe wall*, named after the French engineer Félix Trombe, is the most commonly used passive solar structure. It is built of concrete, brick or stone; it can even be filled with water. It is often painted black for maximum absorption of radiation. This increases its efficiency but does not help to embellish the neighborhood; there are regulations in some residential areas that do not allow these structures on the street-facing side of the house. An alternative system is a *roof pond*: water is contained in large, shallow bags between the ceiling and the roof. Movable insulating material separates it from the roof. During the day, insulation is removed to allow sunlight to strike the pond; during the night, it is placed back in its position so that it allows the heat to be transferred mostly toward the inside of the house.

The most familiar example of a passive solar system is the *greenhouse*, also called sunspace or sunporch. It is used both for growing plants and for residential comfort in winter. It combines direct and indirect gain, by letting the sunshine into the room through south-facing glass and absorbing the radiation on a brick wall inside the room. (This is the origin of the term "greenhouse effect," discussed in Chapter 11.)

FIGURE 17-4. Solar heat gain for different window orientations.
[Source: G. Aubrecht, op. cit.]

In the ruins of ancient civilizations, there are numerous examples of very effective passive solar heating and cooling systems. The ancient cliff dwellings in the Mesa Verde National Park in Colorado are a familiar example. As the cost of heating and cooling increases in our days, architects, home owners and builders are wise in remembering these examples and adapting them to current building materials and lifestyles. It is well documented that they can provide significant energy savings.

Indirect Production of Electricity

The use of a more sophisticated collector system – compared to the one represented in Figures 17-3 and 17-4 – allows the working fluid to achieve a higher temperature. Such a system can then be used to produce electricity. This is illustrated in Figure 17-5. A solar thermal power plant is essentially identical to an ordinary steam-turbine power plant, except that it gets the heat from solar radiation rather than from combustion or nuclear fission.

FIGURE 17-5. Schematic representation of a solar thermal power generation plant.

A flat-plate collector typically raises the temperature of the working fluid to about 100 °C. A number of flat-plate collectors placed in series can raise the temperature of the working fluid to levels that can provide economically competitive electricity. For example, the maximum efficiency of the turbine of a power plant whose entering steam temperature is 200 °C would be

$$E_{max} = \frac{T_H - T_L}{T_H} = \frac{(200 + 273) - (100 + 273)}{(200 + 273)} = 0.21$$

This is a low efficiency, but the 'fuel' (solar energy) is free. A higher temperature can be achieved by using concentrating, or focusing, collectors – as Archimedes did to burn Roman ships. With the use of parabolic trough collectors, for example, steam temperatures of up to 300-400 °C can be reached. This technology is currently cost-competitive in certain markets. In the Mojave desert (Kramer Junction, CA), Luz International has built a plant that delivers 354 MW of electricity to Southern California Edison's power grid (see Investigation 17-1).

Temperatures as high as those in conventional power plants can be achieved easily with solar tower technology. Here, a system of computer-controlled mirrors (called heliostats) tracks the sun across the sky so that the reflected sunlight from all the mirrors falls on a central tower containing water or oil or, in more recent designs, a molten salt. At Barstow, California, some 1900 heliostats were used to raise the temperature of water to 510 °C and the 10 MW(e) Solar One plant had an overall efficiency comparable to that of conventional power plants. And the new 10-MW(e) Solar Two at the same location is advertised today as the world's most technically advanced solar power plant. It uses a molten salt as the heat transfer fluid. The advantage is that the thermal energy collected during sunny hours can be stored in the molten salt (see Illustration 17-2) and used on cloudy days or at night. If successful, it will pave the way for a new generation of commercial power plants.

Illustration 17-2. How much less heat storage medium would be needed in Illustration 17-1 if a molten salt were used instead of water? Because it undergoes a phase change (from solid to liquid), the amount of heat that can be stored in the salt is larger, say 120 BTU/lb, than the amount that can be stored in water.

Solution.
The mass of molten salt required is

$$\text{Mass} = \frac{\text{Heat}}{[\text{Heat capacity}]\,[\text{Temperature difference}]} = \frac{(62\text{ kWh})\left(\frac{3414\text{ BTU}}{1\text{ kWh}}\right)}{120\ \frac{\text{BTU}}{\text{lb}}} = 1764\text{ lb}$$

Compare this to almost 3000 pounds of water needed for the same heat storage task.

The Department of Energy reports that annual shipments of these high-temperature collectors were less that 5 thousand square feet in 1994, down from 5.24 million square feet in 1990. Clearly, non-electric use of low- and medium-temperature solar collectors is more popular at the present time (see Figure 17-1).

Direct Production of Electricity

Indirect production of electricity from solar energy, while quite promising because of recent significant progress in technology and in economic competitiveness (see Chapter 18), has two major drawbacks. Because of its relatively low efficiency (especially using flat-plate-collector systems), the size of the proposed *solar farms* can be very large. This is illustrated below.

Illustration 17-3. How much collector area would a 1000-MW(e) solar farm require if the individual efficiencies of the collector system, turbine and generator are 30, 25 and 90%, respectively?

Solution.
Let us assume that the average incident solar radiation at the proposed site of the plant is 200 W(solar)/m^2. This means that 1 m^2 of earth's surface receives 200 W of solar radiation. If a collector is placed on this surface, it will convert 30% of this energy into heat; therefore for every square meter of collector, 60 W of thermal energy will be available. Now, taking into account the efficiencies of the turbine and the generator, we have that the collector area required is:

$$\text{Collector area} = \left(\frac{1\ \text{m}^2}{60\ \text{W(th)}}\right)\left(\frac{1\ \text{W(th)}}{0.25\ \text{W(m)}}\right)\left(\frac{1\ \text{W(m)}}{0.9\ \text{W(e)}}\right)(10^9\ \text{W(e)}) = 7.4\text{x}10^7\ \text{m}^2$$

Thus, with the efficiencies given above, this solar farm would occupy an area of about 75 square kilometers. If land is expensive, this would represent a significant capital investment.

Direct conversion of solar energy to electricity would not only avoid this problem, but would avoid the "thermodynamic bottleneck" illustrated in Figure 17-6, which none of the technologies mentioned so far are capable of doing. In most of our discussion of electricity generation so far, the energy conversion path has been the one shown in the upper portion of Figure 17-6.

The direct conversion of chemical energy to electricity is possible in devices called *fuel cells*. These are a type of large-scale batteries that have been used for decades in the NASA

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The direct conversion of chemical energy to electricity is possible in devices called *fuel cells*. These are a type of large-scale batteries that have been used for decades in the NASA space programs. In contrast to ordinary batteries, however, fuel cells require a continuous supply of chemical energy (from natural gas, for example) and the electrode material is not depleted as it supplies electricity. Their commercial use in power plants and electric transportation is increasingly being considered, particularly in densely populated areas (because of their very low environmental emissions and silent operation). A 4.8 MW(e) demonstration plant had been operational in downtown Manhattan since the early eighties. A number of utility companies across the U.S. have purchased 2 MW(e) plants, one of them to power the New York City subway system (*The New York Times*, June 30, 1991, p. F6). More recently, a 2 MW(e) plant that is considered to be simpler and more efficient than many other types of fuel cell power plants was connected to the grid of the Santa Clara municipal electric system. (For an update on this Santa Clara demonstration project, see www.ercc.com/scdp.html. For an update on fuel cell technology in general, visit the Web site of the Morgantown Energy Technology Center of the Department of Energy, www.metc.doe.gov.)

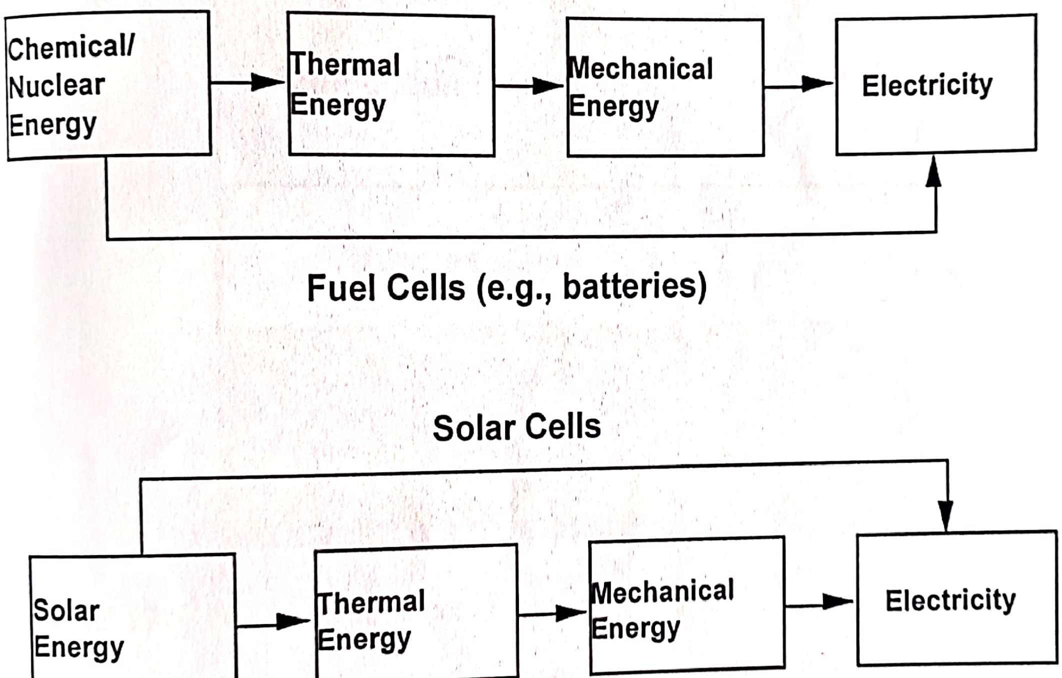

FIGURE 17-6. Energy conversion pathways of fuel cells and solar cells.

Like fuel cells, *solar cells* produce electricity directly, without going through the thermodynamically unfavorable conversion of high-entropy thermal energy into low-entropy mechanical energy (remember Chapter 3). Therefore, in theory at least, the efficiency of this conversion could be as high as 100% and this – together with the fact that solar energy is free, inexhaustible and nonpolluting – provides great incentive to develop this new technology.

A solar cell, also called *photovoltaic cell*, is thus a device that directly converts solar radiation into electricity. It is based on the photoelectric (or photovoltaic) effect, which was known since the early 19th century, but which was translated into a useful device only in the 1950s, in response to the needs of the U.S. space program. This effect, exhibited by materials called *semiconductors* (such as silicon), is illustrated in Figure 17-7. Transistors and computer chips, which have revolutionized the electronics industry since the 1940s, are also made from semiconducting materials.

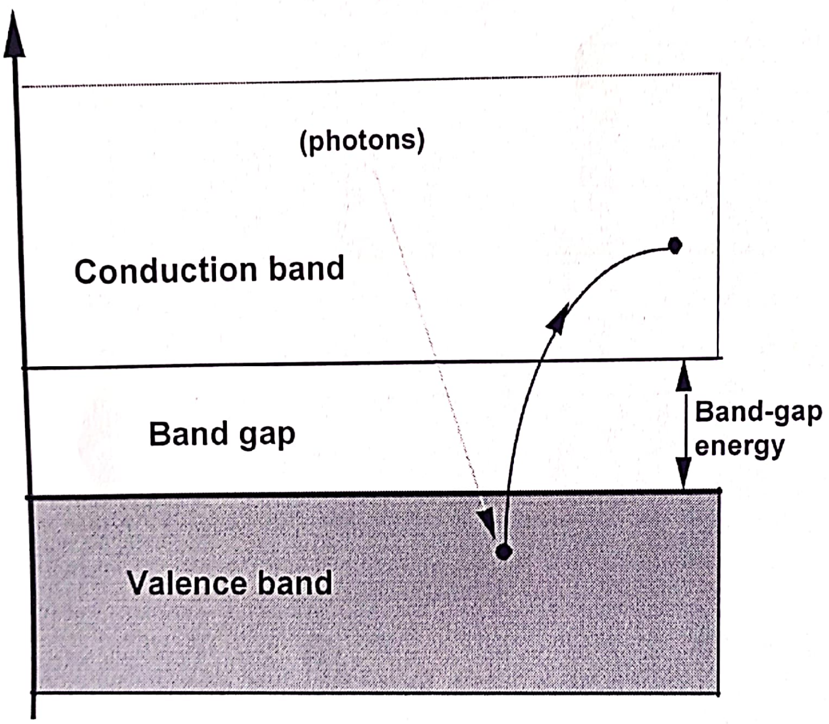

FIGURE 17-7. Photovoltaic effect in semiconductors.

The electrons that have the potential to create an electric current are normally tied up in their valence band, that is, at a low energy level. An energy barrier (called the band-gap energy) must be overcome before they can become carriers of electricity in this material, by jumping into the so-called conduction band. Solar radiation, in the form of elementary particles called photons, provides the needed energy; the photons strike the surface of the semiconductor and some of the valence electrons are ejected into the conduction band. They are thus made free or available for *conduction* of electricity. But for the *production* of electricity, the actual solar cell device must be made from two different types of so-called 'doped' semiconductors. This is shown in Figures 17-8 and 17-9 and described below.

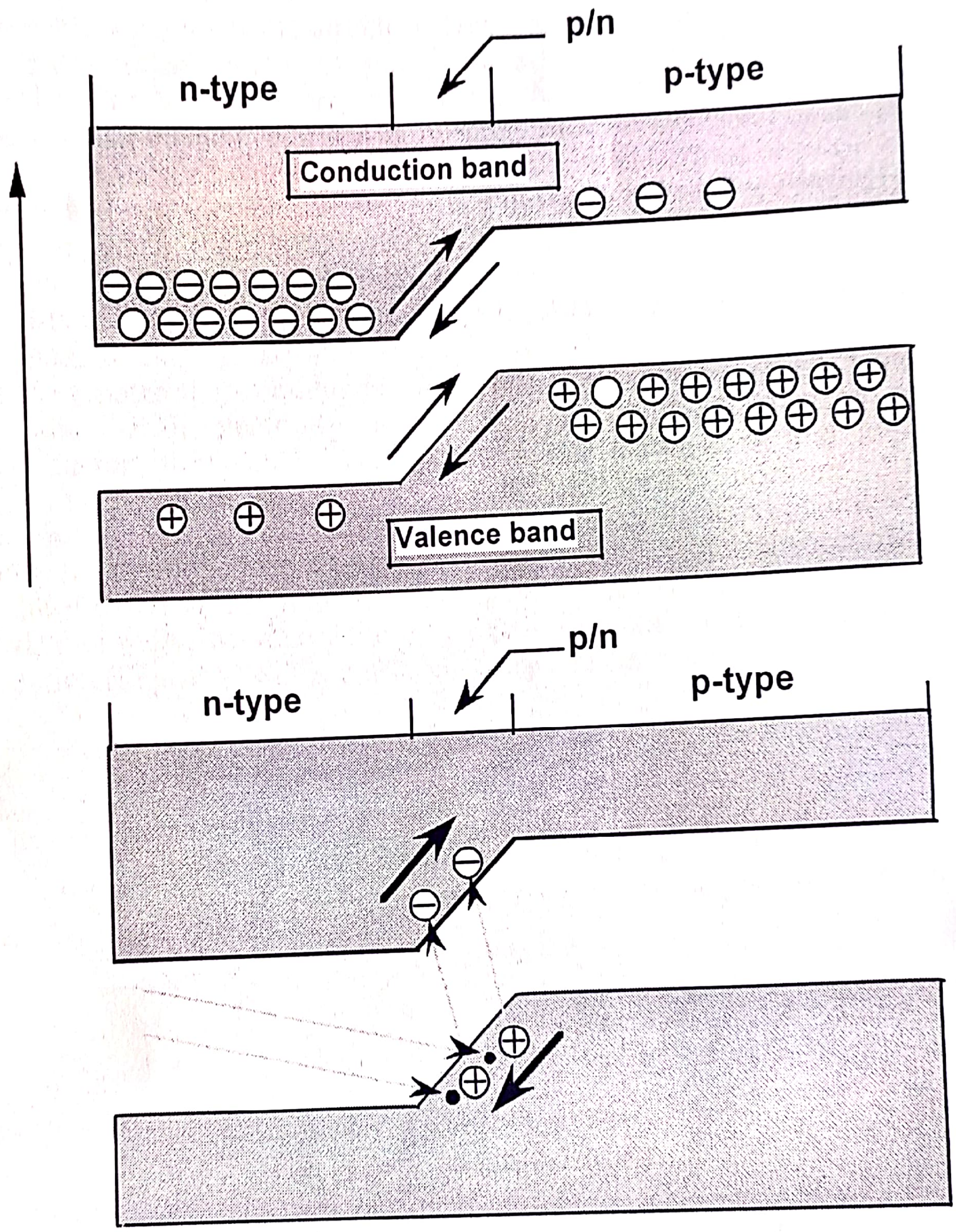

FIGURE 17-8. The charge distribution in the p/n junction region of a solar cell: (a) without solar radiation; (b) with solar radiation.

In a normal silicon crystal, there are four valence electrons in every atom. They are held in place by the positive charge from the nuclei of the silicon atoms. They easily come back to the valence band before they can give up their energy in an external electric circuit. However, if the silicon is doped with a small quantity of an element that has five valence electrons and can fit into the silicon crystal structure (such as phosphorus or arsenic), some extra electrons are created. Such a doped material is called an *n-type semiconductor*, because the extra electrons carry a *negative* charge. Alternatively, if the semiconductor is doped with an element that has only three valence electrons (such as boron or gallium), instead of creating extra electrons, extra missing electrons, or *positive* holes, are created. This is a *p-type semiconductor*. Still, both materials are electrically neutral when they are separated: in the n-type material the negative charge of the extra electrons is balanced by the higher positive charge of the dopant nuclei (e.g., phosphorus), and in the p-type material the extra electron holes are balanced by the lower positive charge of the dopant nuclei (e.g., boron).

When these two types of material are combined, a p/n junction is formed. This is what makes possible the production of electricity, as opposed to simple conduction of electricity in a semiconductor illuminated by solar radiation. Because of the high concentration of electrons in the n-type semiconductor, some of the extra electrons spill over into the holes of the p-type semiconductor. This makes the n-type material positively charged in the vicinity of the junction. Conversely, the p-type material becomes negatively charged in the vicinity of the junction. An (internal) electric field across the junction is thus created. Normally, however, there is equal flow of electrons in both directions across the junction (Figure 17-8a) and no electricity can be produced.

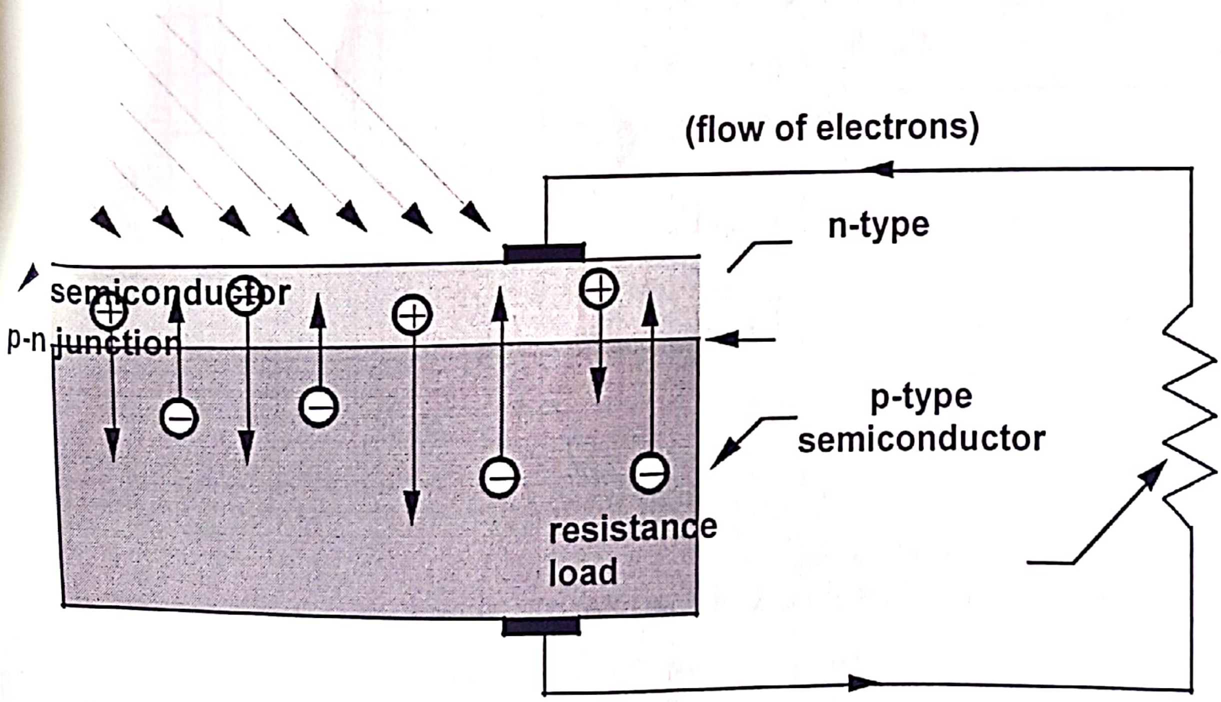

FIGURE 17-9. Schematic representation of a solar cell.

When solar radiation strikes the solar cell (Figure 17-8b), excess electrons flow from the n-type material to the p-type material and excess holes 'flow' in the opposite direction. This, together with the existence of the electric field across the junction, makes possible the flow of electrons away from the (charge-separating) junction and through an *external* circuit (Figure 17-9). Thus, solar energy is converted into electricity.

Figures 17-10 and 17-11 summarize the growth of the photovoltaic-cell market in the U.S. and the world. The contribution to the overall energy supply is still low (see Chapters 5 and 18) but the growth has been phenomenal. It has occurred mostly in the developed nations (U.S., Japan, Europe). The growth in the U.S. has been most significant in the residential sector. Developing nations (such as Brazil, India, and China) have also contributed to the worldwide growth, because one of the key advantages of the photovoltaic technology is its rural applicability, in remote areas lacking access to central power supplies. The cumulative world capacity now approaches 600 MW. It is mostly used for on-peak consumption (see Chapter 18). It must be concluded, however, that both economic and efficiency problems still stand in the way of large-scale commercial utilization of this technology.

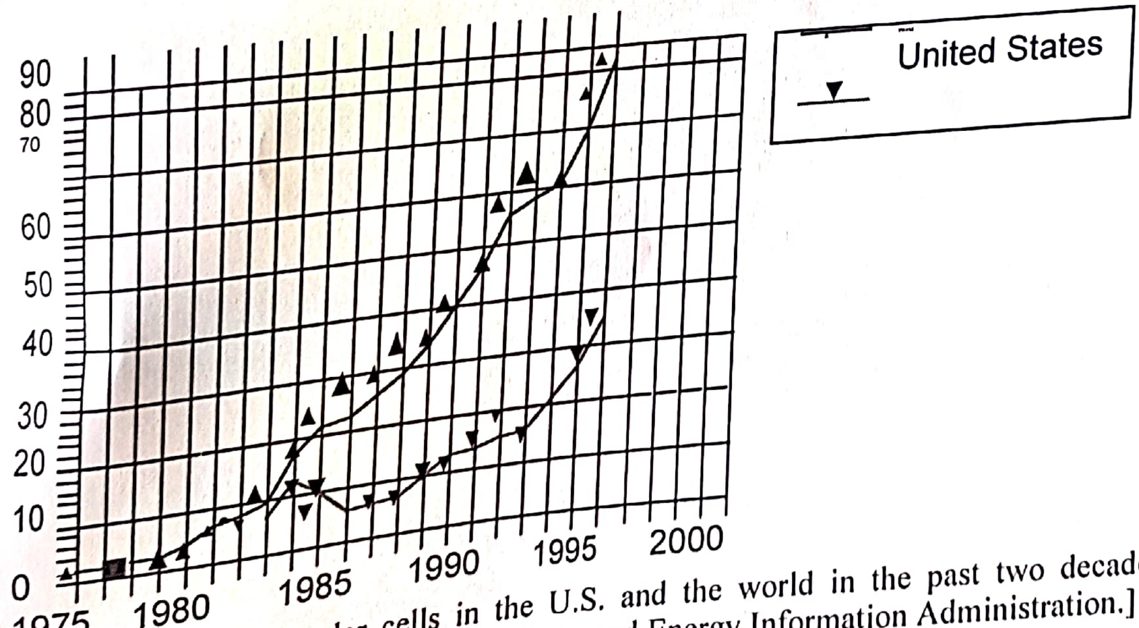

FIGURE 17-10. Use of solar cells in the U.S. and the world in the past two decades. [Source: *Vital Signs 1996*, Worldwatch Institute, and Energy Information Administration.]

Every new incremental increase in the efficiency of a solar cell attracts a great deal of attention in the popular press. While there are no thermodynamic limitations, as mentioned above, there are inherent energy losses that severely limit the performance of currently available cells. These include optical losses (for example, reflection of the radiation from the cell's surface, before reaching the p-n junction) and the (more serious) inability of the currently designed cells to provide for the conversion of the entire sunlight spectrum (see Figure 2-2) into electricity. Despite these limitations, the efficiency of an individual solar cell has increased from 5% in the early designs to about 35% in the most advanced designs.

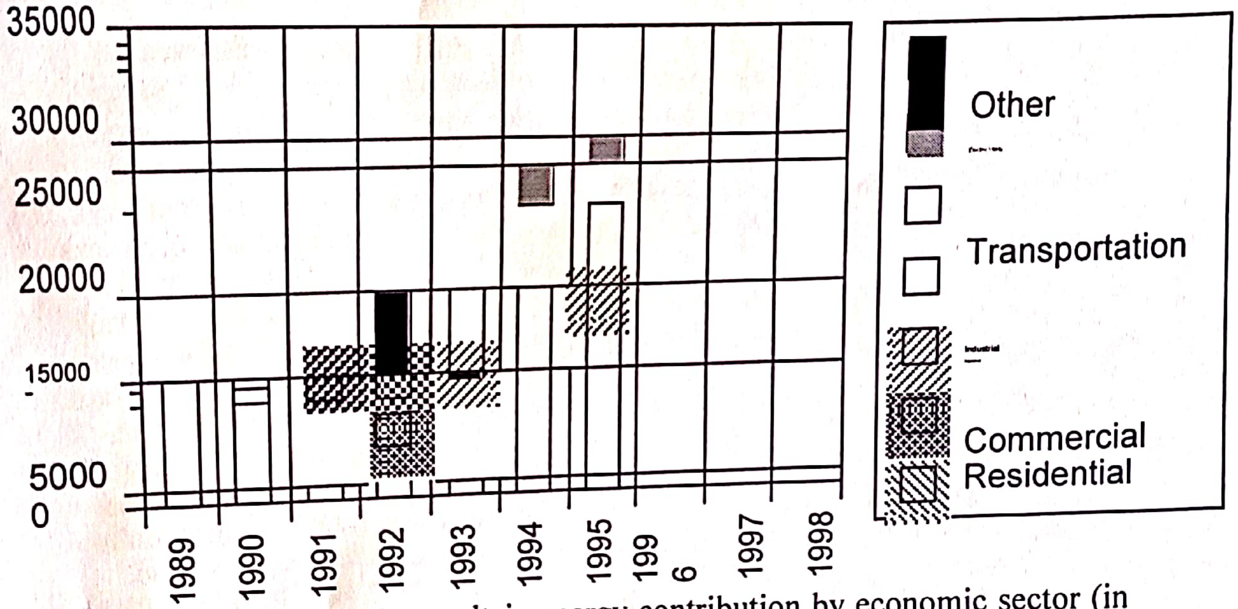

FIGURE 17-11. U. S. photovoltaic energy contribution by economic sector (in kilowatts purchased). [Source: Energy Information Administration.]

More important than the issue of efficiency is the cost issue – after all, solar energy comes for free – and here dramatic changes have taken place. This is illustrated in Figure 17-12. In *Vital Signs 1996*, the Worldwatch Institute reports no additional decrease in the price of solar electricity; today solar cells cost $3.50-4.00 per watt. In a recent NYT article ("70's Dreams, 90's Realities. Renewable Energy: A Luxury Now. A Necessity Later?," 4/11/95), the following costs for a kilowatthour of electricity are given:

Natural gas	3 cents
Wind	5 cents
Geothermal	5.5 cents
Solar (thermal)	14 cents

A similar summary was published in a May 1994 issue of *Business Week* ("The sun shines brighter on alternative energy"):

Coal	4-5 cents
Natural gas	4-5 cents
Wind	5-9 cents
Geothermal	5-8 cents

Hydropower	4-7 cents
Biomass	6-8 cents
Solar (thermal)	10-12 cents
Photovoltaic	30-40 cents

(Environmental benefits of solar energy may not have been factored into these prices; see Chapter 21.) In these circumstances, some companies in the U.S. have abandoned solar energy, unsure of when they will be able to convert it into electricity with a profit (see "U.S. Companies Losing Interest in Solar Energy," in the NYT of 3/7/89; see also Investigation 17-1). Others are using cheaper but lower-efficiency materials (thin films of amorphous silicon) and are still working on efficiency improvements.

During the Bush Administration, the Department of Energy had anticipated (in its *National Energy Strategy*) that utility-scale applications of photovoltaics will reach commercial level around the year 2015. Current official projections do not seem to be as optimistic. In the *Sustainable Energy Strategy*, the statement about DOE's Photovoltaics System Program is more vague when it comes to commercial-scale utilization: "[This] Program supports private sector research to develop roofing materials and windows that incorporate photovoltaics and can produce electricity. These efforts are pursued in close collaboration with industry in programs with the Utility PV Group."

Finally, photovoltaic technology is expected to bring closer to reality the use of hydrogen as an energy source. The concept is illustrated in Figure 17-13. It is a sun-assisted water cycle. Solar radiation is converted to electricity, which is then used to break up water into hydrogen (H_2) and oxygen (O_2). Hydrogen is then used as a clean gaseous fuel, whose combustion regenerates water, produces a lot of energy (274 BTU/ft^3) and causes no pollution. But don't expect to see this wonderful technology at your local electric utility any time soon (in your lifetime, I mean).

INTERNET INFO	For the most recent developments in solar energy and other renewable energy sources, visit the following Internet sites: •www.nrel.gov; •www.eren.doe.gov/RE/solar.html •solstice.crest.org •www.energy.ca.gov/education/index.html •www.crest.org/renewables/usecre// •www.ises.org/

SRI Y N COLLEGE (A), NARSAPUR

PROJECT WORK

Academic Year 2017-2018

Submitted to

DEPARTMENT OF PHYSICS

TOPIC: BIO ENERGY

BY

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Under the guidance of :

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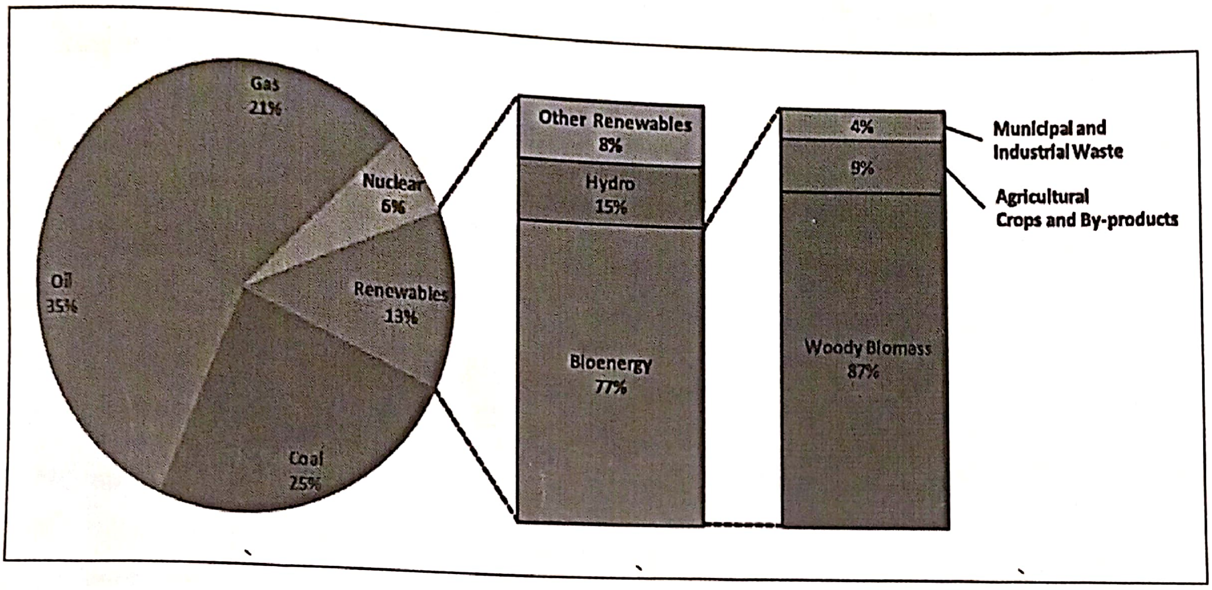
INTRODUCTION:

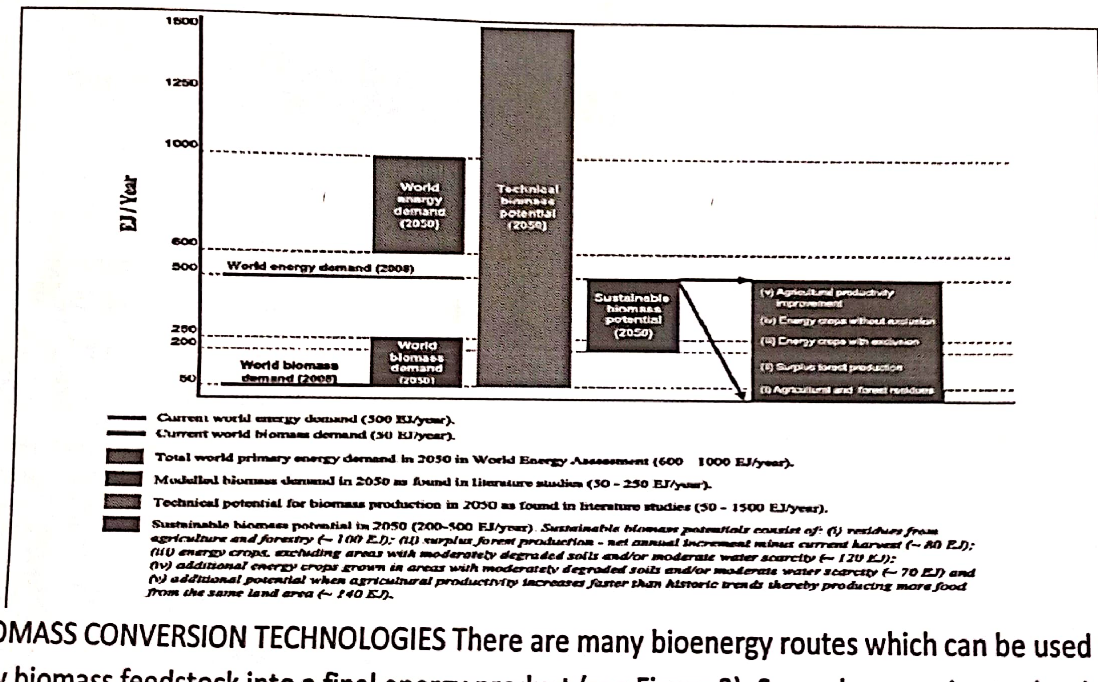
The supply of sustainable energy is one of the main challenges that mankind will face over the coming decades, particularly because of the need to address climate change. Biomass can make a substantial contribution to supplying future energy demand in a sustainable way. It is presently the largest global contributor of renewable energy, and has significant potential to expand in the production of heat, electricity, and fuels for transport. Further deployment of bioenergy, if carefully managed, could provide: • an even larger contribution to global primary energy supply; • significant reductions in greenhouse gas emissions, and potentially other environmental benefits; • improvements in energy security and trade balances, by substituting imported fossil fuels with domestic biomass; • opportunities for economic and social development in rural communities; and • scope for using wastes and residues, reducing waste disposal problems, and making better use of resources. This review provides an overview of the potential for bioenergy and the challenges associated with its increased deployment. It discusses opportunities and risks in relation to resources, technologies, practices, markets and policy. The aim is to provide insights into the opportunities and required actions for the development of a sustainable bioenergy industry

BIOMASS RESOURCEs:

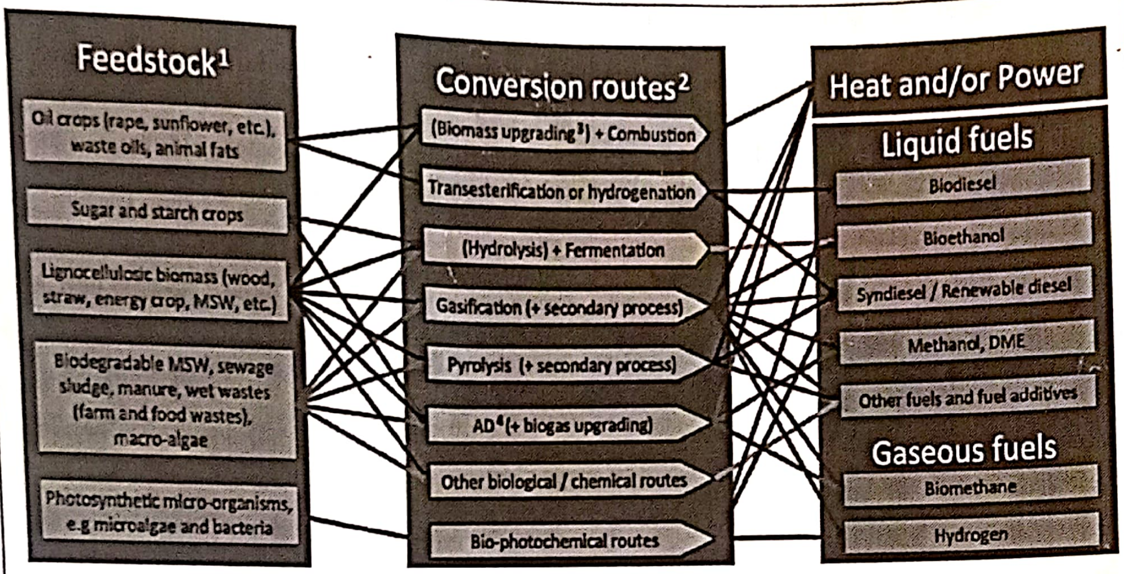
At present, forestry, agricultural and municipal residues, and wastes are the main feedstocks for the generation of electricity and heat from biomass. In addition, a very small share of sugar, grain, and vegetable oil crops are used as feedstocks for the production of liquid biofuels. Today, biomass supplies some 50 EJ1 globally, which represents 10% of global annual primary energy consumption. This is mostly traditional biomass used for cooking and heating. See Figure 1. There is significant potential to expand biomass use by tapping the large volumes of unused residues and wastes. The use of conventional crops for energy use can also be expanded, with careful consideration of land availability and food demand. In the medium term, lignocellulosic crops (both herbaceous and woody) could be produced on marginal, degraded and surplus agricultural lands and provide the bulk of the biomass resource. In the longer term, aquatic biomass (algae) could also make a significant contribution. Based on this diverse range of feedstocks, the technical potential for biomass is estimated in the literature to be possibly as high as 1500 EJ/yr by 2050, although most biomass supply scenarios that take into account sustainability constraints, indicate an annual potential of between 200 and 500 EJ/yr (excluding aquatic biomass). Forestry and agricultural residues and other organic wastes (including municipal solid waste) would provide between 50 and 150 EJ/year, while the remainder would come from energy crops, surplus forest growth, and increased agricultural productivity. See Figure 2. Projected world primary energy demand by 2050 is expected to be in the range of 600 to 1000 EJ (compared to about 500 EJ in 2008). Scenarios looking at the penetration of different low carbon energy sources indicate that future demand for bioenergy could be up to 250 EJ/yr. This projected demand falls well within the sustainable supply

potential estimate, so it is reasonable to assume that biomass could sustainably contribute between a quarter and a third of the future global energy mix. See Figure 2. Whatever is actually realised will depend on the cost competitiveness of bioenergy and on future policy frameworks, such as greenhouse gas emission reduction targets





BIOMASS CONVERSION TECHNOLOGIES There are many bioenergy routes which can be used to convert raw biomass feedstock into a final energy product (see Figure 3). Several conversion technologies have been developed that are adapted to the different physical nature and chemical composition of the feedstock, and to the energy service required (heat, power, transport fuel). Upgrading technologies for

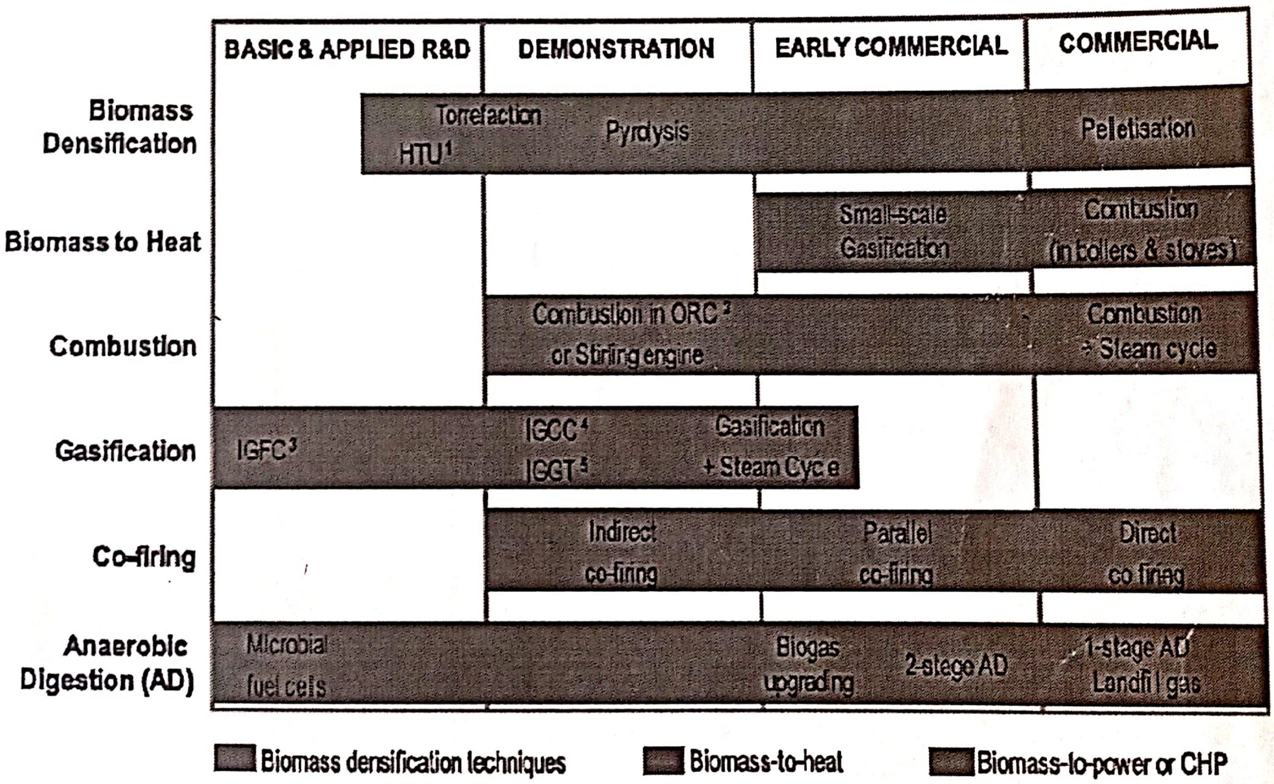


[1] Parts of each feedstock, e.g. crop residues, could also be used in other routes

[2] Each route also gives co-products

[3] Biomass upgrading includes any one of the densification processes (pelletisation, pyrolysis, torrefaction, etc.)

[4] AD = Anaerobic Digestion



[1] Hydrothermal upgrading; [2] Organic Rankine Cycle; [3] Integrated gasification fuel cell; [45] Integrated gasification combined cycle (CC) / gas turbine (GT)

biomass feedstocks (e.g. pelletisation, torrefaction, and pyrolysis) are being developed to convert bulky raw biomass into denser and more practical energy carriers for more efficient transport, storage and convenient use in subsequent conversion processes. The production of heat by the direct combustion of biomass is the leading bioenergy application throughout the world, Figure 3: Schematic view of the wide variety of bioenergy routes. Source: E4tech, 2009. Ethanol pilot plant based on corn fibre and other cellulosic material, New Energy Company of Indiana, USA. (Courtesy DOE/NREL and W. Gretz) and is often cost-competitive with fossil fuel alternatives. Technologies range from rudimentary stoves to sophisticated modern appliances. For a more energy efficient use of the biomass resource, modern, large-scale heat applications are often combined with electricity production in combined heat and power (CHP) systems. Different technologies exist or are being developed to produce electricity from biomass. Co-combustion (also called co-firing) in coal-based power plants is the most costeffective use of biomass for power generation. Dedicated

SRI Y N COLLEGE (A), NARSAPUR

PROJECT WORK

Academic Year 2017-2018

Submitted to

DEPARTMENT OF PHYSICS

TOPIC: ENVIRONMENT CHANGE

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INTRODUCTION

EFFECTS OF THE ENVIRONMENT:

ON THE PROJECT Effects of the Environment on the Project are associated with risks of natural hazards and influences of nature on the Project. Typically, potential effects of the environment on any project are a function of project or infrastructure design in the context of its receiving environment, and ultimately how the project is affected by nature. These effects may arise from physical conditions, land forms, and site characteristics or other attributes of the environment which may act on the project such that the project components, schedule, and/or costs could be substantively and adversely changed. In general, environmental conditions that can affect Construction of the Project, infrastructure, or operational performance will be communicated to the Design Team and addressed through engineering design and industry standards. Good engineering design involves the consideration of environmental effects and loadings or stresses (from the environment) on a project. The planning and engineering design for this Project are no exception. As a matter of generally accepted engineering practice, responsible and viable engineering designs tend to consistently overestimate and account for possible forces of the environment, and thus inherently incorporate several factors of safety to ensure that a project is designed to be safe and reliable throughout its lifetime. For the Project, long-term environmental management and Project longevity are inherent considerations in the best management practices of the design and associated Project risk management. Equipment and materials that are able to withstand severe weather and other influences will be used. Environmental stressors, such as those that could arise as a result of climate change, severe weather, or other factors (e.g., seismic events, fires), would more than adequately be addressed by good engineering design, materials selection, best practices, and engineering foresight. As will be demonstrated, while there is potential for natural forces to affect the Project, it is not likely to have a substantive effect on Construction or Operation due to planned mitigation and design. Mitigation strategies for minimizing the likelihood of a significant adverse effect of the environment on the Project are inherent in: the planning process being conducted, the application of engineering design codes and standards, construction practices, and monitoring. As such, and in consideration of the responsible design and best management practices that will be applied throughout the design, Construction, Operation, and Decommissioning, Reclamation and Closure phases of the Project, as will be demonstrated in the following sub-sections, the Effects of the Environment on the Project during all phases of the Project have been rated not significant

Environmental Attributes:

The environmental attributes that are considered to have a potential effect on the Project are based on the Final Guidelines (NBENV 2009), the Terms of Reference (Stantec 2012a), regulatory consultation, public and stakeholder input, a review of the known past and existing conditions, and knowledge gained through projections of potential future conditions (e.g., potential effects of climate change).

Based on the issues and concerns identified, the environmental attributes selected for consideration include: severe weather, including:• wind;• precipitation;• floods;• hail;• electrical storms; and• tornadoes;• climate change;• seismic activity; and• forest fires resulting from causes other than the Project.• Effects of the environment are largely addressed through design and compliance with codes and standards that provide sufficient margins of safety to prevent damage from environmental forces based on known information (e.g., design standards for protecting structures from earthquakes, severe wind, snow loads, and other severe weather), or through existing practices and mechanisms aimed at preventing the occurrence of or responding to these types of effects (e.g., prevention and response procedures for forest fires). Climate conditions and climate change are presently the focus of much concern globally, however. "With global attention now focused on climate change, government agencies, non-profit organizations, the private sector, and individual citizens are gearing up to face climate-related challenges" (NOAA 2010). As a result, a more thorough investigation of the effects of climate and climate change on the Project was undertaken as compared to that undertaken for the other environmental attributes listed above, to assess the potential effects of the environment on the Project from this emerging global environmental threat.

Selection of Effects: The environmental attributes listed in Section 8.16.1 have the potential to affect the Project in several ways. For example, effects on the Project may include: reduced visibility and inability to manoeuver construction and operation equipment;• delays in receipt of materials and/or supplies (e.g., construction materials, reagents) and/or in• delivering products; changes to the ability of workers to access the site (e.g., if a road were to wash out);•

Environmental Assessment Boundaries :

1. Spatial Boundaries:

The spatial boundaries for the assessment of the Effects of the Environment on the Project include all areas where Project-related activities are expected to occur. For the purpose of this EIA Report, the spatial boundaries for Effects of the Environment on the Project are limited to the Project Development Area (PDA) as defined in Chapter 3. Where consequential environmental effects are identified, they are considered within the boundaries of the specific zone of influence of those consequences. Accidental events that could arise as a result of effects of the environment (e.g., severe weather) are addressed in Section

2. Temporal Boundaries:

The temporal boundaries for the assessment of Effects of the Environment on the Project include the three phases of Construction, Operation, and Decommissioning, Reclamation and Closure (including Post-Closure activities such as ongoing monitoring and maintenance activities) of the Project as defined in Chapter

Administrative and Technical Boundaries :

Climate and Climate Change :

Climate is defined as the statistical average (mean and variability) of weather conditions over a substantial period of time (typically 30 years), accounting for the variability of weather during that period (Catto 2006). The relevant parameters used to characterize climate are most often surface variables such as temperature, precipitation, and wind, among others

Seismic Activity:

Seismic activity is dictated by the local geology of an area and the movement of tectonic plates comprising the Earth's crust. Natural Resources Canada monitors seismic activity throughout Canada and identifies areas of known seismic activity in order to document, record, and prepare for seismic events that may occur

Forest Fires

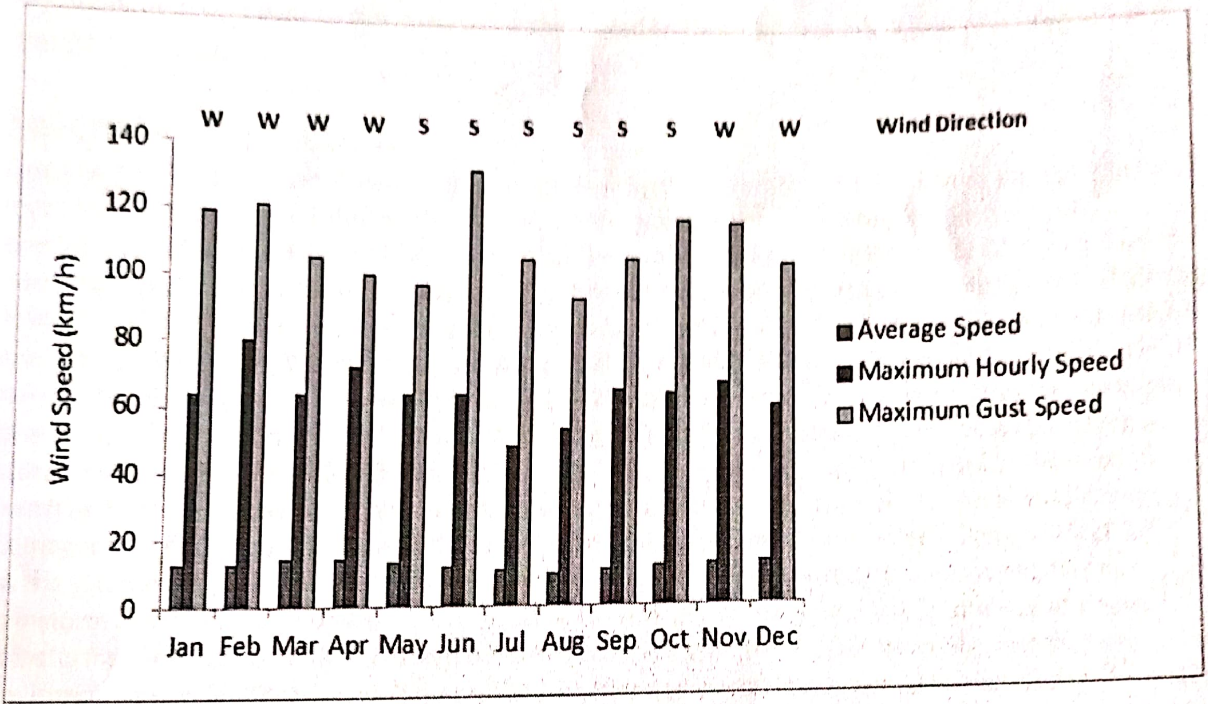
The management, monitoring and control of forest fires in New Brunswick are the responsibility of the New Brunswick Department of Natural Resources (NBDNR) under the Forest Fires Act. Day-to-day management of these issues is carried out by the Forest Fire Management Section of

NBDNR, with onthe-ground assistance by NBDNR's conservation offices throughout the province. Monitoring and response to major fire events is coordinated by the province's Emergency Measures Organization, with assistance as necessary from private contractors (e.g., Forest Protection Limited). There are no known technical boundaries for the establishment of existing conditions for forest fires. Prediction of forest fire activity is linked to the operation of a Fire Weather Index operated during dry seasons to establish burning restrictions in specific geographic areas when dry conditions prevail, though the index is more of a management tool to prevent forest fires than a predictive tool to predict if, when and where a fire may occur

Residual Effects Rating Criteria A significant adverse residual effect of the environment on the Project is one that would result in: a substantial change of the Project schedule (e.g., a delay resulting in the construction period• being extended by one season); a long-term interruption in service (e.g., an interruption in mining activities such that production• targets cannot be met); damage to Project infrastructure resulting in a significant environmental effect;• damage to the Project infrastructure resulting in a substantial increase in risks to the health• and/or safety of the public, or substantial risks of a business interruption; and/or damage to the Project infrastructure resulting in repairs that could not be technically or• economically implemented.

Existing Conditions:

Climatological Background (1971 to 2000) The current climate conditions are generally described by the most recent 30 year period for which Environment Canada has developed statistical summaries—generally referred to as "climate normals". The closest weather station to the Project with available historical data is the Juniper weather station, located approximately 25 km from the Project. No historical climate data for wind speed and wind direction are available for the Juniper station, therefore, wind data from the Fredericton Airport weather station, located approximately 70 km from the Project, are also briefly discussed to provide some indication of the magnitude of winds experienced in the region. The most recent 30-year period for which climate normals data are available from the Juniper and Fredericton Airport weather stations is for the period of 1971 to 2000; this period has been chosen as the applicable period for summarizing current climate conditions for the Project (Environment Canada 2012h; 2012k). It is also important to note that the climate normals data presented herein for precipitation at Juniper and Fredericton (Environment Canada 2012h; 2012k) are statistically similar with data collected and estimated for the Project at the Sisson site (Section 8.4.2; Knight Piésold 2012d). Wind Monthly average wind speeds measured at the Fredericton Airport range from 10.0 to 14.6 km/h, with an annual average wind speed of 12.4 km/h (Figure 8.16.1). From May to October, the dominant wind direction is from the south, with winds predominantly blowing from the west from November to April (Environment Canada 2012h). Maximum hourly wind speeds, averaged from 1971 to 2000 for each month, range from 48 km/h to 80 km/h; while maximum gusts for the same period range from 93 km/h to 132 km/h. Occurrences of extreme winds are uncommon at Fredericton—over the last three decades there has been an average of 2.2 days per year with winds greater than or equal to 52 km/h and 0.3 days per year with winds greater than or equal to 63 km/h (Environment Canada 2012h).



Predominant Monthly Wind Direction, Monthly Mean, Maximum Hourly and Maximum Gust Wind Speeds (1971 to 2000) at Fredericton, New Brunswick

Precipitation

Precipitation in Juniper has been, on average, well distributed throughout the year (Section . From 1971 to 2000, Juniper received an average of 1,190.7 mm of precipitation each year, of which 885.1 mm (73% of the total) was rain and 305.6 mm (27% of the total) was snowfall (as water equivalent). Extreme daily precipitation at Juniper ranged from 50.6 mm (June 1993) to 91.2 mm (April 1973). On average in Juniper, there have been 7.1 days a year with rainfall greater 25 mm, while snowfalls greater than 25 cm occur on average 1.4 days per year (Environment Canada 2012k). Precipitation at the Fredericton Airport has also been, on average, well distributed throughout the year (Section 8.2.2.1). From 1971 to 2000, Fredericton received an average of 1,143.3 mm of precipitation a year, of which 885.5 mm was rain and 276.5 mm was snowfall (as water equivalent). Extreme daily precipitation at the Fredericton Airport ranged from 45.4 mm (March 1998) to 148.6 mm (August 1989). On average, there have been 6.6 days each year with rainfall greater than 25 mm, and snowfalls greater than 25 cm occur on average 1.1 days each year (Environment Canada 2012h). In a recent Hydrometeorology study conducted in support of the Project (Knight Piésold 2012d), it was concluded, based on an analysis of the site and long-term regional data, that the PDA is estimated to be wetter and receive approximately 27% more precipitation than Juniper (1,136 mm between the years 1969-2012). Furthermore, based on the results from the watershed modelling conducted by Knight Piésold, the mean annual precipitation (MAP) was estimated to be approximately 1,350 mm/year (which is the MAP estimate adopted for the Project), with 1,013 mm falling as rain and 337 mm falling as snow. The estimated mean annual lake evaporation is 500 mm at the TSF. Snow can generally be expected from November to March, with accumulations remaining on the ground from December to February. The annual wet and dry year precipitation values, which provide a measure of

variability from one year to the next, were calculated to be 1,634 mm and 1,066 mm, respectively (Knight Piésold 2012d).

Severe Weather Events

Extreme precipitation and storms can occur in New Brunswick throughout the year but tend to be more common and severe during the winter. Winter storms generally bring high winds and a combination of snow and rain. Freezing rain has been observed on approximately 12 days a year in New Brunswick, ranging from an average of 34 hours to 59 hours a year at Fredericton and Moncton, respectively. One of the most noteworthy storms in recent history struck eastern New Brunswick on January 4, 1989, where Moncton experienced 110 km/h winds and 67 cm of snow over a 24 hour period. The Groundhog Day storm in February 1976 was an intense winter storm that caused a great deal of damage in southern New Brunswick (Environment Canada 2004). More recently, extreme storm events in December 2010 affected much of New Brunswick, where some areas received as much as 200 mm of rain; these events threatened public safety and transportation systems, and damages were estimated to be approximately $50 million (Government of New Brunswick 2012). In the summer and fall, southern New Brunswick is expected to experience at least one heavy rainstorm every one to two years (Environment Canada 2004). Although the frequency of heavy rainstorms is not available for western New Brunswick, based on climate normals compiled by Environment Canada (2012h; 2012k) and the fact that southern New Brunswick experiences heavier rainfall than western New Brunswick, the frequency of heavy rainstorms for the Project is expected tobe less than one every one to two years. In a study conducted in support of the Project (Knight Piésold 2012d), the mean extreme 24-hour rainfall was estimated, based on annual maximum daily precipitation from Juniper (1969-2004), to be 72.2 mm, with a standard deviation of 17.3 mm. In New Brunswick, river valleys and flood plains can pose a risk because of ice jams, harsh weather and the floods of annual spring thaw (Government of Canada 2012). Flooding in New Brunswick is rather common, especially along the St. John River (Environment Canada 2004). Therefore, flooding is listed as one of the regional hazards in New Brunswick through the federal governments "Get Prepared" campaign (Government of Canada 2012), and the New Brunswick Emergency Measures Organization monitors flooding as a natural risk and hazard through its "River Watch" program (http://www2.gnb.ca/content/gnb/en/news/public_alerts/river_watch.html). Electrical storms, or thunderstorms, which are more frequent in New Brunswick than the rest of Atlantic Canada, occur on average 10 to 20 times a year (Environment Canada 2004). Generally, only one of these storms (per year) is extreme enough to produce hail. Thunderstorms can produce extremes of rain, wind, hail and lightning; however, most of these storms are relatively short-lived (Environment Canada 2004).

Tornadoes are rare, but do occur in New Brunswick. According to Environment Canada (2012l), western New Brunswick is considered part of Canada's tornado zone. In fact, 423 confirmed and probable F2 Tornadoes[1] have occurred in western New Brunswick between 1729 and 2009 (Environment Canada (2012m)). Of Canada's ten worst tornadoes on record, one F3 tornado occurred in eastern New Brunswick at Bouctouche on August 6, 1879 (Natural Resources Canada 2009), which killed 5 people, injured 10, and left 25 families homeless—this is considered to be the easternmost major tornado in North America (Public Safety Canada 200

1 Tornadoes are classified on a scale known as the Fujita scale. F2 Tornadoes ("significant tornado") have winds ranging between 181–252 km/h, where: roofs are torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; and light object missiles generated. F3 Tornadoes ("severe tornado") have winds ranging between 253-330 km/h and result in roofs and walls torn off well-constructed houses, trains overturned, and most trees in forests uprooted

Seismic Activity

As discussed in Section 6.3.1.3.1, the Project lies within the Northern Appalachians seismic zone, one of five seismic zones in southeastern Canada, where the level of historical seismic activity is low. Historical seismic data recorded throughout eastern Canada has identified clusters of earthquake activity. Earthquakes in New Brunswick generally cluster in three regions: the Passamaquoddy Bay region, the Central Highlands (Miramichi) region, and the Moncton region (Burke 2011). The largest earthquake instrumentally recorded in New Brunswick was a magnitude 5.7 event (on the Richter scale) on January 9, 1982, located in the north-central Miramichi Highlands. This earthquake was followed by strong aftershocks of magnitude 5.1 and 5.4. Prior to 1982, other moderate earthquakes with estimated magnitude in the range of approximately 4.5 to 6.0 occurred in 1855, 1869, 1904, 1922, and 1937 (Basham and Adams 1984). The 1869 and 1904 earthquakes were both located within the Passamaquoddy Bay region, with estimated magnitudes of 5.7 and 5.9, respectively (Fader 2005). The maximum credible earthquake magnitude for the Northern Appalachians region is estimated to be magnitude 7.0, based on historical earthquake data and the regional tectonics (Adams and Halchuk 2003). There is potential for large earthquakes of up to about magnitude 7.5 along the 7

fault zones associated with the St. Lawrence River. However, these events would be located over 200 km from the Project site, and therefore the amplitude of ground motions experienced at the Project site would be low due to attenuation over a large distance. Review of historical earthquake records and regional tectonics indicates that the Project site is situated in a region of low seismicity. A probabilistic seismic hazard analysis has been carried out using historical earthquake data and the regional tectonics to identify potential seismic sources and to estimate the maximum earthquake magnitude for each seismic source. The corresponding median maximum acceleration is 0.07g for a return period of 500 years (Samuel Engineering 2013). ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REPORT

July 2013 8-683

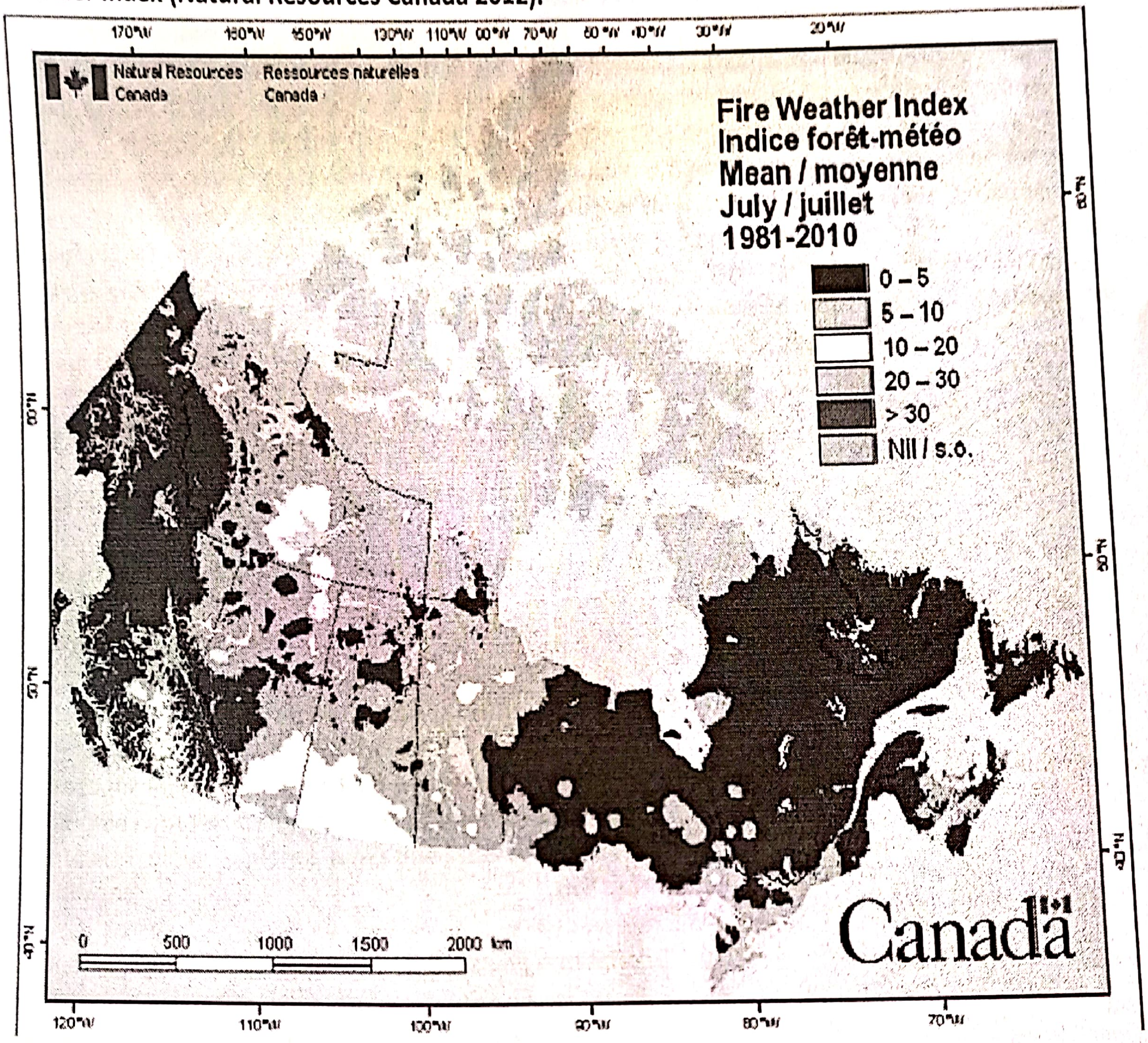
fault zones associated with the St. Lawrence River. However, these events would be located over 200 km from the Project site, and therefore the amplitude of ground motions experienced at the Project site would be low due to attenuation over a large distance. Review of historical earthquake records and regional tectonics indicates that the Project site is situated in a region of low seismicity. A probabilistic seismic hazard analysis has been carried out using historical earthquake data and the regional tectonics to identify potential seismic sources and to estimate the maximum earthquake magnitude for each seismic source. The corresponding median maximum acceleration is 0.07g for a return period of 500 years (Samuel Engineering 2013).

8.16.5.3 Forest Fires

The Fire Weather Index is a component of the Canadian Forest Fire Weather Index System. It is a numeric rating of fire intensity. It combines the Initial Spread Index and the Buildup Index, and is a general index of fire danger throughout the forested areas of Canada (Natural Resources Canada 2012).

The mean Fire Weather Index in Napadogan for July (*i.e.*, normally the driest month of the year), when risk of forest fire is typically the greatest, is rated from 5-10 (for years 1981-2010) (Figure 8.16.2); this is in the lower range of possible risk which, at the highest range, can exceed 30 on the Fire

Weather Index (Natural Resources Canada 2012).



Average Fire Weather Index for the Month of July (1981-2010)

Effects Assessment

As discussed in Chapter 3, the Project will be designed, constructed, and operated in compliance with various codes, standards, best practices, acts and regulations that govern the required structural integrity, safety, reliability, and environmental and operating performance of the various Project components to minimize the potential for significant adverse effects of the environment on the Project. Adherence to these codes, standards, acts and regulations will help ensure that the Project is carried out in a manner that minimizes the potential effects of the environment on the Project, including damage to infrastructure that could result from their occurrence.

As outlined in the introduction to this section, the Project will be designed in accordance with several best management and engineering design practices. As a factor of safety, and a matter of responsible engineering practice, the design and materials to be chosen for construction of the Project will be selected so that the Project will withstand environmental stressors that could occur from various natural and environmental phenomena (*e.g.*, extreme storms, increased precipitation and other factors arising from climate change, and others). The EIA has been carried out in parallel to Project design, and the results of the EIA have informed the design of the Project such that any potential concerns are addressed and the potential for significant adverse effects of the environment on the Project is minimized.

The Project will be constructed to meet all applicable building, safety and industry codes and standards. The engineering design of the Project will consider and incorporate potential future changes in the forces of nature that could affect its operation or integrity (*e.g.*, climate change), and Project components and infrastructure will be designed and built to adapt to or withstand these effects. The Project components will be designed to meet the National Building Code of Canada, the Canadian Dam Association Guidelines, and other design codes and standards for wind, snowfall, extreme precipitation, seismicity, and other weather variables. These standards and codes provide factors of safety regarding environmental loading (*e.g.*, snow load, high winds, seismic events), and Project specific activities and events. Design requirements address issues associated with environmental extremes including:

- wind loads;
- storm water drainage from rain storms and floods;
- weight of snow and ice, and associated water;
- earthquake loads; and
- erosion protection of slopes, embankments, ditches and open drains.

To account for potential weather extremes, engineering specifications of the National Building Code of Canada contains design specific provisions, such as:

- critical structures, piping, tanks and steel selection to prevent brittle fracture at low ambient conditions;
- electrical grounding structures for lightning protection;
- maximum motor ambient temperature; and
- ice and freeze protection.

Compliance with this and other Codes will minimize the likelihood of adverse effects of the environment on the Project, including those that may be significant and as a consequence of extreme events. Building codes are established in Canada to manage normal effects of the environment on structures (*e.g.*, weatherproofing) but also for extreme events that can possibly be anticipated. Other mitigation measures implemented as part of the planning process, including adherence to engineering design codes and standards, use of good engineering judgment and careful construction practices, care in selection of appropriate construction materials and equipment, careful planning of operation activities (*e.g.*, TSF embankment raises; receipt of materials and/or supplies, product deliveries), and the implementation of a proactive monitoring, maintenance and safety management program, will minimize the potential for adverse effects of the environment on the Project to such an extent that they are not significant.

Codes and standards are set in legislation as minimum requirements. They are continuously reviewed as new information becomes available. In addition to complying with codes and standards, the Basic Engineering Team for the Project will adopt a proactive approach to incorporate climate change considerations and adaptation measures into the Project. Several publications are available to guide design engineers in this regard, including, for example, the PIEVC (Public Infrastructure Engineering Vulnerability Committee) "Engineering Protocol for Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate" (PIEVC 2011). This protocol outlines a process to assess the infrastructure component responses to changing climate to assist engineers and proponents in effectively incorporating climate change into design, development and management of their existing and planned infrastructure. This and other guidance will be considered, as applicable, in advancing the design and construction of the Project.

8.16.6.1 Effects of Climate on the Project

To assess the environmental effects of climate on the Project, current climate and climate change must both be considered. Current climate conditions are established by compiling relevant historical data and establishing a climatological background for the Napadogan area. Climate change effects projected over the life of the Project are determined through reviewing the climate modelling research to establish the current state of understanding of trends likely in the Napadogan area over the next 50 to 100 years. Projections vary among these global and downscaled model results, mainly as a result of varying levels of precision in data used to run climate models and because of variations in the projections of future greenhouse gas (GHG) emission scenarios. A consensus has evolved regarding the climate change-related effects most likely to affect Atlantic Canada and New Brunswick (Vasseur and Catto 2008).

Numerous climate-related conditions, linked primarily to global warming, have been observed across Atlantic Canada, the entire country and globally. Many believe that these changes to the climate regime will accelerate over the next century, as has been the case with global temperatures over the past two decades (IPCC 2007a; 2007b). For example, increased temperatures, changing precipitation patterns and intensity, and increasing drought and associated lowering water levels are all conditions that are being studied and measured. Of these, several have been projected to affect infrastructure in

Climate Change Predictions for New Brunswick and Atlantic Canada

Predicting the future environmental effects of climate change for a specific area using global data sets is problematic due to generic data and larger scale model outputs which do not take into account local climate. Accurate regional and local projections require the development of specific regional and local climate variables and climate change scenarios (Lines *et al.* 2005). As a result, downscaling techniques have emerged over the last decade as an important advancement in climate modelling. Downscaling is used to introduce micro-scale interactions by including local climate variables. Downscaling techniques are particularly important for Atlantic Canada due to the inherent variability associated with this predominantly coastal climate. Statistical downscaling uses global climate model (GCM) projections as well as historical data from weather stations across the region, and studies the relationship between these sets of data. Downscaling produces more detailed predictions for each of these weather stations (Lines *et al.* 2005) and has allowed for a better understanding of future climate scenarios based on precise and accurate historic data sets.

Results tend to differ between a Statistical Downscaling Model (SDSM) and Canadian Global Climate Model (CGCM). The overall mean annual maximum temperature increase projected for Atlantic Canada between years 2020 and 2080 ranged from 1.6C° to 4.7C° for the SDSM model results, and 1.1C° to 3.6C° for the CGCM1 model results (Lines *et al.* 2005). This is consistent with predicted mean annual maximum temperature for the same time period at Fredericton (the nearest location to the Project), predicted to range from 1.8C° to 5.0C° for the SDSM model results and 1.1C° to 3.9C° for the CGCM1 model results (Lines *et al.* 2005) (Table 8.16.1). Table 8.16.1 Projected Mean Annual Maximum and Minimum Temperature Change, and Precipitation Percent Change for both SDSM and CGCMI Model Results

Period	T_{max}		T_{min}		% Precipitation	
	SDSM	CGCM1	SDSM	CGCM1	SDSM	CGCM1
2020s	1.8	1.1	1.8	1.8	20	2
2050s	3.1	2.1	2.8	2.9	21	-2
2080s	5.0	3.9	4.2	4.2	21	3

Notes:
1) A positive value denotes an increase, a negative value denotes a decrease.
SDSM = Statistical Downscaling Model.
CGCM = Canadian Global Climate Model.
T_{max} = Mean annual maximum temperature change.
T_{min} = Mean annual minimum temperature change.

The SDSM projections for maximum temperature for 2050 at Fredericton are for summer, fall and winter increases (2.7C° to 5.5C°), while for the spring, slight cooling is anticipated (-0.5C°) (Lines *et al.* 2005). By the year 2080, temperatures are projected to increase in all seasons, with greater warming in the summer, fall and winter (4.3C° to 7.0C°) than the spring (1.3C°) (Lines *et al.* 2005). This average temperature change is expected to be gradual over the period and is likely to affect precipitation typesand patterns. The warmer fall and winter temperatures could mean later freeze up; wetter, heavier snow; more liquid precipitation occurring later into the fall; and possibly more freezing precipitation during both seasons. With little change in spring temperatures, differences in fresh water ice formation and breakup patterns will likely be slight over the next century. Changes to precipitation patterns due to warmer weather over the fall and winter months, on the other hand, could lead to stronger spring run-off (Natural Resources Canada 2001).

There is less agreement among the global circulation and regional downscaling models regarding changes in precipitation. Annual precipitation increases projected for Atlantic Canada between the years 2020 and 2080 range from 18% to 21% for the SDSM model results, and -2% to 2% for the CGCM1 model results (Lines *et al.* 2005). Precipitation trends are of more interest when taken together with the temperature increases and the seasonality of the predicted changes. Statistical Downscaling Model trends for the years 2020 to 2080 indicate a temperature increase of 8% to 12% for the winter months and 21% to 35% for the summer months (Lines *et al.* 2005). It is generally considered that the increased precipitation being projected for portions of western Atlantic Canada may be the result of continued landfall of dying hurricanes and tropical storms reaching into this area in the summer and fall months (Lines, G., Personal communication, March 5, 2006). While SDSM results highlight an increase in summer and fall precipitation, the CGCM1 results range from no change in the 2020s to a reduction in precipitation over the summer season for the years 2050 to 2080 (Lines *et al.* 2005). This is consistent with trends projected by Environment Canada (2008), where global model results highlight a reduction in summer precipitation for the 2080s.

The inconsistencies between SDSM and CGCM1 predicted seasonal precipitation changes highlight the inherent variability and uncertainty in climate modelling, which is considered as a technical boundary in this assessment. Due to the increased precision of localized data used in SDSM relative to global modelling, confidence is considered to be greater in the SDSM results relative to global model results. Nonetheless, SDSM methods still embody the uncertainties inherent in all climate models, and as such, their results must be interpreted with some caution.

Regardless of the differences in the temperature and precipitation changes between global climate and SDSM projections, there is a general consensus in the climatological community concerning the

overall anticipated environmental effects of climate change. For example, over the next 100 years, Atlantic Canada will likely experience warmer temperatures, more storm events, increasing storm intensity, and flooding (Vasseur and Catto 2008). In a recent study (Knight Piésold 2012d), the 24-hour extreme precipitation values for return periods of 10, 50, and 200 years at the PDA have been estimated to be 95 mm, 117 mm, and 136 mm, respectively. The 24-hour Probable Maximum Precipitation (PMP) value, considered in the design of the Project, was estimated to be 352 mm. . As described above, severe weather is predicted to be more frequent and more intense over the next 100 years. Many reports indicate the likelihood of growing insurance claims and other measures of these changes. For instance, in Canada, the insured catastrophe losses totalled approximately $1.6 billion in 2011 and nearly $1 billion in each of the previous two years (IBC 2012). These losses have been attributed to extreme weather events, an increase in claims resulting from smaller weather events that result in significant property damage, and aging sewer infrastructure which is often incapable of handling higher levels of precipitation. As a result, water claims have now surpassed fire as the number one cause of home insurance losses in many parts of the country (IBC 2012). While advances in modelling science over the last decade have improved confidence in long-term, projections, like all modelling projections, the results and guidance they provide are not meant as absolutes, but rather are intended to allow for preparations, for design considerations, and to facilitate adaptation. SISSON PROJECT: ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REPORT
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TOPIC: SOLAR ENERGY

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Solar energy

Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis.[1][2]

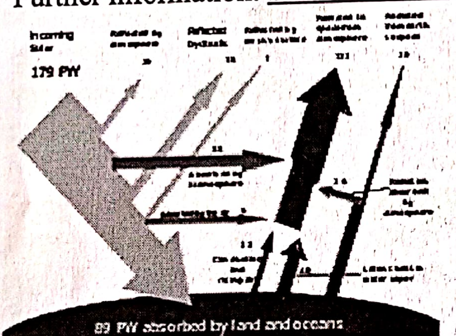
It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

The large magnitude of solar energy available makes it a highly appealing source of electricity. The United Nations Development Programme in its 2000 World Energy Assessment found that the annual potential of solar energy was 1,575–49,837 exajoules (EJ). This is several times larger than the total world energy consumption, which was 559.8 EJ in 2012.[3][4]

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared".[1]

Potential

Further information: Solar radiation



About half the incoming solar energy reaches the Earth's surface.

Average insolation. The theoretical area of the small black dots is sufficient to supply the world's total energy needs of 18 TW with solar power.

The Earth receives 174 petawatts (PW) of incoming solar radiation (insolation) at the upper atmosphere.[5] Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet.[6] Most of the world's population live in areas with insolation levels of 150–300 watts/m², or 3.5–7.0 kWh/m² per day.[citation needed]

Solar radiation is absorbed by the Earth's land surface, oceans – which cover about 71% of the globe – and atmosphere. Warm air containing evaporated water from the oceans rises, causing atmospheric circulation or convection. When the air reaches a high altitude, where the temperature is low, water vapor condenses into clouds, which rain onto the Earth's surface, completing the water cycle. The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as wind, cyclones and anti-cyclones.[7] Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C.[8] By photosynthesis, green plants convert solar energy into chemically stored energy, which produces food, wood and the biomass from which fossil fuels are derived.[9]

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year.[10] In 2002, this was more energy in one hour than the world used in one year.[11][12] Photosynthesis captures approximately 3,000 EJ per year in biomass.[13] The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined,[14]

Yearly solar fluxes & human consumption[1]	
Solar	3,850,000 [10]
Wind	2,250 [15]
Biomass potential	~200 [16]
Primary energy use[2]	539 [17]
Electricity[2]	~67 [18]

[1] Energy given in Exajoule (EJ) = 10^{18} J = 278 TWh
[2] Consumption as of year 2010

The potential solar energy that could be used by humans differs from the amount of solar energy present near the surface of the planet because factors such as geography, time variation, cloud cover, and the land available to humans limit the amount of solar energy that we can acquire.

Geography affects solar energy potential because areas that are closer to the equator have a greater amount of solar radiation. However, the use of photovoltaics that can follow the position of the sun can significantly increase the solar energy potential in areas that are farther from the equator.[4] Time variation effects the potential of solar energy because during the nighttime there is little solar radiation on the surface of the Earth for solar panels to absorb. This limits the amount of energy that solar panels can absorb in one day. Cloud cover can affect the potential of solar panels because clouds block incoming light from the sun and reduce the light available for solar cells.

In addition, land availability has a large effect on the available solar energy because solar panels can only be set up on land that is otherwise unused and suitable for solar panels. Roofs have been found to be a suitable place for solar cells, as many people have discovered that they can collect energy directly from their homes this way. Other areas that are suitable for solar cells are lands that are not being used for businesses where solar plants can be established.[4]

Solar technologies are characterized as either passive or active depending on the way they capture, convert and distribute sunlight and enable solar energy to be harnessed at different levels around the world, mostly depending on distance from the equator. Although solar energy refers primarily to the use of solar radiation for practical ends, all renewable energies, other than Geothermal power and Tidal power, derive their energy either directly or indirectly from the Sun.

Active solar techniques use photovoltaics, concentrated solar power, solar thermal collectors, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand side technologies.[19]

In 2000, the United Nations Development Programme, UN Department of Economic and Social Affairs, and World Energy Council published an estimate of the potential solar energy that could be used by humans each year that took into account factors such as insolation, cloud cover, and the land that is usable by humans. The estimate found that solar energy has a global potential of 1,575–49,837 EJ per year *(see table below)*.[4]

Annual solar energy potential by region (Exajoules) [4]

Region	North America	Latin America and Caribbean	Western Europe	Central and Eastern Europe	Former Soviet Union	Middle East and North Africa	Sub-Saharan Africa	Pacific Asia	South Asia	Centrally planned Asia	Pacific OECD
Minimum	181.1	112.6	25.1	4.5	199.3	412.4	371.9	41.0	38.8	115.5	72.6
Maximum	7,410	3,385	914	154	8,655	11,060	9,528	994	1,339	4,135	2,263

Note:

- Total global annual solar energy potential amounts to 1,575 EJ (minimum) to 49,837 EJ (maximum)
- Data reflects assumptions of annual clear sky irradiance, annual average sky clearance, and available land area. All figures given in Exajoules.

Quantitative relation of global solar potential vs. the world's primary energy consumption:

- Ratio of potential vs. current consumption (402 EJ) as of year: 3.9 (minimum) to 124 (maximum)
- Ratio of potential vs. projected consumption by 2050 (590–1,050 EJ): 1.5–2.7 (minimum) to 47–84 (maximum)
- Ratio of potential vs. projected consumption by 2100 (880–1,900 EJ): 0.8–1.8 (minimum) to 26–57 (maximum)

Source: United Nations Development Programme – World Energy Assessment (2000)[4]

Thermal energy

Main article: Solar thermal energy

Solar thermal technologies can be used for water heating, space heating, space cooling and process heat generation.[20]

Early commercial adaptation

In 1878, at the Universal Exposition in Paris, Augustin Mouchot successfully demonstrated a solar steam engine, but couldn't continue development because of cheap coal and other factors.

1917 Patent drawing of Shuman's solar collector

In 1897, Frank Shuman, a U.S. inventor, engineer and solar energy pioneer, built a small demonstration solar engine that worked by reflecting solar energy onto square boxes filled with ether, which has a lower boiling point than water, and were fitted internally with black pipes which in turn powered a steam engine. In 1908 Shuman formed the Sun Power Company with the intent of building larger solar power plants. He, along with his technical advisor A.S.E. Ackermann and British physicist Sir Charles Vernon Boys,[citation needed] developed an improved system using mirrors to reflect solar energy upon collector boxes, increasing heating capacity to the extent that water could now be used instead of ether. Shuman then constructed a full-scale steam engine powered by low-pressure water, enabling him to patent the entire solar engine system by 1912.

Shuman built the world's first solar thermal power station in Maadi, Egypt, between 1912 and 1913. His plant used parabolic troughs to power a 45–52 kilowatts (60–70 hp) engine that pumped more than 22,000 litres (4,800 imp gal; 5,800 US gal) of water per minute from the Nile River to adjacent cotton fields. Although the outbreak of World War I and the discovery of cheap oil in the 1930s discouraged the advancement of solar energy, Shuman's vision and basic design were resurrected in the 1970s with a new wave of interest in solar thermal energy.[21] In 1916 Shuman was quoted in the media advocating solar energy's utilization, saying:

> We have proved the commercial profit of sun power in the tropics and have more particularly proved that after our stores of oil and coal are exhausted the human race can receive unlimited power from the rays of the sun.
>
> —*Frank Shuman, New York Times, 2 July 1916*[22]

Water heating

Main articles: Solar hot water and Solar combisystem

Solar water heaters facing the Sun to maximize gain

Solar hot water systems use sunlight to heat water. In low geographical latitudes (below 40 degrees) from 60 to 70% of the domestic hot water use with temperatures up to 60 °C can be provided by solar heating systems.[23] The most common types of solar water heaters are evacuated tube collectors (44%) and glazed flat plate collectors (34%) generally used for domestic hot water; and unglazed plastic collectors (21%) used mainly to heat swimming pools.[24]

As of 2007, the total installed capacity of solar hot water systems was approximately 154 thermal gigawatt (GW_{th}).[25] China is the world leader in their deployment with 70 GW_{th} installed as of 2006 and a long-term goal of 210 GW_{th} by 2020.[26] Israel and Cyprus are the per capita leaders in the use of solar hot water systems with over 90% of homes using them.[27] In the United States, Canada, and Australia, heating swimming pools is the dominant application of solar hot water with an installed capacity of 18 GW_{th} as of 2005.[19]

Heating, cooling and ventilation

Main articles: Solar heating, Thermal mass, Solar chimney, and Solar air conditioning

In the United States, heating, ventilation and air conditioning (HVAC) systems account for 30% (4.65 EJ/yr) of the energy used in commercial buildings and nearly 50% (10.1 EJ/yr) of the energy used in residential buildings.[28][29] Solar heating, cooling and ventilation technologies can be used to offset a portion of this energy.

MIT's Solar House #1, built in 1939 in the U.S., used seasonal thermal energy storage for year-round heating.

Thermal mass is any material that can be used to store heat—heat from the Sun in the case of solar energy. Common thermal mass materials include stone, cement and water. Historically they have been used in arid climates or warm temperate regions to keep buildings cool by absorbing solar energy during the day and radiating stored heat to the cooler atmosphere at night. However, they can be used in cold temperate areas to maintain warmth as well. The size and placement of thermal mass depend on several factors such as climate, daylighting and shading conditions. When properly incorporated, thermal mass maintains space temperatures in a comfortable range and reduces the need for auxiliary heating and cooling equipment.[30]

A solar chimney (or thermal chimney, in this context) is a passive solar ventilation system composed of a vertical shaft connecting the interior and exterior of a building. As the chimney warms, the air inside is heated causing an updraft that pulls air through the building. Performance can be improved by using glazing and thermal mass materials[31] in a way that mimics greenhouses.

Deciduous trees and plants have been promoted as a means of controlling solar heating and cooling. When planted on the southern side of a building in the northern hemisphere or the northern side in the southern hemisphere, their leaves provide shade during the summer, while the bare limbs allow light to pass during the winter.[32] Since bare, leafless trees shade 1/3 to 1/2 of incident solar radiation, there is a balance between the benefits of summer shading and the corresponding loss of winter heating.[33] In climates with significant heating loads, deciduous trees should not be planted on the Equator-facing side of a building because they will interfere with winter solar availability. They can, however, be used on the east and west sides to provide a degree of summer shading without appreciably affecting winter solar gain.[34]

Cooking

Main article: Solar cooker

Parabolic dish produces steam for cooking, in Auroville, India

Solar cookers use sunlight for cooking, drying and pasteurization. They can be grouped into three broad categories: box cookers, panel cookers and reflector cookers.[35] The simplest solar cooker is the box cooker first built by Horace de Saussure in 1767.[36] A basic box cooker consists of an insulated container with a transparent lid. It can be used effectively with partially overcast skies and will typically reach temperatures of 90–150 °C (194–302 °F).[37] Panel cookers use a reflective panel to direct sunlight onto an insulated container and reach temperatures comparable to box cookers. Reflector cookers use various concentrating geometries (dish, trough, Fresnel mirrors) to focus light on a cooking container. These cookers reach temperatures of 315 °C (599 °F) and above but require direct light to function properly and must be repositioned to track the Sun.[38]

Process heat

Main articles: Solar pond, Salt evaporation pond, and Solar furnace

Solar concentrating technologies such as parabolic dish, trough and Scheffler reflectors can provide process heat for commercial and industrial applications. The first commercial system was the Solar Total Energy Project (STEP) in Shenandoah, Georgia, USA where a field of 114 parabolic dishes provided 50% of the process heating, air conditioning and electrical requirements for a clothing factory. This grid-connected cogeneration system provided 400 kW of electricity plus thermal energy in the form of 401 kW steam and 468 kW chilled water, and had a one-hour peak load thermal storage.[39] Evaporation ponds are shallow pools that concentrate dissolved solids through evaporation. The use of evaporation ponds to obtain salt from seawater is one of the oldest applications of solar energy. Modern uses include concentrating brine solutions used in leach mining and removing dissolved solids from waste streams.[40] Clothes lines, clotheshorses, and clothes racks dry clothes through evaporation by wind and sunlight without consuming electricity or gas. In some states of the United States legislation protects the "right to dry" clothes.[41] Unglazed transpired collectors (UTC) are perforated sun-facing walls used for preheating ventilation air. UTCs can raise the incoming air temperature up to 22 °C (40 °F) and deliver outlet temperatures of 45–60 °C (113–140 °F).[42] The short payback period of transpired collectors (3 to 12 years) makes them a more cost-effective alternative than glazed collection systems.[42] As of 2003, over 80 systems with a combined collector area of 35,000 square metres (380,000 sq ft) had been installed worldwide, including an 860 m^2 (9,300 sq ft) collector in Costa Rica used for drying coffee beans and a 1,300 m^2 (14,000 sq ft) collector in Coimbatore, India, used for drying marigolds.[43]

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TOPIC: FORMATION OF TSUNAMIS

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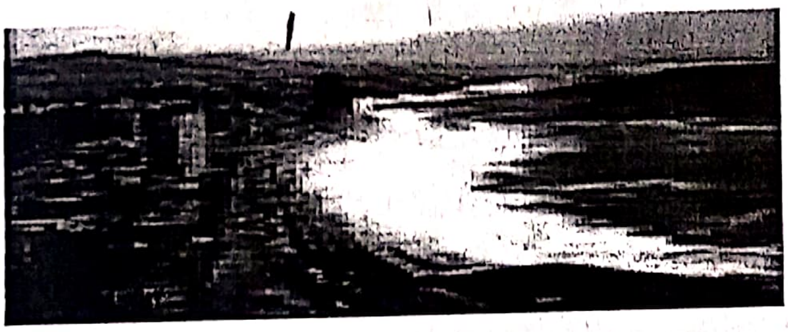
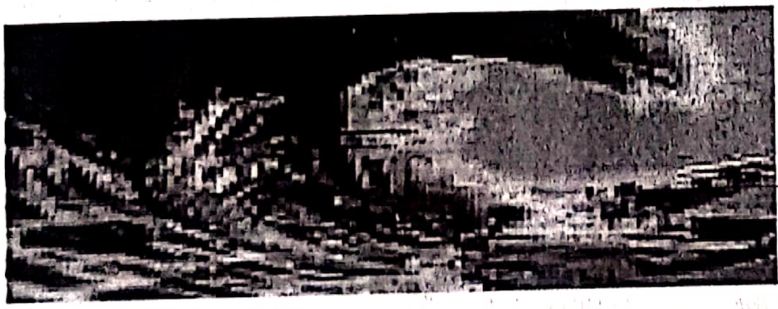
The Physics of Tsunamis

What is a tsunami?

A tsunami (pronounced tsoo-nah-mee) is a wave train, or series of waves, generated in a body of water by an impulsive disturbance that vertically displaces the water column. Earthquakes, landslides, volcanic eruptions, explosions, and even the impact of cosmic bodies, such as meteorites, can generate tsunamis. Tsunamis can savagely attack coastlines, causing devastating property damage and loss of life.





Would you like to learn more about tsunamis?

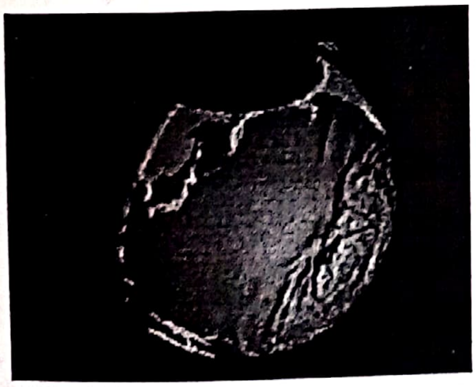
What does "tsunami" mean?

Tsunami is a Japanese word with the English translation, "harbor wave." Represented by two characters, the top character, "tsu," means harbor, while the bottom character, "nami," means "wave." In the past, tsunamis were sometimes referred to as "tidal waves" by the general public, and as "seismic sea waves" by the scientific community. The term "tidal wave" is a misnomer; although a tsunami's impact upon a coastline is dependent upon the tidal level at the time a tsunami strikes, tsunamis are unrelated to the tides. Tides result from the imbalanced, extraterrestrial, gravitational influences of the moon, sun, and planets. The term "seismic sea wave" is also misleading. "Seismic" implies an earthquake-related generation mechanism, but a tsunami can also be caused by a nonseismic event, such as a landslide or meteorite impact.

How do tsunamis differ from other water waves?

Tsunamis are unlike wind-generated waves, which many of us may have observed on a local lake or at a coastal beach, in that they are characterized as shallow-water waves, with long periods and wave lengths. The wind-generated swell one sees at a California beach, for example, spawned by a storm out in the Pacific and rhythmically rolling in, one wave after another, might have a period of about 10 seconds and a wave length of 150 m. A tsunami, on the other hand, can have a wavelength in excess of 100 km and period on the order of one hour.

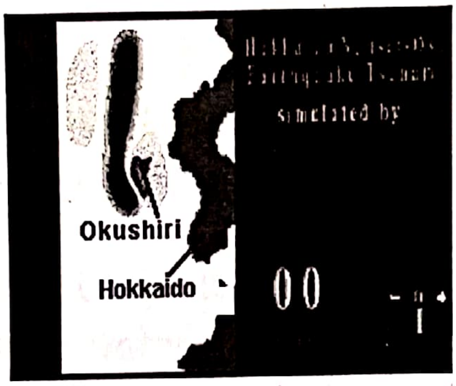
As a result of their long wave lengths, tsunamis behave as shallow-water waves. A wave becomes a shallow-water wave when the ratio between the water depth and its wave length gets very small. Shallow-water waves move at a speed that is equal to the square root of the product of the acceleration of gravity (9.8 m/s/s) and the water depth - let's see what this implies: In the Pacific Ocean, where the typical water depth is about 4000 m, a tsunami travels at about 200 m/s, or over 700 km/hr. Because the rate at which a wave loses its energy is inversely related to its wave length, tsunamis not only propagate at high speeds, they can also travel great, transoceanic distances with limited energy losses.



Note the vastness of the area across which the tsunami travels - Japan, which is over 17,000 km away from the tsunami's source off the coast of Chile, lost 200 lives to this tsunami. Also note how the wave crests bend as the tsunami travels - this is called refraction. Wave refraction is caused by segments of the wave moving at different speeds as the water depth along the crest varies. Please note that the vertical scale has been exagaerated in this animation - tsunamis are only about a meter high at the most in the open ocean.

How do earthquakes generate tsunamis?

Tsunamis can be generated when the sea floor abruptly deforms and vertically displaces the overlying water. Tectonic earthquakes are a particular kind of earthquake that are associated with the earth's crustal deformation;



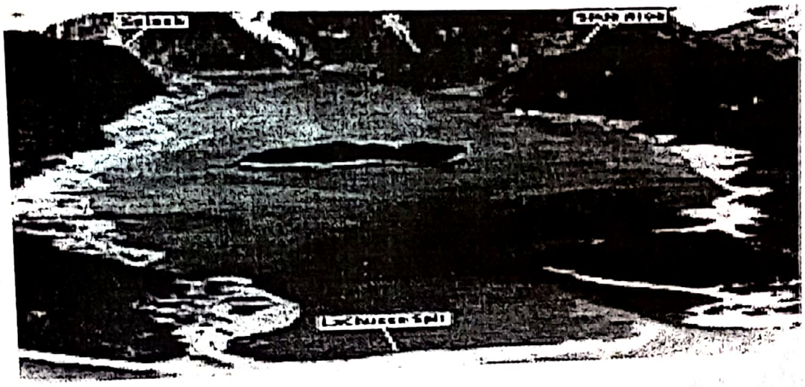
when these earthquakes occur beneath the sea, the water above the deformed area is displaced from its equilibrium position. Waves are formed as the displaced water mass, which acts under the influence of gravity, attempts to regain its equilibrium. When large areas of the sea floor elevate or subside, a tsunami can be created.

Large vertical movements of the earth's crust can occur at plate boundaries. Plates interact along these boundaries called faults. Around the margins of the Pacific Ocean, for example, denser oceanic plates slip under continental plates in a process known as subduction. Subduction earthquakes are particularly effective in generating tsunamis.

Areas in blue represent a water surface that is lower than the mean water level, while areas in red represent an elevated water surface. The initial water-surface profile, as shown in this image, reflects a large, long uplifted area of the sea floor lying to the west (left) of Okushiri Island, with a much smaller subsided area immediately adjacent to the southwest corner of Okushiri

How do landslides, volcanic eruptions, and cosmic collisions generate tsunamis?

A tsunami can be generated by any disturbance that displaces a large water mass from its equilibrium position. In the case of earthquake-generated tsunamis, the water column is disturbed by the uplift or subsidence of the sea floor. Submarine landslides, which often accompany large earthquakes, as well as collapses of volcanic edifices, can also disturb the overlying water column as sediment and rock slump downslope and are redistributed across the sea floor. Similarly, a violent submarine volcanic eruption can create an impulsive force that uplifts the water column and generates a tsunami. Conversely, supermarine landslides and cosmic-body impacts disturb the water from above, as momentum from falling debris is transferred to the water into which the debris falls. Generally speaking, tsunamis generated from these mechanisms, unlike the Pacific-wide tsunamis caused by some earthquakes, dissipate quickly and rarely affect coastlines distant from the source area.



This image shows Lituya Bay, Alaska, after a huge,
landslide-generated tsunami occurred on July 9, 1958.
The earthquake-induced rockslide, shown in upper right-
hand corner of this image, generated a 525 m splash-up
immediately across the bay, and razed trees along the
bay and across LaChausse Spit before leaving the bay and
dissipating in the open waters of the Gulf of Alaska.

What happens to a tsunami as it approaches land?

As a tsunami leaves the deep water of the open ocean and
travels into the shallower water near the coast, it
transforms. If you read the "How do tsunamis differ
from other water waves?" section, you discovered that a
tsunami travels at a speed that is related to the water
depth - hence, as the water depth decreases, the tsunami
slows. The tsunami's energy flux, which is dependent on
both its wave speed and wave height, remains nearly

constant. Consequently, as the tsunami's speed diminishes as it travels into shallower water, its height grows. Because of this shoaling effect, a tsunami, imperceptible at sea, may grow to be several meters or more in height near the coast. When it finally reaches the coast, a tsunami may appear as a rapidly rising or falling tide, a series of breaking waves, or even a bore.

What happens when a tsunami encounters land?

Just like other water waves, tsunamis begin to lose energy as they rush onshore - part of the wave energy is reflected offshore, while the shoreward-propagating wave energy is dissipated through bottom friction and turbulence. Despite these losses, tsunamis still reach the coast with tremendous amounts of energy. Tsunamis have great erosional potential, stripping beaches of sand that may have taken years to accumulate and undermining trees and other coastal vegetation. Capable of inundating, or flooding, hundreds of meters inland past the typical high-water level, the fast-moving water associated with the inundating tsunami can crush homes and other coastal structures. Tsunamis may reach a maximum vertical height onshore above sea level, often called a runup height, of 10, 20, and even 30 meters.

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Submitted to

DEPARTMENT OF PHYSICS

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SRI YN COLLEGE

(AUTONOMOUS)

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FIBRE OPTICS IN TELECOMMUNICATIONS

A history of BSNL

Under the guidance of Physics dept.,Sri. Y.N.College

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FIBRE OPTICS IN TELECOMMUNICATION

INTRODUCTION

Telecommunication occurs when the exchange of information takes place between two entities that use technology. Communication technology uses channels to transmit info either through physical medium or in the form of electromagnetic waves.

A revolution in wireless began in the first decade of 20th century with the pioneering developments in radio communications by Gulielmo Macroni who won Nobel prizes in physics in 1909. Other inventors and prominent people are Charles Wheatstone, Samuel Morse , Alexander Graham Bell, Edwin Armstrong and Lee Dee Forest as well as John l Baird, Philo Fransworth.

In a telephone network, the caller is connected to the person he wants to talk to by switches at various telephone exchanges .The switches form an electrically connected path between the two users and the setting of these switches are determined electronically when the caller dials the number. Once the connection is made, the caller's voice is transformed to an electrical signal using a small microphone in the caller's handset. This electrical signal is then sent through the network to the user at the other end, where it is transformed back into sound by a small speaker in that person's headset .The landline telephone in most residential homes are analog, i.e., the speaker's voice directly determines the signal voltage.

TELEPHONE EXCHANGE

A telephone exchange is a telephone system located at service centers (central offices) responsible for a small geographic area that provides the switching or interconnection of two or more individual subscriber lines for calls made between them, rather than requiring direct lines between subscriber stations. This made it possible for subscribers to call each other at homes, business places, or public spaces. Telephony thus became an available and comfortable communication tool for everyday use, and it gave the impetus for the creation of a whole new industrial sector.

One of the pioneers to build a telephone exchange was a Hungarian, Tivadar Puskás in 1877. While he was working for Thomas Edison[3][4][5][6]. The first experimental telephone exchange was based on the ideas of Puskás, and it was built by the Bell Telephone Company in Boston in 1877[7]. The world's first commercial telephone exchange opened on November 12, 1877 in Friedrichsberg, close to Berlin[8]. George W. Coy designed and built the first commercial US telephone exchange which opened in New Haven, Connecticut in January, 1878. The switchboard was built from "carriage bolts, handles from teapot lids and bustle wire" and could handle two simultaneous conversations[9]. Charles Glidden is also credited with establishing an exchange in Lowell, MA, with 50 subscribers in 1878.

There are mainly 3 stages in the history of Public Switched telecommunication network, known as PSTN

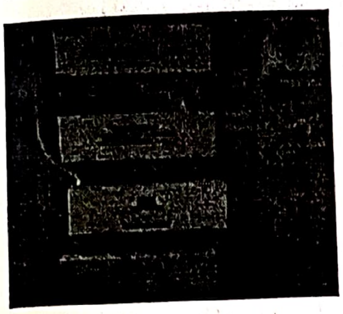
They are:

1) Manual
2) Cross bar strowger
3) Electronic

In the manual phase of communication, there is an exchange where we have human intervention. When a person 'A' makes a call, the exchange used to be able to know it, by a signal coming to the exchange. Then they connected the call to the receiver whose number was dialed by connecting the pins. This was a very difficult process as there had to be a man working even during the night time. If there were 5 members working in the exchange for instance and there were 10 calls at a time, then it was really difficult for the users in exchange to work. Besides, only 5 customers could have their call and the other 5 members could not access the service.

SDCA and LDCA

Fixed Telephone Network is geographically divided with SDCA(Short Distance Charging Area) s and LDCA(Long Distance Charging Area)s. There is a fixed code for every SDCA which we called as STD code. Any exchange in that SDCA has the same code. Geographically adjacent SDCAs are grouped into one LDCA which is normally spreaded to one district and the Long Distance Charging Center is situated at the district head quarters. This concept used for deciding the Network building and deciding tariff structure



division of optical fibre into individual channels..

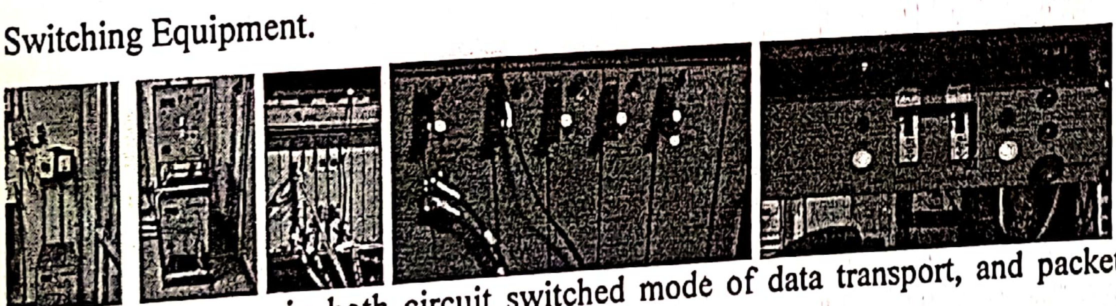
For Making a call from one subscriber of an exchange in a particular SDCA say with a STD Code (08814) need to prefix STD code before dialing to call same number in that SDCA, But the code is to be prefixed for making a call out of their home SDCA, say for making a call to Eluru, 08812 is to added before the telephone number. If you want to make a call to one from a nearby village of Mumbai, then call would be got connected through LDCC at Eluru. From there it will get connected to Mumbai LDCC and then its SDCA. From there we get connected to the concerned Exchange then finally to destination. Thus network finds a definite path for establish a communication.

We Know, though audible range of humans are 20 to 20000Hz, in which 300 to 3400Hz only human voice can generate hence this is only considered for passing through Telephone system. Here in telecommunications we use a concept of **sampling theory which states that any audio signal that is picked 8000 times per second is equivalent to the original audio signal.** This is most vividly used and is a very significant theorem in telecommunications. In the PSTN, on receiving telephone call that is generated from a telephone instrument, the microprocessor in the Telephone Exchange takes one fragment of signal quantized in 8 bits of data in the pulse coded modulation form at the interval of every 1/8000 sec. Hence a traditional Telephone line has the ability to transmit the bits at the rate of 8000x8bits=64000 bits/sec. Meanwhile, Microprocessor is used to pick another signal so that other subscriber can also use the service. So the microprocessor is capable to process 8000 call requests.

TELEPHONE EXCHANGE STRUCTURE

In the telephone exchange, there are 3 main units say

1) Line side Equipment
2) Control Equipment
3) Switching Equipment.



The line side is common in both circuit switched mode of data transport, and packet switched mode of transport of the signal. The Packet Switched mode of data transport is upcoming trend in voice communication. The line side is connected to the telephone. It takes care of extending voltage of 48V to Telephone line, loop detection for off-hook or on-hook condition of Telephone, Analog signal to Digital signal conversion and arranging AC current for ringing a telephone when call is in.