Chapter – 1

INTRODUCTION

Energy is one of the major inputs for the development of the country. In case of developing countries, the energy sector assumes a critical importance in view of ever increasing energy needs requiring huge investments to meet them. Energy can be easily classified as **Renewable** and **Non-Renewable** energy. Renewable energy is obtained from sources that are essentially inexhaustible. e.g. solar power, wind power, geothermal energy, tidal power, hydroelectric power. The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants. Non-Renewable energy is the conventional fuels such as coal, oil and gas which are likely to deplete with time.

Today world is moving towards the sustainable energy sources which are renewable and biodegradable in nature. There are several resources and means to convert these resources into useful form of energy. One of the most sustainable energy source is sunlight that too is inexhaustible and available free of cost. But majority of the world energy demand is dependent upon the fossil fuels either they are power sector, agricultural sector or transportation sector.

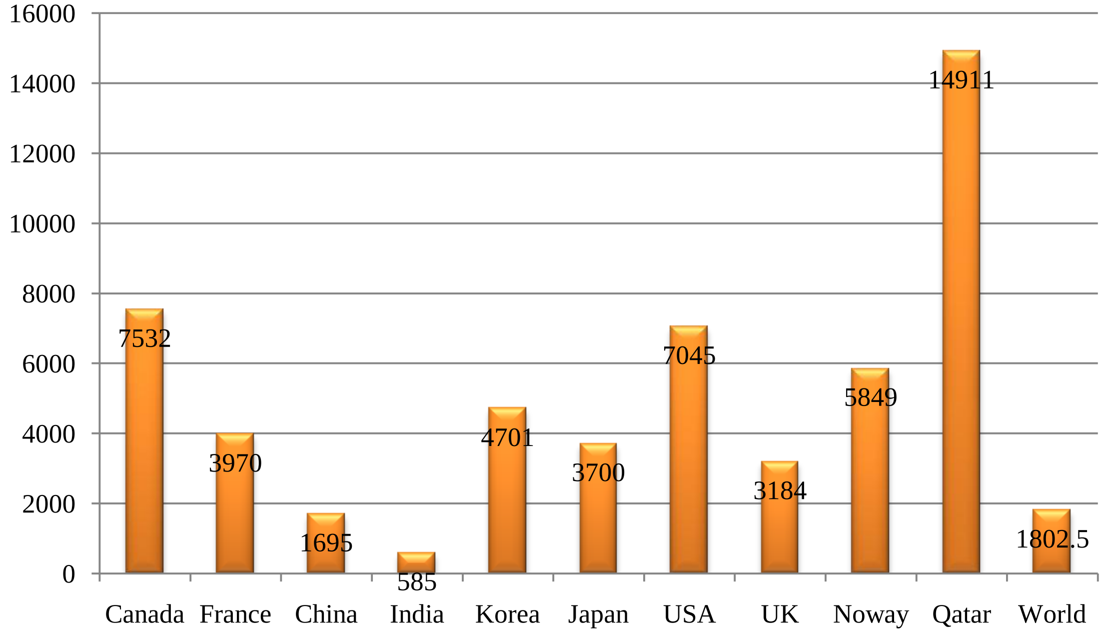
1.1 WORLD ENERGY SCENARIO

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

[Reference-12] Fossil energy usage increased mostly in 2000-2008. In October 2012 the IEA noted that coal accounted for half the increased energy use

of the prior decade, growing faster than all renewable energy sources. Energy consumption is loosely correlated with gross national product and climate, but there is a large difference even between the most highly developed countries, such as Japan and Germany with an energy consumption rate of 6 kW per person and the United States with an energy consumption rate of 11.4 kW per person. In developing countries, particularly those that are sub-tropical or tropical such as India, the per person energy use rate is closer to 0.7 kW. Bangladesh has the lowest consumption rate with 0.2 kW per person. Per captia energy consumption of different countries are shown below for the year of 2012.

Chart 1.1 : Country-wise Per Captia Energy Consumption of year 2009 in kgoe [*Reference-12*]



1.1.1 COAL

Global coal reserve is estimated 860938 million tones by end of 2011. This will be available for 112 years at current consumption rate. USA is largest share of the global reserve with 27.6% and will remain for 239 years in USA.

Russia is 2nd largest with 18.2% which will be consumed up to 471 years and China having 13.3% is at 3rd place and will consume up to 33 years. Australia is at 4th place with 8.9% of total global reserve and it will use up to 184 years. Our Country India is at 5th place with 7% global reserve which will remain available for 103 years at current consumption rate. Coal map of the world is shown below.

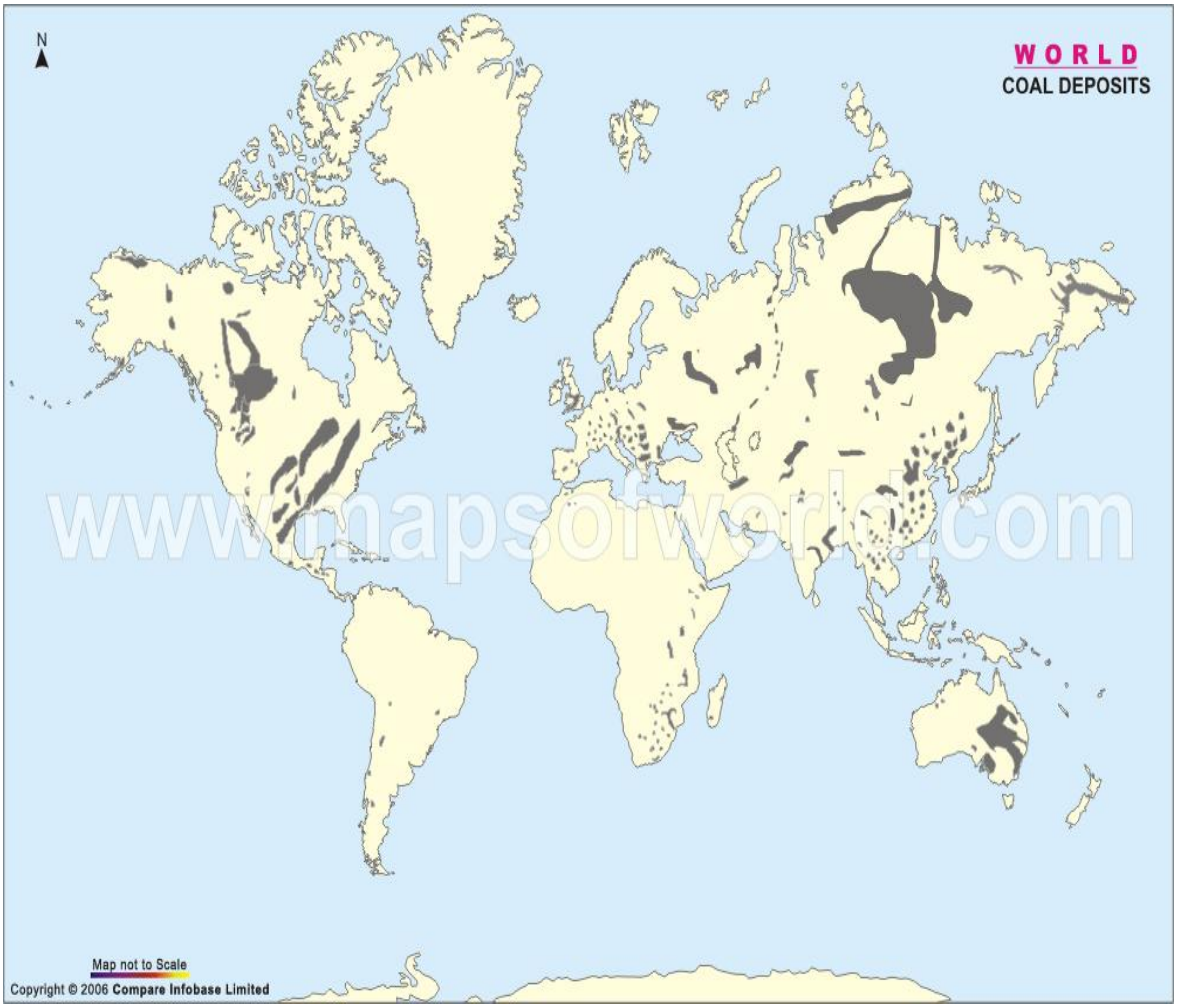


Fig. 1.1 : Global coal map

1.1.2 OIL

Global proven oil reserve is estimated 1652.6 million barrels by end of 2011. This will be available for 54.2 years at current consumption rate. Saudi Arabia is largest share of the global reserve with 19.1% and will remain for 65.2 years in Saudi Arabia. Venezuela is 2nd largest with 15.3% which will be consumed up to 100 years and Iran having 9.9% is at 3rd place and will consume up to 88.4 years Iraq is having 8.3% of total global reserve, Kuwait7.3%, UAE 7.1% and Russia 5.6%. Our Country India has only 0.7% share of total global reserve which will remain available for 30 years at current consumption rate. Oil map of the world is shown below.

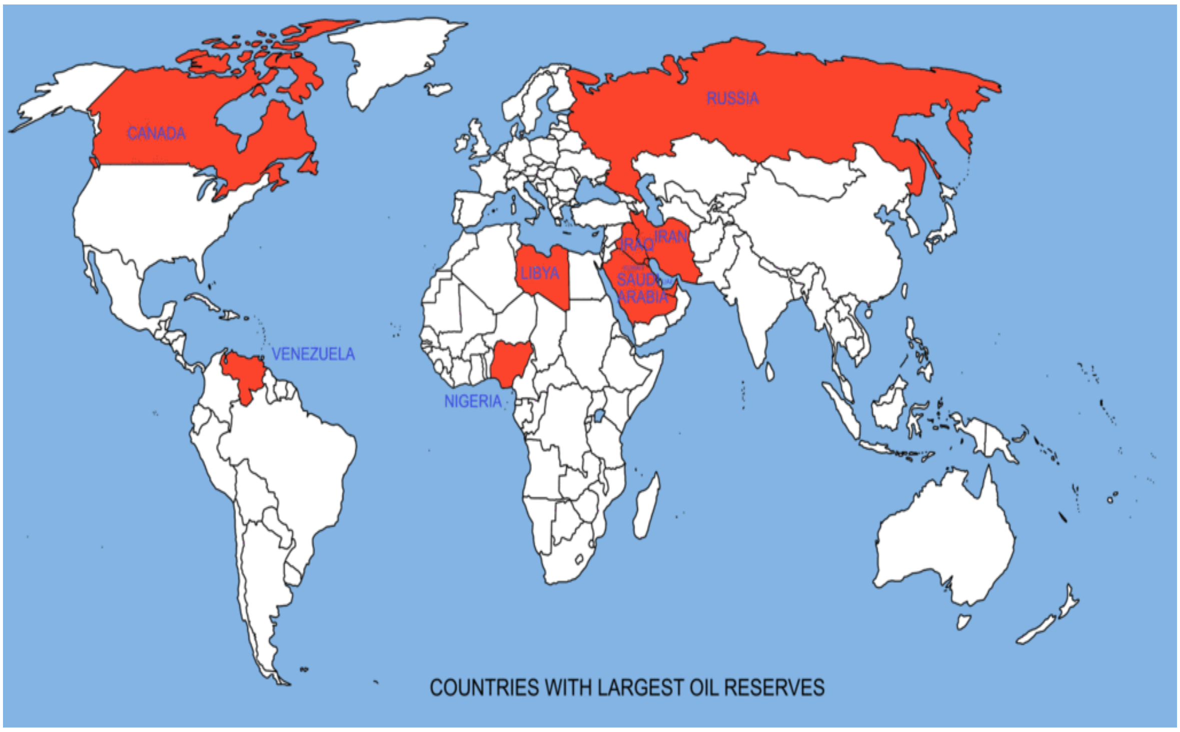
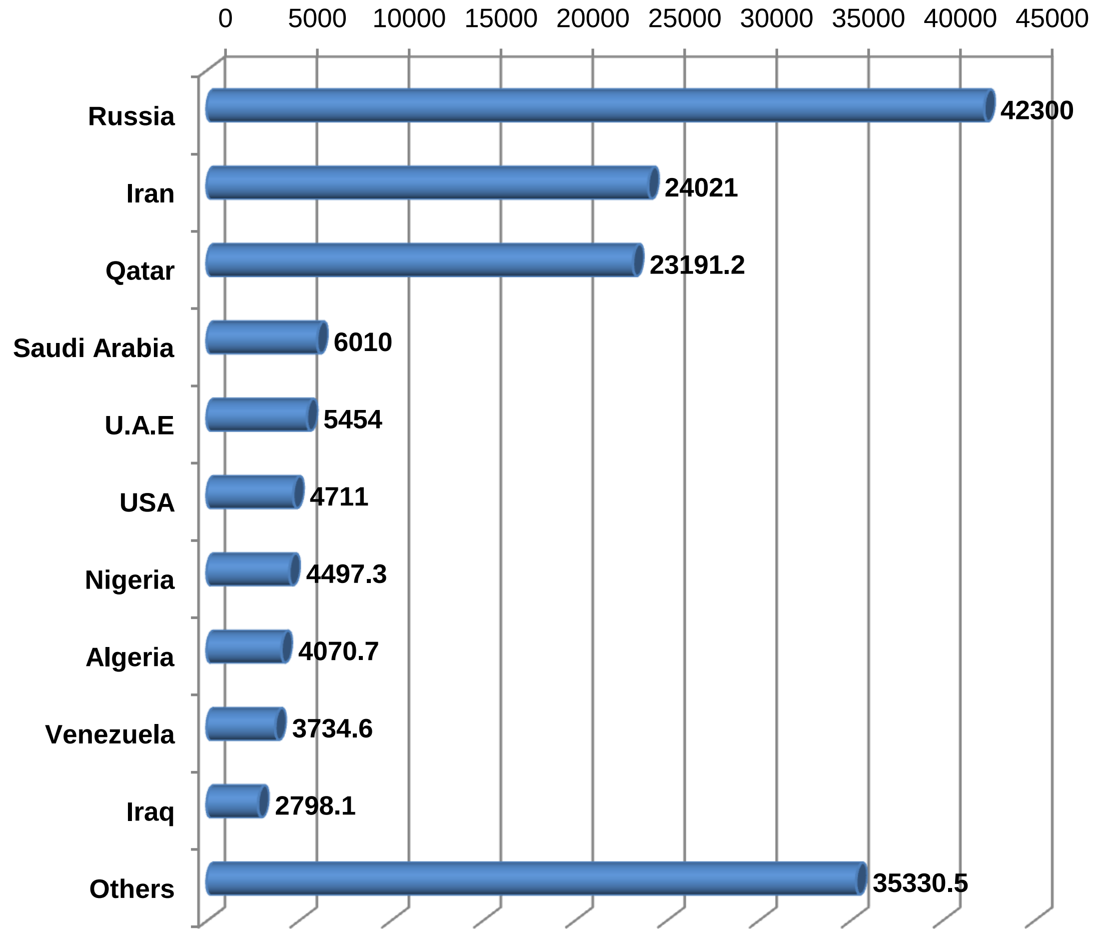


Fig. 1.2 : Global oil map *[Source : www.mapsofworld.com]*

1.1.3 NATURAL GAS

Global proven gas reserve is estimated 187.1 million barrels by end of 2011. This will be available for 58.6 years at current consumption rate. Russian Federation is largest share of the global reserve with 23.9% and will remain for 76 years in Saudi Arabia. Iran is 2nd largest with 15.8% which will be consumed up to 100 years and Qatar having 13.5% is at 3rd place and will consume up to 100 years. Our Country India has only 0.8% share of total global gas reserve which will remain available for 29 years at current consumption rate. Proven natural gas reserve of the world is shown below.

Chart 1.2 : Top Ten Countries of Proven Natural Gas Reserves in **Million Tonnes of oil equivalent** *[Reference-23]*



<u>1.1.4</u> <u>WIND POWER</u>

The worldwide installed capacity of wind power reached 283 GW by the end of 2012. China (75564 MW), US (60007 MW), Germany (31332 MW) and Spain (22796 MW) are far ahead of India in fifth position. Wind power is growing at the rate of 30% annually. Several countries have achieved relatively high levels of wind power penetration, such as 21% of stationary electricity production in Denmark, 18% in Portugal, 16% in Spain, 14% in Ireland and 9% in Germany in 2010. As per year end of 2012, 83 countries around the world are using wind power on a commercial basis.

Chart 1.3 : **Top 10 countries of windpower capacity** (2012 year-end) *[Reference-12]*		
Country	**Windpower capacity (MW) provisional**	**% world total**
China	75564	26.3
United States	60007	19.7
Germany	31332	12.2
Spain	22796	9.1
India	16084	6.7
France	6800	2.8
Italy	6747	2.8
United Kingdom	6540	2.7
Canada	5265	2.2
Portugal	4083	1.7
(Rest of World)	32446	13.8
World total	**283 GW**	**100%**

1.1.5 SOLAR POWER

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar energy technologies include solar heating, solar photovoltaics, solar thermal electricity and solar architecture, which can make considerable contributions to solving some of the most urgent problems the world now faces. The International Energy Agency projected that solar power could provide "a third of the global final energy demand after 2060, while CO_2 emissions would be reduced to very low levels. Global solar map is shown in figure1.3.

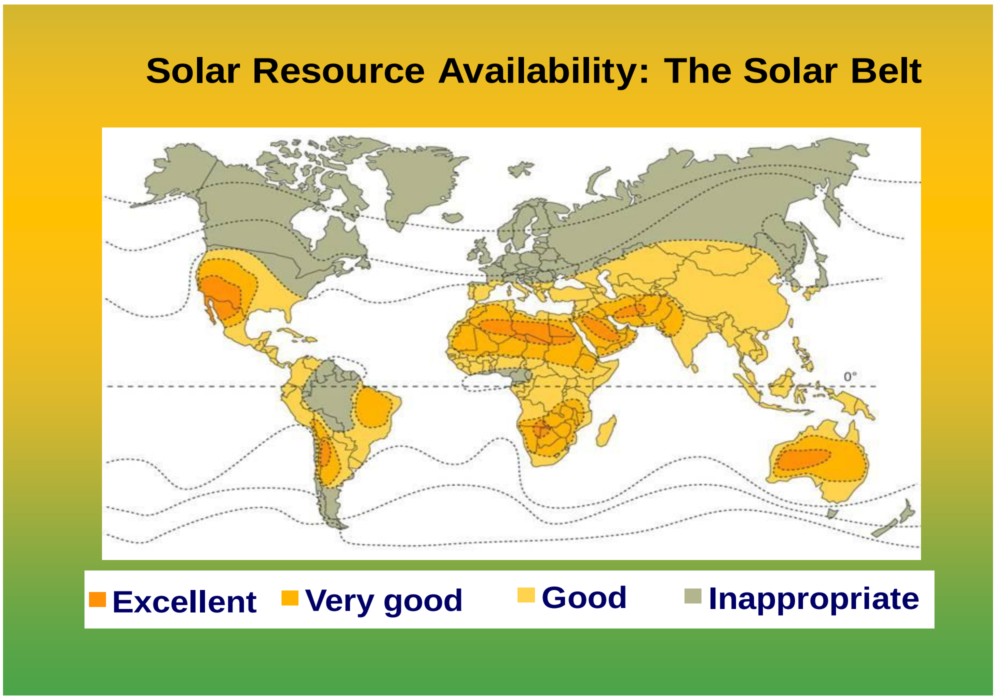


Fig. 1.3 : Global solar map

1.2 INDIAN ENERGY SCENARIO

The complexity and dynamics of India's economy, coupled with its democratic polity and meeting aspiration of 1.2 billion people have made the energy segment a vastly diverse one. Problems stare us as challenges and get unfolded as opportunities. All the stakeholders in India's energy industry, few of them are global, are striving to ensure energy availability and accessibility to all, at affordable price, within the framework of inclusive growth.

Even after the global economic meltdown, India registered a GDP growth of 6.5% in 2011-12. Planning Commission has estimated that during 12th Five Year plan period (2012-13 to 2016-17), for a GDP growth of 9% per year, energy supply has to grow at 6.5% per year. The ability to meet the energy requirement will depend upon India's ability to expand domestic production in the critical subsectors such as petroleum, natural gas and coal, and meeting the balance requirement through imports.

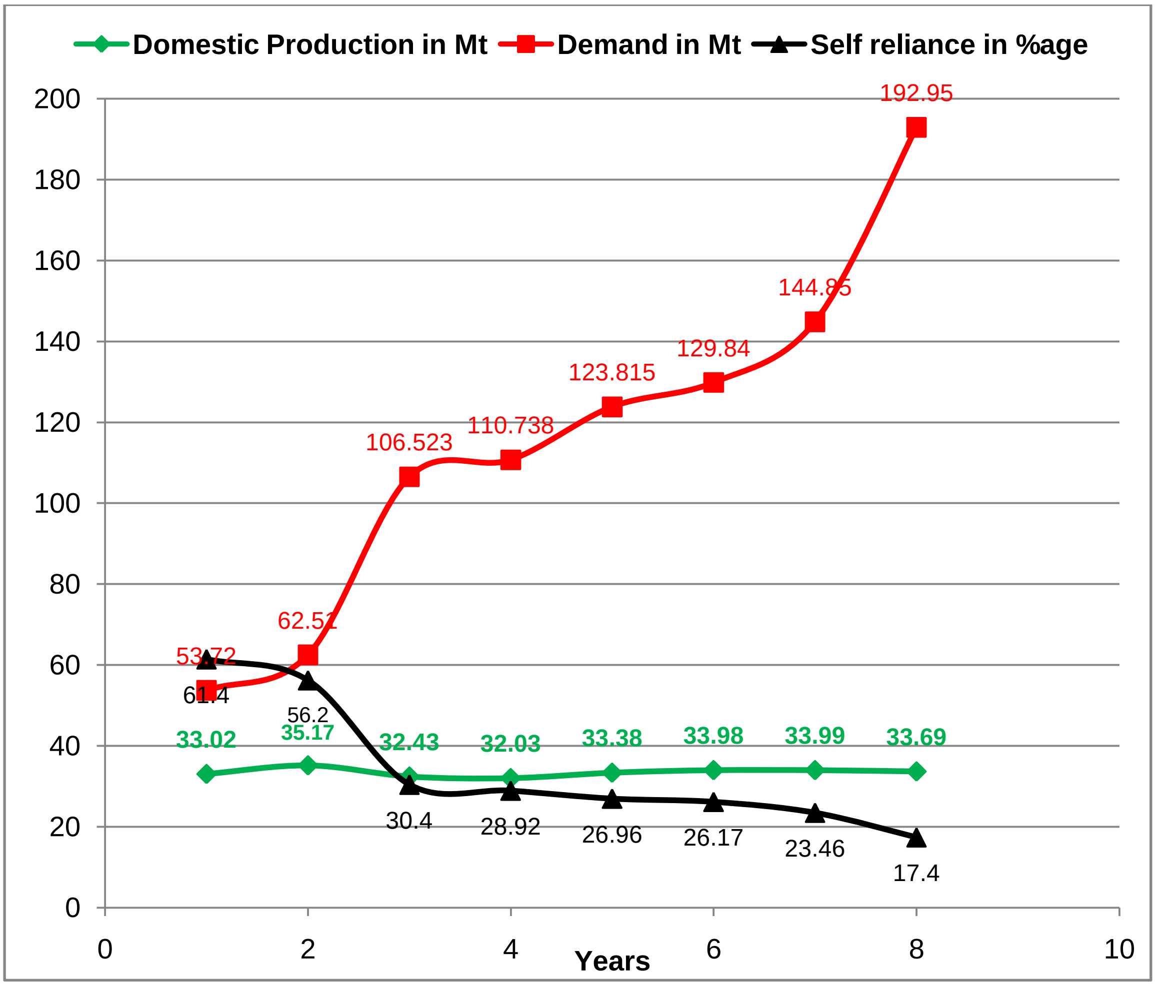


Chart 1.4 : Indian Petroleum Scenario

[Source : Energy Statistics; www.mospi.gov.in]

As per the chart 1.4 (Indian Petroleum Scenario), we observe that demand of petroleum is increasing day by day but our domestic production almost constant (though increasing) due to limited oil reserves in India. As a result we are being dependent on other countries i.e. our self reliability is decreasing day by day.

Almost there is the same case with coal. Since India's limited coal reserves (only 7% of total global coal reserve) are depleting day by day, and also all these fossil fuels produce very high amount of smoke which pollutes environmental air. So we must approach towards **Renewable Energy** sources like wind energy and **Solar Energy**.

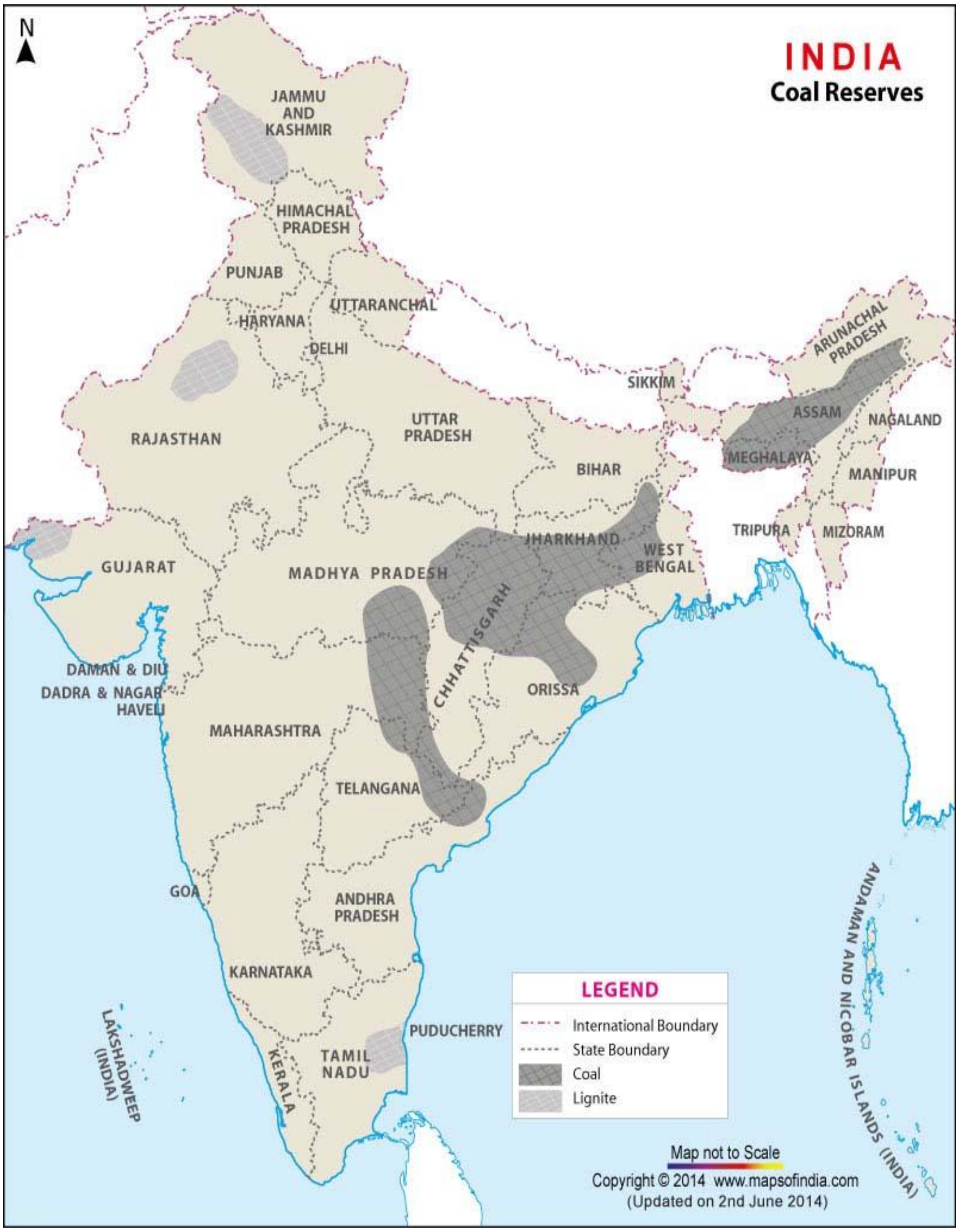


Fig. 1.4 : Indian Coal map

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. Although a relative newcomer to the wind industry compared with Denmark or the United States, India has the fifth largest installed wind power capacity in the world. In 2009-10 India's growth rate was highest among the other top four countries. As of 31 March 2014 the installed capacity of wind power in India was 21136.3 MW. As we are observing in above figure 1.5 of wind map, there are much more scope of wind power in India.

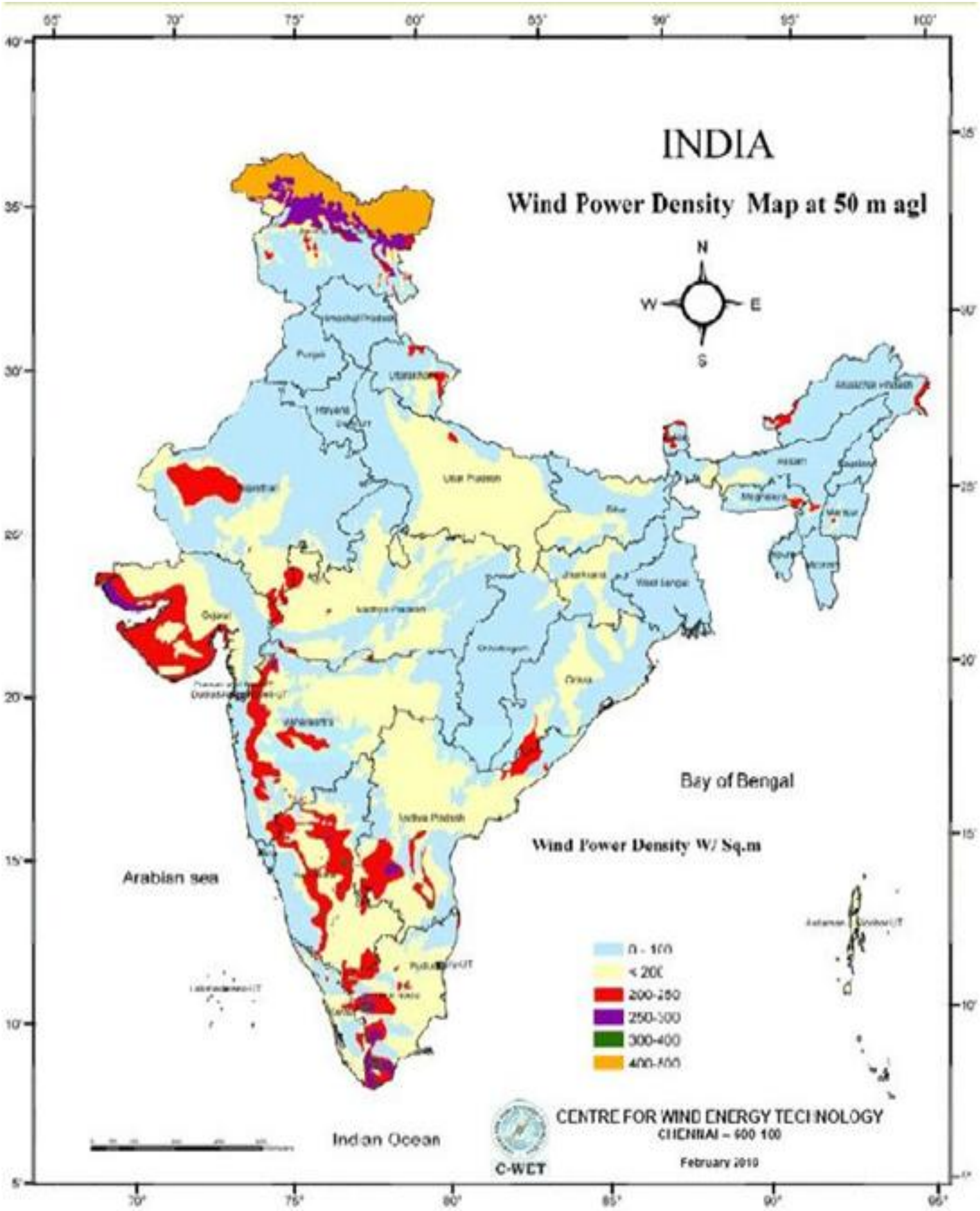


Fig. 1.5 : Wind Resource Map

India is densely populated and has high solar insolation, an ideal combination for using solar power in India. With about 300 clear, sunny days in a year, India's theoretical solar power reception, on only its land area, is about 5000 PWh/yr (Petawatt-hours per year). The daily average solar energy incident over India varies from 4 to 7 kWh/m^2 with about 1500–2000 sunshine hours per year (depending upon location), which is far more than current total energy consumption. For example, assuming the efficiency of PV modules were as low as

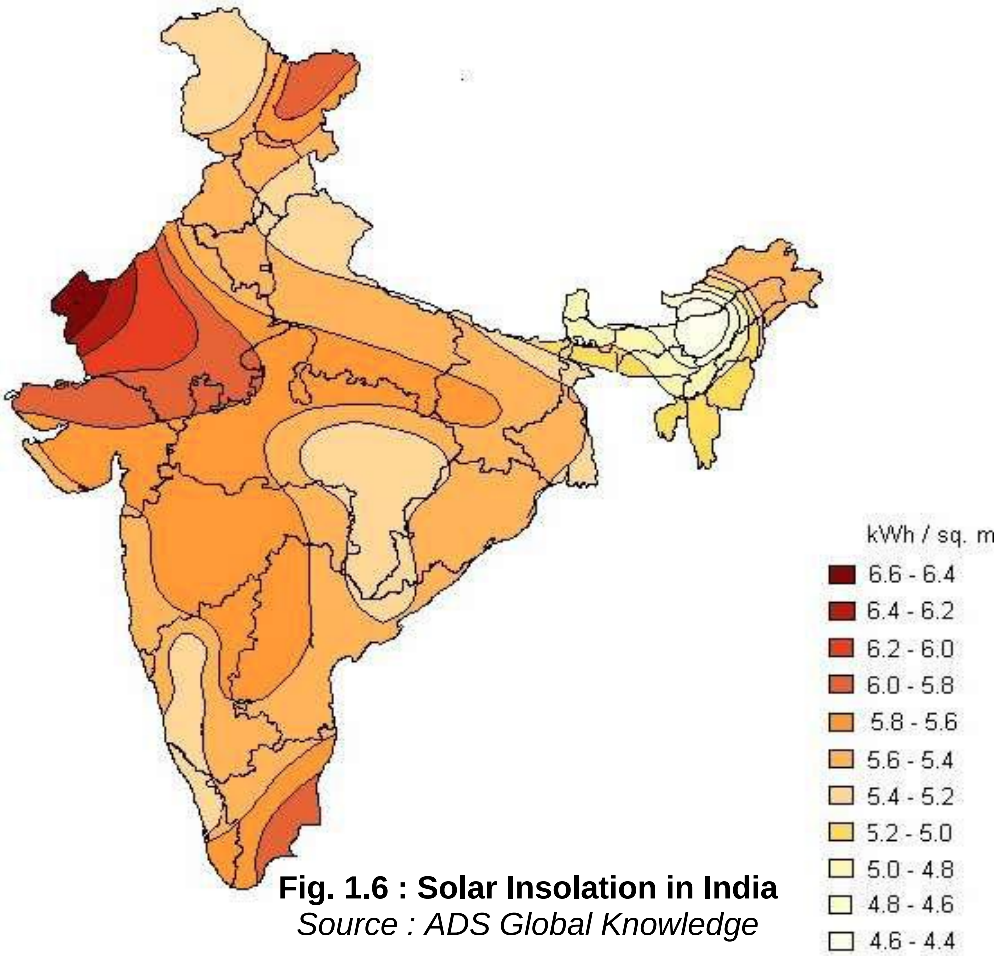


Fig. 1.6 : Solar Insolation in India
Source : ADS Global Knowledge

10%, this would still be a thousand times greater than the domestic electricity demand projected for 2015. In the solar energy sector, some large projects have been proposed, and a 35000 km^2 (14000 sq mi) area of the Thar Desert has been set aside for solar power projects, sufficient to generate 700 to 2100 GW.

As per discussion held above, we conclude that almost all the energies are obtained from either coal or gas or oil. As per data available in 2011, Coal, gas and oil together all constitute 65.66% of total installed capacity of 210936.72 MW in India. 18.64% of total capacity is obtained from hydle power which is 39324.40 MW and 2.57% is obtained from nuclear power which is 4780Mw. RES (Renewable energy sources like wind & solar power) available is 25856.14 MW which is only 10.86% of total capacity, so there is much more requirement of development in the field of Renewable Energy Sector.

Chart 1.5 : **Fuel wise total installed capacity** (*Source : Enery Statistics; www.mospi.gov.in*)		
Fuel	**MW**	**%age**
Total Thermal	140976.18	65.66
Coal	102863.38	55.45
Gas	17742.85	9.56
Oil	1199.75	0.64
Hydro (Renewable)	39324.4	18.64
Nuclear	4780.00	2.57
RES	25856.14	10.86
Total	210936.72	100

1.3 ADVANTAGES OF SOLAR POWER

- One of most sustainable energy source is sunlight that too is totally inexhaustible and available free of cost, as far as we know for thousands of years. Often one can use as an excellent supplement to other renewable sources.
- The solar energy produced is very clean with no pollutants. The burning of oil releases carbon dioxide and other greenhouse gases and carcinogens into the air. Whereas solar crematorium needs no fuel and produces no waste and no pollution.
- There is no any problem of global warming with solar power which is common problem with any other conventional fuels.
- All of us are aware of the rising cost of fuels. Although solar reflectors or combustion chamber, etc. may be expensive to buy at the onset, you can save money in the long run. After all, you do not have to pay the money for the energy from the sun.

- Solar reflectors are totally silent. They can extract energy from the sun without making a peep. Now imagine the noise that the giant machines used to do.
- Solar powered lights and other solar powered products are also very easy to install. You do not even need to worry about wires.
- In sunny countries, solar power can be used where there is no easy way to get electricity to a remote place.
- Handy for low-power uses such as solar powered garden lights and battery chargers.

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 self-reliability of countries energy security through inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, mitigate climate change, 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; they must be wisely spent and need to be widely shared.

1.4 ENERGY INDEPENDENCE IN INDIA BY 2030

As per Energy Statics [*Reference-15*] of Govt. of India, the total energy requirement by the year of 2030 for our country would increase to 400000 MWs from the existing 210000 MWs. Ideally India has to plan for 215000 MWs of power to be realized from renewable energy resources like hydel, wind, solar, nuclear and conversion of municipal waste into energy by 2030. India can generate additional solar energy to the extent of 60000 MWs by having large scale solar power plants. Gujarat State has already generated 680 MWs of solar electric power through public-private partnership program and the power is being fed to the grid.

Here we have to consider the reduction in load factor in solar, wind and hydel which will necessitate generation of 20 to 30% excess power beyond 400000 MWs.

1.5 EXISTING FUNERAL PRACTICES IN HINDU RELIGION

I am intended to investigate the possibility of employing solar energy for the Hindu ritual of cremation. In order to design the broad scope of specifications for solar crematoriums, there arises a concern considering the religious sentiments connected to the cremation process.

While cremation is an established Hindu ritual practiced since ancient times and the Hindu religion permits the cremation of dead body in day-time only, there is much scope of solar crematorium in this ritual; as solar power is also available in day-time only.

According to Hindu traditions *[Reference-21]*, the reasons for preferring to destroy the corpse by fire, over burying into ground, is to induce a feeling of detachment into the freshly disembodied spirit, which will be helpful to encourage it into passing to its next destination, otherwise it may stay with its former body. Hindus have 16 rites of passage (as per Samskara). i.e. a Hindu undergoes 16 rituals during their lifetime, like Naming ceremony, Thread ceremony (beginning of student life), Marriage, etc., and the last being cremation. Cremation is referred to as *antim-sanskara*, literally meaning "the last rites". At the time of the cremation or "last rites," a "Puja" (prayer) is performed. The holy text of Rigveda, one of the oldest Hindu scriptures, has many Ruchas (also written and pronounced as Richas in form of small poems) related to cremation, which state that Lord Agni (God of Fire) will purify the dead body.

As per Hindu ritual practice, dead people are traditionally cremated on an open woodpile. There is an established sentimental fact of cremating the dead body completely at one goes. And there must not be left any un-burnt portion of the body. Otherwise the soul of that person will remain unsatisfied, and it will be converted into the devil or imp which will victimize or terrorize the concerned relatives for his/her satisfaction.

1.6 PROBLEMS ASSOCIATED WITH TRADITIONAL CREMATION SYSTEM

Dead people are traditionally cremated on an open woodpile. Between 500 and 600 kg of wood are used for this purpose. So there are following problems with traditional cremation system :

- Since many trees are felled to meet this requirement. So we are depleting forests which purify environment through photo synthesis.
- The burning of fuel releases carbon dioxide and other greenhouse gases and carcinogens into the air. As a result we are significantly polluting the atmospheric air much more.
- All of us are aware of the rising cost of wood.
- There is common problem of global warming which is associated with any conventional fuel. Since too much heat is released in the atmosphere through traditional cremation process, so we are significantly contributing in global warming.

1.7 WHY TO OPT A TOPIC OF SOLAR CREMATORIUM?

Between 500 and 600 kg of wood are used to cremate a dead body. Many trees are felled to meet the requirement. As a result we are significantly contributing in global warming and atmospheric air pollution much more and forest are depleting day by day. So today, world is moving towards the sustainable energy sources which are renewable and biodegradable in nature. There are several resources and several means to convert these resources into useful form of energy. One of most sustainable energy source is sunlight that too is totally inexhaustible and available free of cost. The heat (energy) produced is very clean with no pollutants. Hence the above environmental problems can be the addressed by using solar crematorium. Nearly the sun is the source of all the energies on earth. Therefore anyone can be firm believer of world powered by solar energy.

Since the sunlight has very little part, only 20% of its energy as lighting effect and large portion, 80% as thermal effect. So energy of solar radiation can be utilized more in solar thermal power generation than in solar photo-voltaic (which utilizes only lighting effect of sunlight) for power generation. A crematorium too requires very large amount of heat energy which can be harnessed by directly by solar concentrator. On the other hand, we can never suggest using of solar photo-voltaic panels to obtain such a large amount of heat indirectly for cremating a corpse. As firstly, PV panels first convert only 20% (lighting effect) of solar energy into electricity, and then this electricity is converted into heat by passing through very high amount of resistance. This conversion of electricity into the heat is too associated with several losses. So employing solar PV panels will not be feasible for cremating a corpse. Although these PV panels can be used to get electricity for running the accessories like tubes, fans in office/cabins and necessary motors installed in tracking system.

Therefore we can be mainly interested in utilization of “solar thermal power” and not in “solar PV panels” as only 20% energy of sunlight can be utilized in photo-voltaic for power generation that too with several losses. I am a **firm believer of world powered by solar energy**. Since no fuel is required to run the solar powered equipments. Considering above facts, solar crematorium is very hot topic. While cremation is an established Hindu ritual practiced since ancient times and the Hindu religion permits the cremation of dead body in day-time only, there is much more scope for development of solar crematorium in near future; as solar power is also available in day-time only.

1.8 INTRODUCTION TO THE SOLAR CREMATORIUM

While cremation is an established Hindu ritual practiced since ancient times and the Hindu religion permits the cremation of dead body in day-time only, there is much more scope for development of solar crematorium since sunlight is also available in day-time only. With the population of the earth increasing steadily, and resources quickly being consumed, environmentally conscious inventions are on the rise. In the late 1980s, one eco-friendly inventor came up with the idea for a Solar Crematorium, an invention that used the light of the sun to cremate dead bodies.

A solar crematorium is a solar furnace that uses special reflectors to heat the cremation chamber by concentrating solar power to produce high temperatures, offering an environmentally friendly option to electric power & traditional pyre cremations currently employed in India. Parabolic mirrors or heliostats (device which turns so as to keep reflecting sunlight toward a predetermined target, compensating for the sun's apparent motions in the sky) concentrate light-insolation (irradiation) onto a focal point. The temperature at the focal point may reach 3500°C (6330°F), and this heat can be used to cremate dead

Fig. 1.7 : An schematic view of Solar Crematorium

bodies. An existing, but non-operational, the world's first solar crematorium was installed in the *Muni Seva Ashram* at Goraj village near Vaghodia town in Vadodara district of Gujarat state of India.

In India, most of the dead people are traditionally cremated on an open woodpile. Between 500 and 600 kg of wood are used for this. Many trees are felled to meet the requirement. In towns, the wood is to some extent replaced with electric and gas fired cremation chambers. A solar powered cremation chamber will be another very much welcome alternative.

Limitations of Solar Crematorium

- The actual harnessing of the energy can only happen in daylight hours so there may be problems of storing the energy at night.
- It can be unreliable unless you're in a very hot sunny climates but the need for energy is often greater in colder, northern or southern latitudes.
- It is very expensive to build solar crematorium as you need a very large area of solar panels to get a decent amount of power. Solar reflectors still cost a great deal compared to the amount of power they'll produce in their lifetime.
- Although solar reflectors or combustion chamber, etc. may be expensive to buy at the onset, you can save money in the long run. After all, you do not have to pay the money for the energy from the sun.
- Almost all reflectors (concentrators) have a rigid structure and moves along with the direction of the sun. This makes its use a bit impractical.
- In the US, solar power isn't much use except for low-power applications; however, for these applications it's definitely worthwhile.
- Very diffuse source means low energy production--large numbers of solar panels (and thus large land areas) are required to produce useful amounts of heat or electricity.
- Only few areas of the world with lots of sunlight are suitable for solar power generation.

As you can see (in section 1.3) that advantages of using solar energy creates a much longer list than the disadvantages, and the disadvantages are things that can be improved as technology improves, so solar crematorium can be much more viable option.

Chapter – 2

LITERATURE REVIEW

Not much extensive and dedicated work is seen after studying a lot of different popular journals available. Few works has been reported and added in this report for solar furnaces and cost estimation of solar equipments.

2.1 LITERATURE REVIEW

Wolfgang Scheffler [*Reference-20*] described some ideas about the intricate design of the Scheffler reflectors and how it was developed. Parabolic Scheffler Reflectors can provide (you with) high temperature heat for all types of cooking, steam generation and many other applications. The hot area where all light is concentrated, moves along with the direction of the sun. This makes its use a bit impractical.

World's first solar crematorium [*Reference-1*] is being developed in our country of Goraj village (30 km East of Baroda) in Gujarat state by Muni Seva Ashram with the help of Ronnie Sabawalla of Rashron Energy and Auto limited. In 1998 they started with a specially designed Scheffler reflector with 50m^2 mirror surfaces. But its initial concentration-factor of about C = 100 turned out to be by no means enough to allow proper cremation.

Peter Mitchell [*Reference-11*] studied the feasibility of providing a crematorium to serve the Rugby. He presented an analysis of current and future demands for burial and cremation facilities in Rugby. He also estimated the cost for the development of a new crematorium and estimated the income likely to be received from a new crematorium.

2.2 SOLAR FURNACE AT ODEILLO IN FRANCE

The largest solar furnace [*www.wikipedia.org*] is located in Font-Romeu-Odeillo-Via, high in the Pyrenees Mountains in the Basque region of the

French/Spanish border. It has been operational since 1970. The Pyrenees were chosen as the site because this area experiences extremely high air quality and approximately 300 days of sunlight a year, making it a perfect spot for a solar furnace. This is also the same area in which the world's first solar furnace was built; this solar furnace was put in place at Mont-Louis in 1949 by Professor Felix Trombe. Odeillo and Mont-Louis are within 15km of each other.

Fig. 2.1 : World's largest solar furnace at Odeillo in France

The furnace makes use of an array of 10000 mirrors to reflect sunlight into a gigantic concave hemisphere (pictured above) which then focuses the energy onto an area roughly the size of a cooking pot. The flat mirrors track the sun in unison and redirect the solar thermal energy towards the crucible, which is being used for melting steel.

2.3 REVIEW OF WORK ON SOLAR CREMATORIA

On one hand, biogas cremation systems are already demonstrated. However on the other hand, there have been a few demonstrations of solar thermal systems ranging from community cooker applications to generating electricity, where temperatures range from 1000°C to 3000°C, respectively. Important questions remain on how well this method will work, and how widely it will be accepted in India, let alone elsewhere. It is important to keep in mind that the traditional cremation in India does not achieve the temperature of combustion that is expected in North America and Europe. 700°C is at the low end of incineration temperatures used in the West, so this method would be more time consuming and result in more recognizable remains. Adoption of this method may be difficult for families and operators unless the technology advances, and higher temperatures can be created in the chamber.

Wolfgang Scheffler [*Reference-20*] initially performed experiments to construct a solar crematorium in 1998 using small reflector of 3.4m^2 area, and achieved concentration up to 670 Suns and temperature up to 800°C, thus established the feasibility of solar crematorium. An existing but non-operational first solar crematorium [*www.greenashram.org*] was installed at the Muni Seva Ashram at Goraj near Vadodara in Gujarat. This first solar crematorium is developed by the author jointly with Ronnie Sabawalla of Rashron Energy and Auto Limited in Baroda, Gujarat, India. In 1998 they started with a specially designed Scheffler

Fig. 2.2

Experimental set-up for solar cremation in Baroda, India, with two axis tracking of the sun reflector with $50m^2$ mirror surfaces. But its initial concentration factor about C = 100 turned out to be by no means enough to allow proper cremation.

As a next step they undertook experiments on a much smaller scale to establish what would be the correct conditions for a successful solar cremation. First they used the focus of different sized Fresnel lenses, which provided high enough temperatures to melt even stones, but with very limited power due to their small size.

Later they continued with an experimental reflector of $3.4m^2$ aperture and a small cremation chamber. This set up had the same proportions as the $50m^2$ scheffler reflector, but downsized by a factor of three. To simplify the construction the shape was not flexible and therefore the chamber together with the reflector had to be mounted on a 2-axis tracking system.

2.4 PROBLEM STATEMENTS AND OBJECTIVES

On the basis of the exhaustive and valuable literature review it can be concluded that on an average 500 to 600 kg of wood are used for a dead body. Many trees are felled to meet this requirement. As a result forest are depleting day by day. Global warming potential and air pollution level are too constantly increasing because of cremating dead bodies with wooden piles, it has become very essential to evaluate and analyze potential suitability of solar crematorium.

Therefore, the following objectives and related parameters are envisaged and studied for the present research work:

- Study the existing Indian energy scenario and establishing the solar thermal applications in crematorium

- Detailed Literature Review
- Study of Solar Map, Solar Energy and Solar Policies
- Study of various components of Solar Crematorium
- Development of cremation chamber
- Visiting a solar crematorium for Case Study in the *Muni Seva Ashram* at Goraj village near Vaghodia in Vadodara district of Gujarat state of India
- Maintenance of the solar crematorium
- Feasibility study of solar crematorium
- Estimating the cost of crematorium and income from it
- Conclusion of the work

Chapter – 3

UNDERSTANDING SOLAR ENERGY AND ITS POLICIES IN INDIA

3.1 UNDERSTANDING SOLAR ENERGY

The earth and its atmosphere, depend ultimately on the sun for its energy supply. The fossilisation of organic and inorganic (degradable) substances on the earth provides an indirect supply option for energy. The latent heat and sensible heat transfers involved in the change of state of water also contribute to the energy states. The radiant energy from the sun is absorbed by the earth and the atmosphere and is partially redeployed as emission in the infra-red wavelength region, which controls the entire activity of all living organisms.

The Earth receives 174PW (petawatts) of incoming solar radiation (insolation) at the upper atmosphere. 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.

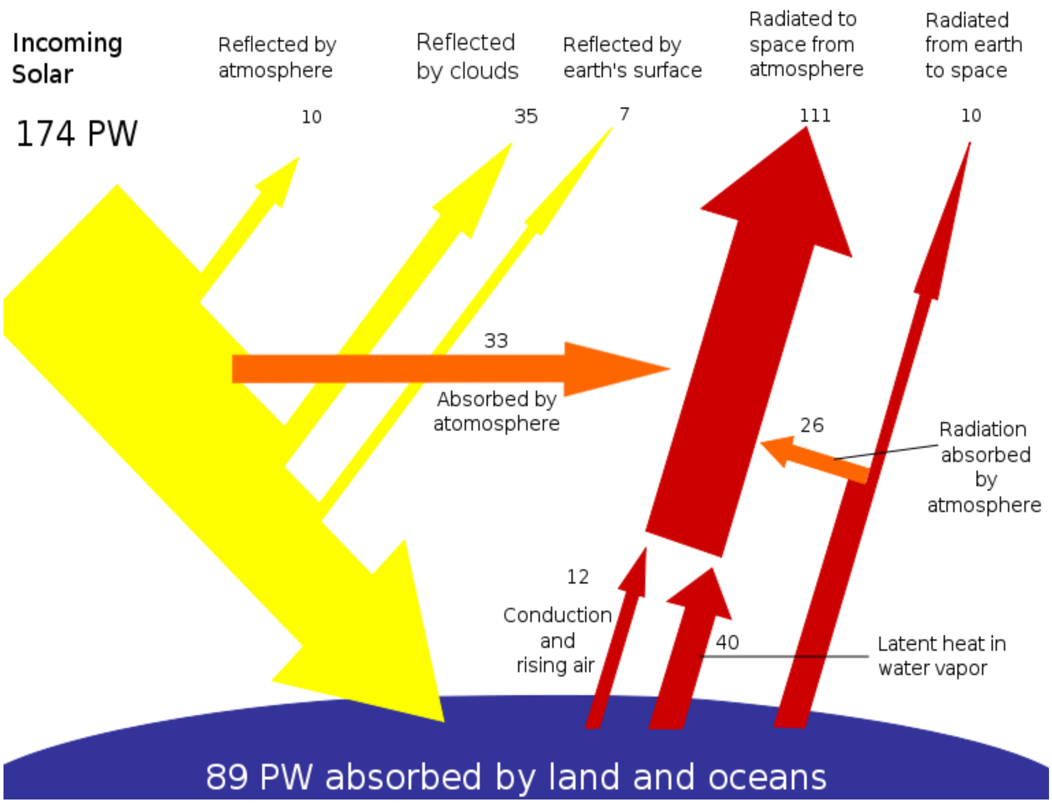


Fig. 3.1 : Distribution of solar radiation

Earth's land surface, oceans and atmosphere absorb solar radiation, and this raises their temperature. 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. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14°C. By photosynthesis green plants convert solar energy into chemical energy, which produces food, wood and the biomass from which fossil fuels are derived.

Chart 3.1 : Yearly Solar fluxes & Human Energy Consumption	
Solar	3850000 EJ
Wind	2250 EJ
Biomass	3000 EJ
Primary energy use (2005)	487 EJ
Electricity (2005)	56.7 EJ

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3850000EJ (exajoules) per year. Photosynthesis captures approximately 3000 EJ per year in biomass. 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.

Solar energy can be harnessed in different levels around the world. Depending on a geographical location the closer to the equator the more "potential" solar energy is available.

3.2 THE SUN

The sun is basically a young and an almost invariable magnetic star. It is a slowly rotating body of hot and highly condensed gases with a strongly variable temperature gradient. The core of the sun is assumed to be made of ionized hydrogen and helium nuclei at very high temperatures. The various parts of the sun exhibit different temperatures. Its period of rotation around its axis is 25.38 days. It has a mean density of 1409 Kg/m^3, with a surface gravity nearly 28 times stronger than that of the earth. Its radius and surface area are 6.96 x10^{8}m and 6.087 x 10^{18} m^2, respectively.

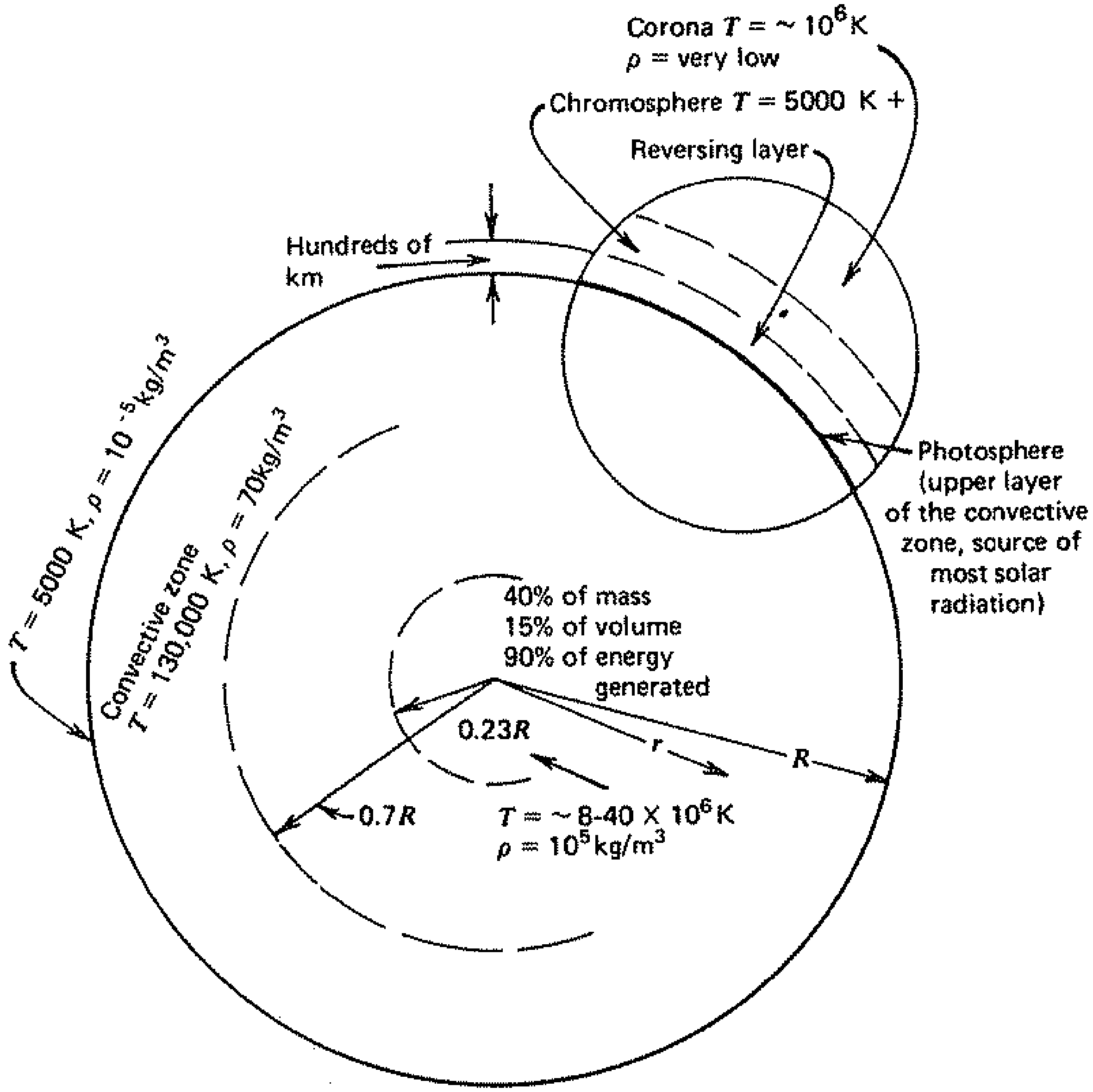


Fig. 3.2 : Structure of the Sun [*Refence-3*]

A temperature level of the order of 10^6K is maintained at the core by the nuclear fusion processes. Outside of this core area is the photosphere which is seen from the earth as a flat bright disc. This is the main source of solar radiation. The apparently smooth disc as it looks, is not of uniform brightness and has many brighter and darker regions. The darker regions which are at around 4500K are called the sunspots. The brighter ones are made up of 35-40 per cent brighter granules and faculae. The average temperature of the photosphere is estimated to be about 5800K. Outside the photosphere lies a narrow reversing layer which is at a relatively lower temperature of about 5300K. This layer has various elements in excited state and consequently gives rise to Fraunhofer's absorption lines. Chromosphere which is red in colour is an extension of the reversing layer. Spectacular explosions occur in the chromosphere, called the solar flares, sending streams of highly ionized particles into space. These cause intense disturbances in the upper reaches of the earth's atmosphere. Beyond the chromosphere is the corona, a rarified gas layer extending outward for several solar diameters.

The sun emits radiation in the entire electromagnetic spectrum from gamma rays to radio waves. Because of its very mechanism of emission, the radiant energy is a combination of energy released by layers which are at different temperatures. Even the photosphere which is the main source of solar radiation does not have uniform temperature distribution. Thus the sun is not a black body by the strict definition of a black body. However, approximating sun's radiant energy to black body radiation is sufficiently close, that it is normal practice to treat the sun as a black body radiator. The effective temperature at which the radiant energy is assumed to escape the sun is about 5800K.

The earth revolves around the sun in an elliptical orbit with the sun at one of the foci. The distance between the sun and the earth, therefore, changes continually during its revolution around the sun in about 365 days. The average or the mean sun - earth distance is 149.6 x 10^6km. At its perihelion position when the earth is nearest to the sun on January 1, the distance of the earth is about 98.3 percent of the mean distance. On the other hand, it is farthest on the aphelion position on July 2, which is about 101.7 per cent of the mean distance.

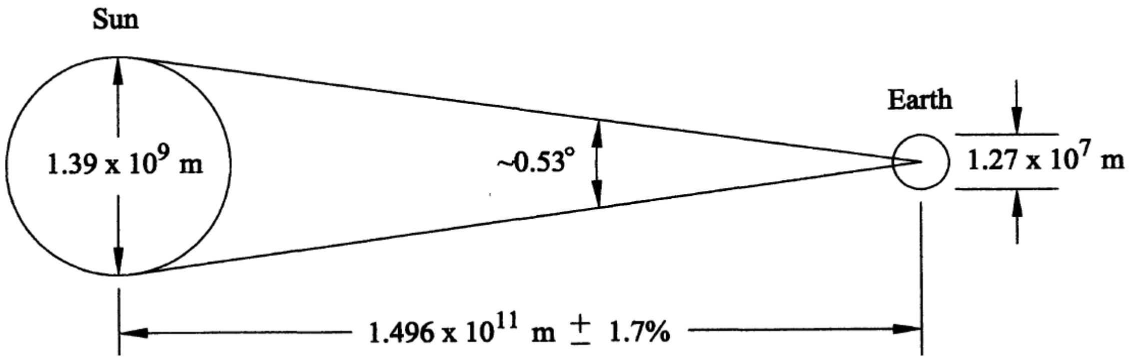


Fig. 3.3 : The Sun & Earth Relationship [*Refence-3*]

Because of these variations in the sun earth distance, the radiant energy intercepted by the earth also varies by about ± 3 per cent of its normal energy value. The radiant energy from the Sun per unit time falling on a unit surface area perpendicular to the direction of propagation of radiation outside the earth's atmosphere at mean sun-earth distance is termed the solar constant (S_o). Thus value of the solar constant varies from day-to-day depending on the actual distance from the sun. The present accepted value of solar constant derived from space-based measurements is 1367 ± 7 W/m^2, the uncertainty in the measurements being about 0.3 percent.

3.3 TERMINOLOGY

Radiometry pertains to the measurement of radiant energy incident on a surface or emitted from it.

Radiant energy (Q) is the energy available due to incidence or emittance. The rate of flow of radiant energy through a surface is a power quantity (Φ) i.e. Φ=dQ/dt. This is also termed radiant flux.

Radiant Flux Density is the radiant flux of any origin crossing unit area.

$$(d\Phi/dA=d^2Q\ /\ dA.dt)$$

Radiant Exitance (M) is the radiant flux emerging from an area element (M=dΦ/dA).

Radiance (L) is the radiant flux leaving a point in the source per unit solid angle of space surrounding the point.

$$L = d^2\Phi/(d\Omega.dA.\cos\theta)$$

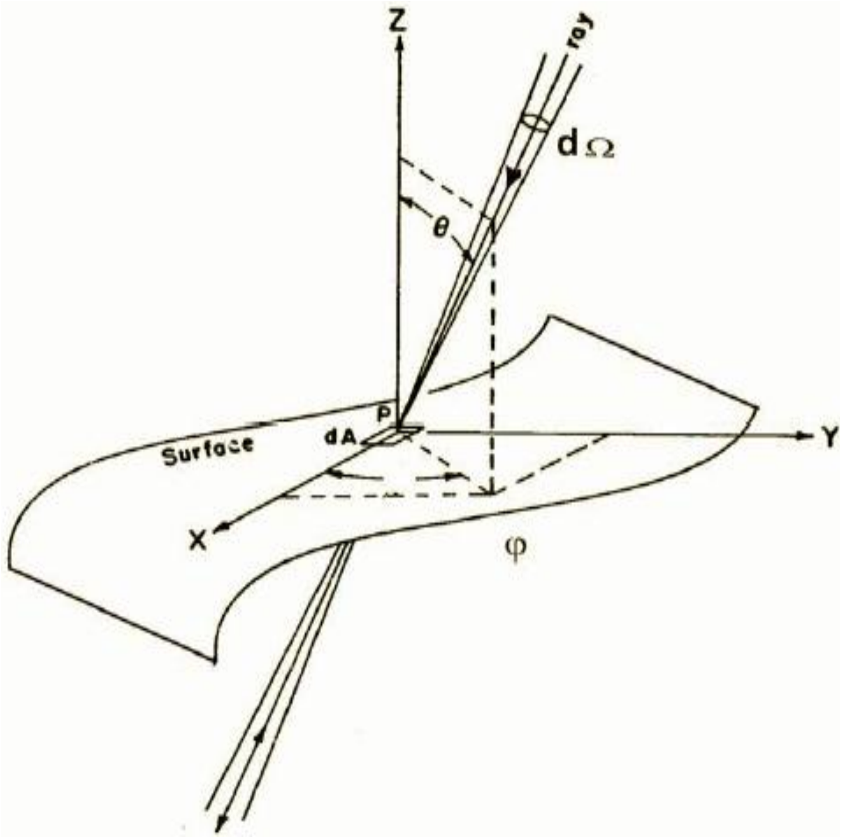


Fig. 3.4 : Geometry of ray-surface intersection [*Refence-3*]

Irradiance (E) is defined as the radiant flux incident on to a unit area element (E= dΦ/dA). It is the power of electromagnetic radiation per unit area (radiative flux) incident on a surface. **Radiant emittance** or **radiant exitance** is the power per unit area radiated by a surface. The SI units for all of these quantities are watts per square meter (W/m^2). These quantities are sometimes called intensity or insolation, but this usage leads to confusion with radiant intensity, which has different units.

Radiant exposure (H) is the radiant energy incident on a unit area element over time. It is the total amount of irradiance integrated over an interval of time.

Radiant intensity (I) is recommended only for the radiant flux leaving a point source per unit solid angle. The use of the term **intensity** to denote the total quantity of radiant energy, as was being done loosely, is deprecated.

Absorptance (α) is the fraction of the incident radiant flux that is absorbed by a medium or a surface. It is the way by which the energy of a photon is taken up by matter, typically the electrons of an atom. Thus, the electromagnetic energy is transformed to other forms of energy for example, to heat. the absorption of waves does not depend on their intensity.

Reflectance (ρ) is the fraction of incident radiant flux that is reflected through a surface on which the flux is incident. Mirrors are reflectors. In general, shiny, hard surfaces are much better reflectors than direction porous, dark surfaces. Reflection differs from scattering in that the direction of reflection is mirror image of incident photon.

Transmittance (T) is the fraction of incident radiant flux transmitted through a medium. When light simply goes right through a medium, it is transmission. Windows are god example of transmitters, and atmosphere is rather good transmitter when air is clear & smog free.

Emittance (ε) is the ratio of the radiant exitance of a body to that of a black body. It is also referred to as emissivity.

Black Body is a substance which absorbs all the radiant energy incident on it i.e. there is no reflection or transmission of the energy. The substance need not be black in colour. And in practice, a perfect black body does not exist. For a given temperature, a black body has maximum radiant exitance in all wavelengths. Substances which emit a fixed proportion of the energy of a black body and which absorb radiant energy at a fixed proportion are called **grey bodies**. They are related to the black body by emittance and absorptance of the grey body.

Scattering occurs when photons interact with molecules, the result being that a secondary form of radiation emits in many directions at once. Scattering is responsible in for such diverse phenomenon as rainbows and dusk/dawn reddening of the sky. It is also called diffusion in some cases.

Conduction is a mode of transfer of energy within and between bodies of matter, due to a temperature gradient. Only heat moves, not the molecules. Conduction means collisional and diffusive transfer of kinetic energy through particles of ponderable matter (as distinct from photons). Conduction takes place in all forms of ponderable matter, such as solids, liquids, gases and plasmas. Heat spontaneously tends to flow from a body at a higher temperature to a body at a lower temperature.

Convection is the concerted, collective movement of ensembles of molecules within fluids. Convection of mass cannot take place in solids, since neither bulk current flows nor significant diffusion can take place in solids. A good model for convection is when you take a heat source (e.g. burner) and place it at any side of a glass full of a liquid; you then can feel the different levels of heat in the glass.

Radiation: All materials continuously emit and absorb radiative energy by lowering or raising their molecular energy levels. This thermal radiative energy may be viewed as consisting of electromagnetic waves or of massless energy parcels, called photons. Electromagnetic waves travel through any medium at the speed of light *c*, which is $c = 2.998 \times 10^8$ m/sec in vacuum and approximately the same in most gases such as air and combustion products. A hot body emits infrared radiation. The sun is a perfect radiator. Fires radiate heat. A really hot fire glows white; all wavelengths are available in the spectrum. As fire cools down, the color changes to orange, then to red, and finally when you can't see the embers anymore but can still feel the heat, the radiation is entirely infrared. The colors reflect the energy content of the fire.

Concentration Ratio: Concentration of solar radiation is achieved by reflecting or refracting on aperture area $\mathbf{A_a}$ to the smaller receiver/absorber area $\mathbf{A_r}$. CR_o (Optical Concentration Ratio) is defined as ratio of average solar energy flux on the receiver/absorber to that on collector aperture. CR_o gives a true concentration ratio because it accounts for optical losses from the reflecting/refracting elemenmts. However since it has no relationship on to receiver area it does not give an insight into thermal losses which are proportional to the receiver/absorber area. Therefore CR (Geometrical Concentration Ratio) is defined as ratio of $\mathbf{A_a}$ (collector aperture) to the $\mathbf{A_r}$ (receiver/absorber area). i.e. CR = $\mathbf{A_a / A_r}$

3.4 SOLAR RADIATION AND TERRESTRIAL RADIANT ENERGY

The radiant energy from the sun covers the entire electromagnetic spectrum. The atmospheric interference restricts this spectrum to 290nm to 3000nm – which is called "**solar radiation**." The maximum spectral radiant energy, irradiance, is at around 474 nm. The earth and the atmosphere being at much lower temperature (around 270K on an average) emit radiant energy in the infra-red region from 4 to 50µm. This is called "**terrestrial radiation" or "terrestrial radiant energy"**.

Direct Solar irradiance (S): It is the irradiance of the sun emitted from the solid angle of the sun's disc, received by a unit surface held perpendicular to the solar

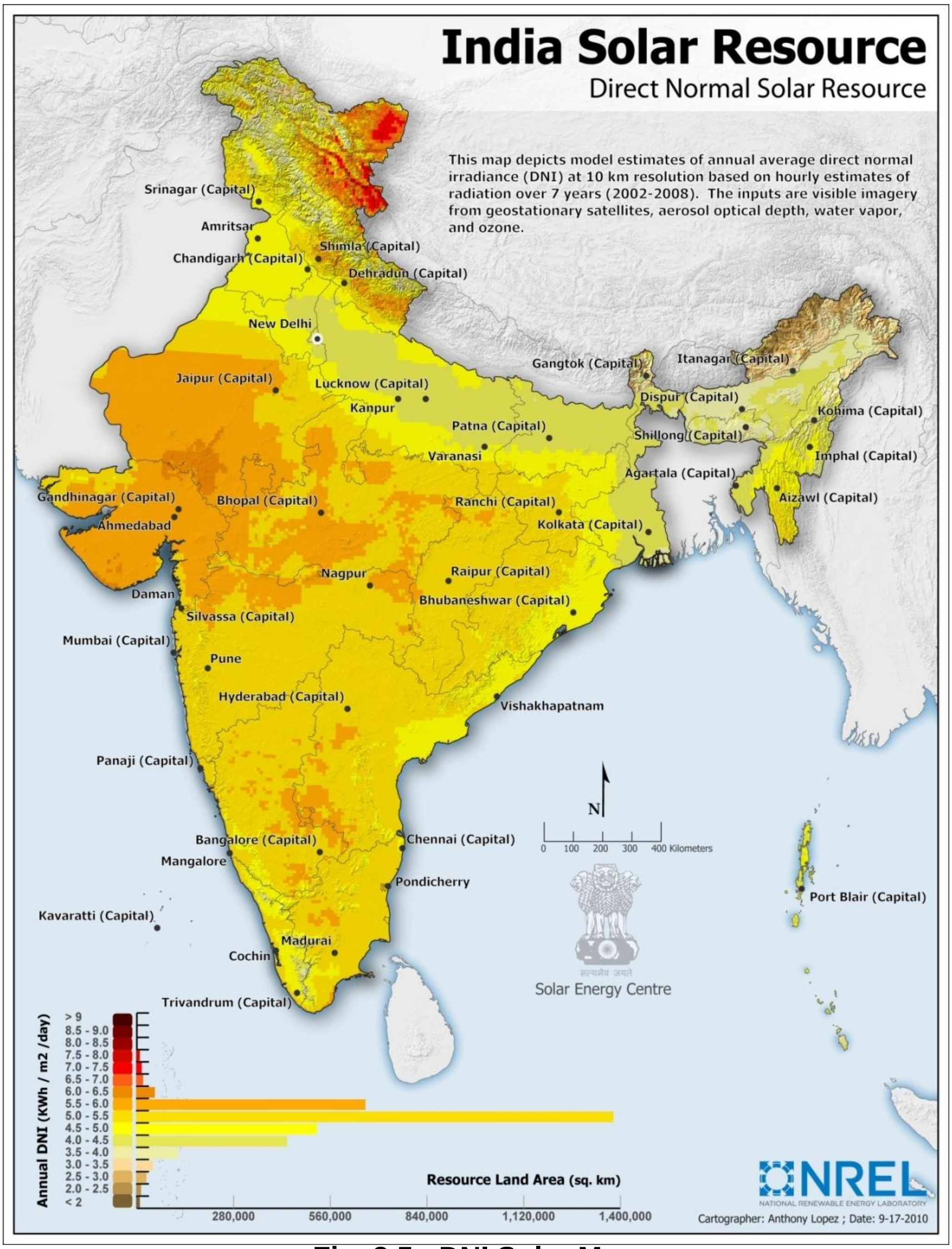


Fig. 3.5 : DNI Solar Map

beam. It includes a small quantity of irradiance that is scattered by the intervening medium along this axis of the cone. The attenuation, if any, is then due to the variation in the relative concentration of the individual constituents of the medium, viz. air. The solar constant is a special case, as it pertains to the value outside the earth's atmosphere and it is denoted by S_o. The term "beam solar radiation" is used to denote the direct solar beam, incident on a horizontal surface. See figure 3.5.

Diffuse Solar irradiance ($E_d\downarrow$): It is the downward irradiance scattered by the atmospheric constituents and reflected and transmitted by the cloud and incident on a unit horizontal surface. This irradiance comes from the whole hemisphere of solid angle of 2π with the exception of the solid angle subtended by the sun's disc.

Global Solar irradiance ($E_g\downarrow$): This is the irradiance that reaches a horizontal unit surface. It is made up of the direct solar beam irradiance and the scattered diffuse solar irradiance. Since the direction of the incident solar beam changes continually from sunrise to sunset, the cosine effect or cosine law comes into play. When a parallel beam of radiant flux of a given cross-sectional area spreads over a flat surface, the area that it covers is inversely proportional to the cosine of the angle between the beam and the normal to the surface. Therefore, the beam irradiance that heats up the area is proportional to the cosine of the angle of incidence. Thus the global irradiance at a place can be written as:

$$E_g\downarrow = S\cos\theta + E_d\downarrow$$

where θ is the angle of incidence. See figure 3.6.

Reflected Solar irradiance ($E_r\uparrow$): Part of the global solar irradiance is reflected by the receiving surface (mainly the earth's surface and diffusely by the atmospheric layer between the surface and the point of measurement.) This is as termed reflected solar irradiance.

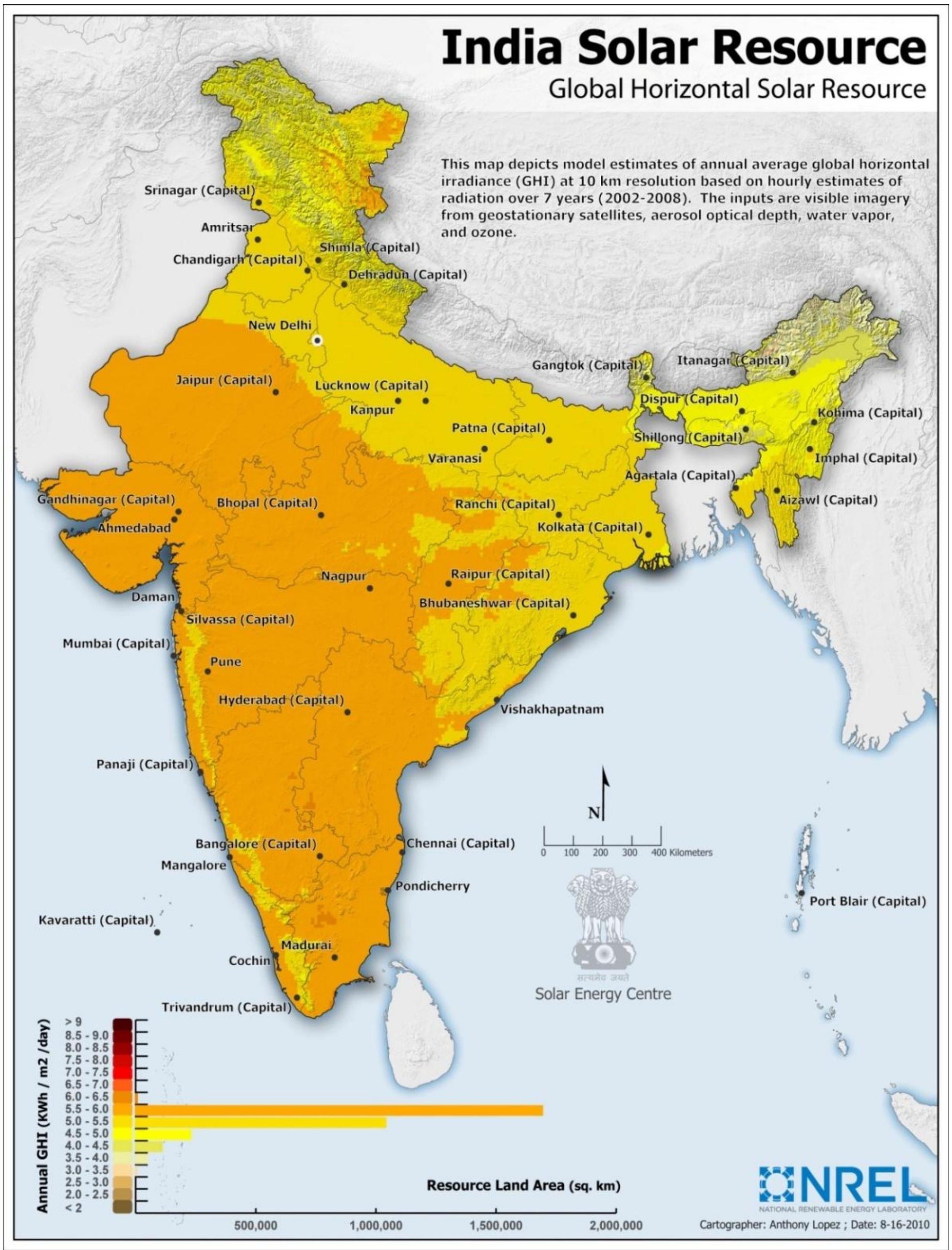


Fig. 3.6 : GHI Solar Map

Irradiation: It is the incident irradiance on a unit area integrated over a specified time interval generally over an hour or a day. See in figure 3.5 and 3.6.

3.5 SOLAR TECHNOLOGY

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar energy technologies include solar heating, solar photovoltaic, solar thermal electricity and solar architecture, which can make considerable contributions to solving some of the most urgent problems the world now faces.

Solar Technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors 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.

3.6 METHODS OF SOLAR ENERGY UTILIZATION

All manner of devices have been used to convert solar radiation or its effects into useful energy. There are two main categories for the conversion devices, as they rely upon either the direct radiation for impetus or harness a by-product of solar radiation.

3.6.1 DIRECT HARNESSING

Direct Harnessing is the more capital intensive means by which to utilize solar radiation. The expense comes from the necessity to cover a large sunlight area to capture the sparse incoming radiation which is to be converted into useful energy. Within the direct category a further subdivision into: Direct Heating, Photovoltaic conversion and Chemical conversion is possible.

A) Direct heating has only recently been used in passive solar building design (50^{o}C). It is also possible to heat fluids via flat plate solar collectors (40-100^{o}C), e.g. hot water systems. For large concentrations of radiation, temperatures of 100 to 3000^{o}C are possible. The use of parabolic or many-directional mirrors (heliostats) achieve the energy density and temperatures to enable, on the large scale, high fluid pressures and temperatures for power generating applications, on the small scale cooking and heating food is possible.

B) Photovoltaic (conversion) arrays are the most modern form of direct conversion. They convert radiation into an electric current via a silicon junction. Having been around since the 1950's (Maxwell, 1983) they are becoming ever cheaper to produce, efficiencies in the order of 8 to 15% are common, and they have a maximum theoretical possible efficiency of 23%.

C) The **chemical** (conversion) process is most commonly used by plants in the photosynthesis process; they are generally between 0.2 and 5.6% efficient. This process is essentially the basis of all life on earth; it is at the very base of the food chain and is also the indirect producer of the fossil fuels which are currently being consumed. This complex natural reaction produces biomass and is not used in any human made reactors.

3.6.2 INDIRECT HARNESSING

The indirect consequences of radiation are the most commonly exploited form of renewable resources for the production of useful energy. This is due to the radiation having already been collected and converted into a form which has a greater power density than the original radiation. The major indirect methods of conversion are: Hydro, Wind and Ocean Thermal.

A) Hydropower is the most prolific and thus historically the most economic form of indirect harnessing of solar energy. Precipitation is collected over vast areas of elevated surfaces (hills) and is then channelled through a turbine as it descends to sea level. The conversion efficiency of water potential energy to power can reach 90%. The water's potential energy is able to be harnessed on all scales from large dams to micro hydro units. Pressure heads and flow rates are accommodated by the use of appropriate wheels or turbines.

B) Wind power has reached a point where it is possible to generate electricity commercially in wind farms (e.g. in California). The wind power systems use large propellers or vertical axis blades to canvas a large area of wind and extract kinetic energy. The most common wind plants are the high speed two blade propeller types, but different conditions may suit other varieties better. In general the power extractable from the wind increases with the cube of wind velocity, so the more windy the location the more economic the wind power will be. There is a 58% maximum theoretical efficiency for the wind to power conversion.

C) Ocean thermal systems work by using the small temperature gradient in the sea (especially near the equator) to run a heat engine type cycle. The temperature difference can be in the order of 25 K and the size of the resource is very large. Unfortunately the negative points are overpowering, being the low conversion efficiency because of the small operating temperature difference and the corrosion problems due to the plant's placement in sea water.

3.7 MINISTRY OF NEW AND RENEWABLE ENERGY

India's search for new and renewable energy resources that would ensure sustainable development and energy security began in early 70's of the last century. Consequently, use of various renewable energy resources and efficient use of energy were identified as the two thrust areas of the sustainable development. Realising the need for concentrated efforts in this sector, the Government of India established a CASE (Commission for Additional Sources of Energy) in the Department of Science and Technology, in 1981. The mandate of CASE is to promote research and development activities in the field of renewable energy. CASE was formally incorporated in 1982, in the newly created Department of Non-conventional Energy Sources (DNES). In 1992 DNES became the Ministry for Non-conventional Energy Sources, commonly known as MNES.

The Ministry continues to support the implementation of a large broad-spectrum programme covering the entire range of new and renewable energies. The Ministry has Regional Offices, three specialised research Institutions and a non-banking financial company: IREDA (Indian Renewable Energy Development Agency) - under its administrative control to promote its policy and programme initiatives. The following sections cover Government of India's major programmes, policies and incentives for the promotion of renewable and non-conventional technologies in India.

3.8 POLICIES

This section covers the policies and programmes of the Government of India, for promotion of the renewable and biomass energy utilisation in India. Today, we can get benefits from a rich set of policies that have been made at national and local levels. In India, JNNSM (Jawaharlal Nehru National Solar Mission) is most useful policy for solar based projects. The objective of the JNNSM [*Reference-25*] under the brand 'Solar India' is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible.

3.8.1 RENEWABLE ENERGY POLICIES

A comprehensive RE Policy for all-round development of the sector, encompassing all the key aspects, has been formulated by MNRE. The broad objectives envisaged in the draft policy are:

- Meeting the minimum energy needs through RE.
- Providing decentralised energy supply in agriculture, industry, commercial and household sectors in rural and urban areas, and
- Providing grid quality power.

The policy envisages 10% of additional grid power Generation capacity to come from RE by 2012. The policy is awaiting approval by the Government.

3.8.2 POLICY FOR ALL-ROUND DEVELOPMENT OF RENEWABLE ENERGY

Policy measures aim at overall development and promotion of renewable energy technologies (RETs) and applications. Policy initiatives encourage private as well as FDI including provision of fiscal and financial incentives for a wide range of RE programmes. Further, the procedures have been simplified, and provide excellent opportunities for increased investment in technology up- gradation, induction of new technologies, market development and export promotion.

3.8.3 FOREIGN INVESTMENT POLICIES

- Foreign investors can enter into a joint venture with an Indian partner for financial and/or technical collaboration and for setting up of RE-based power generation projects
- Proposals for up to 100 per cent foreign equity participation in a joint venture qualify for automatic approval.
- Hundred per cent foreign investment as equity is permissible with the approval of the Foreign Investment Promotion Board (FIPB).
- Foreign investors can also set up a liaison office in India
- The Government of India encourages foreign investors to set up power projects on BOO basis. Investors are required to enter into a power purchase agreement with the concerned state government

- The Government of India also encourages foreign investors to set up RE-based power generation projects on Build, Own and Operate (BOO) basis. Various Chambers of Commerce and industry associations in India provide guidance to the investors in finding appropriate partners
- No prior approval of the government is required to set up an industrial undertaking with Foreign Direct Investment (FDI) by Non-Resident Indians (NRIs) or Overseas Corporate Bodies (OCBS)
- The Reserve Bank of India (RBI) has permitted Indian companies to accept investment under the 'automatic route' without obtaining prior approval from RBI. Investors are required to notify the regional office of RBI, of receipt of inward remittances within 30 days of such receipt and file required documentation within 30 days of issue of shares to foreign investors

FIPB (Foreign Investment Promotion Board) :-

- The FIPB has been revamped and made itself the single-window agency for all matters relating to FDI as well as for promoting investment into India
- The Board is chaired by the Secretary (Department of Industrial Policy & Promotion), Government of India
- It provides appropriate institutional arrangements, transparent procedures and guidelines for investment promotion and to evaluate proposals for foreign investment (other than those eligible for automatic approval by the Reserve Bank of India)
- FIPB would also monitor implementation of mega projects to facilitate further investment and remove bottlenecks
- The Board considers all investment proposals with or without technical collaboration and/or industrial license

- FIPB has made available a mailbox facility for filing applications: The e-mail address for the same is “siaapplication@ub.nic.in”. The format is available at www.indmin.nic.in
- This Board meets every week and considers all applications within 15 days of their receipt with the endeavour to communicate decisions to the applicants within four weeks

FIIA (Foreign Investment Implementation Authority) :-

- The FIIA has been set up in the Ministry of Commerce and Industry to translate FDI approvals and implementations
- It is headed by the Secretary (Department of Industrial Policy & Promotion) and is serviced by the SIA
- FIIA would provide a one-stop after-care service to foreign investors by helping them to expedite approvals and clearances and to sort out operational problems with other government agencies
- The FIIA will act as a single-point interface between the investors and government agencies including administrative ministries, state governments, Pollution Control Boards, Directorate General of Foreign Trade, regulatory authorities, tax authorities and Company Law Board among others
- Approval holders have been requested to get in touch with the respective officers in FIIA

3.8.4 INDUSTRIAL POLICY

- MNRE is promoting medium, small, mini and micro enterprises for manufacturing and servicing of various types of RE systems and devices.
- Industrial clearances are not required for setting-up of an RE industry

- No clearance is required from Central Electricity Authority (CEA) for power generation projects up to Rs 1,000 million
- A five-year tax holiday is allowed for RE power generation projects
- Soft loans are available through IREDA for RE equipment manufacturing
- Facilities for promotion of Export Oriented Units (EOUS) are available for the RE industry
- Financial support is available to RE industries for R&D projects in association with technical institutions
- Import of power projects are allowed
- Private sector companies can set up enterprises to operate as licensee or generating companies
- Customs duty concession is available for RE spares and equipment, including those for machinery required for renovation and modernisation of power plants. Excise duty on a number of capital goods and instruments in the RE sector has been reduced or exempted

3.8.5 POLICIES BY STATE GOVERNMENTS

- A number of states have announced policy packages including banking, third party sale and buy- back, which have been outlined in the respective technology or programme areas in this publication
- Some states are providing concessions or exemption in state sales tax. These rates vary widely from state to state and between different technologies.
- Fourteen states have so far announced policies for the purchase and support of electrical energy generated from various RE sources.

3.9 JHAKHAND SOLAR POLICY, 2013

A shining policy is, finally, in place to tap the resources of the sun and make Jharkhand an energy-efficient state. Jharkhand Solar Policy 2013, prepared by the department of energy, is the first such move to attract investments in the green power sector to meet both domestic and industrial needs.

The draft policy, released in June, 2013 on jharkhand.gov.in, inviting suggestions, recommendations or objections, offers incentives for generating companies to the tune of 50 per cent duty and cess waivers.

Once agreed upon and approved, the policy will ultimately make it mandatory for government buildings and commercial and residential complexes to install solar plants or rooftop gadgets for in-house use.

Government of Jharkhand State is intended to promote solar energy through two means. “First, by paving a platform for big, small and micro industries to come forward to generate power and allied services. Second, by enforcing its use in offices, commercial establishments and households through various subsidies and incentives and reduce load on discoms (distribution companies).” Commercial players can directly sell power to the state electricity board or outside, according to provisions in the draft.

As incentive, provisions for electricity duty and cess exemptions for all solar power projects have been made. “Captive units can enjoy 50 per cent off on electricity duty for a period of five years. There are other incentives like all power projects under the solar policy will be granted the status of an industry under the Industrial Policy 2012. They will receive benefits under the latter like procurement of solar equipment will be exempted from VAT. In a nutshell, the draft addresses most concerns of stakeholders," the under-secretary said.

Further, once the policy is in force, both government and non-government buildings will have to have solar plants or rooftop solar gadgets for in-house use.

"All public buildings will be required to have solar power generation facilities on build, operate and own basis. Departments concerned will have to install solar plants within a period of three years. Jharkhand Renewable Energy Development Agency (JREDA) will prepare the list of empanelled firms from which every office/department shall be free to choose one," says the draft.

Commercial establishments such as star hotels, hospitals and residential complexes, with more than 50KVA total connected load, the use of solar water heating systems shall be made mandatory. In the domestic field, all new buildings having floor area equal to or greater than 3,000ft^2 will have to have at least 100kW solar photo-voltaic system to replace diesel-based generator systems. In case of housing societies, five per cent of energy use is mandatory from solar source for common amenities.

"Non-compliance after the grace period of three years shall attract penalty in the form of green cess to be decided by the appropriate authority," the 16-page draft adds.

The policy will be implemented from the date of its notification and remain in force for five years until modified or superseded by the state, whichever is later.

The extensive policy covers all necessary aspects such as incentives, land use and availability, legal provisions, et al. It, thus, provides a roadmap and encourages people to join hands to tap the natural resource.

The energy department has made a final move to get the policy notified in the form of an act after July 15. Provisions endorsed in it would have to be followed by all.

Chapter – 4

THEORETICAL STUDY OF SOLAR CREMATORIUM

4.1 CREMATION PROCESS

A crematorium is a furnace that is able to generate temperatures of 760–1150°C to ensure disintegration of the corpse. Cremation is the process of burning a dead body at very high temperatures until there are only brittle, calcified bones left, which are then pulverized into "ashes." These ashes can be kept in an urn, buried, scattered or even incorporated into objects as part of the last rites of death.

The heat raises the temperature of the cremator. During the cremation process, the greater portion of the body (especially the organs and other soft tissues) which is composed of 75 percent water is vaporized and oxidized by the intense heat; gases released are discharged through the exhaust system. As the soft tissues begin to tighten burn and vaporize from the heat, the skin becomes waxy, discolors, blisters and splits. The muscle begins to char, flexing and extending limbs as it tightens. The bones, which are the last to go, become calcified as they are exposed to the heat and begin to flake or crumble.

The time required for cremation varies from body to body, and, in modern furnaces, the process may be as fast as one hour per 45 kg of body weight. An average human body takes from two to three hours to burn completely and will produce an average of 1.4 to 4.1 kg of ash.

4.1.1 ASH WEIGHT AND COMPOSITION

Cremated remains are mostly dry calcium phosphates with some minor minerals, such as salts of sodium and potassium. Sulfur and most carbon are driven off as oxidized gases during the process, although a relatively small amount of carbon may remain as carbonate.

The ash remaining represents very roughly 3.5% of the body's original mass (2.5% in children). The amount of ash depends usually on the bone structure of the person and not so much on their weight. A newborn, which has mostly cartilage and very little set bone, even might not leave any residue after the cremation. Because the weight of dry bone fragments is so closely connected to skeletal mass, their weight varies greatly from person to person. Because of many changes in body composition (such as fat and muscle loss or gain) do not affect the weight of cremated remains, the weight of the remains can be more closely predicted from the person's height and sex (which predicts skeletal weight), than it can be predicted from the person's simple weight.

Ashes of adults can be said to weigh from 1.8 kg to 2.7 kg, but the first figure is roughly the figure for women, and the second, for men. The mean weight of adult cremated remains in a Florida, U.S. sample was approx. 2.4 kg for adults (range 0.91 to 3.63 kg). This was found to be distributed bimodally according to sex, with the mean being 2.7 kg for men (range 1.8 to 3.6 kg) and 1.8 kg for women (range 0.91 to 2.72 kg). In this sample, generally all adult cremated remains over 2.7 kg were from males and those less than 1.8 kg were from females.

4.1.2 FACTORS AFFECTING CREMATION TIME

The duration of a cremation process usually depends on certain factors. They are:

- weight or size of the body
- percentage of body fat to lean muscle mass
- the performance of cremation equipments used

- operating temperature of the cremation chamber
- the type of cremation container or casket in which the body is placed

4.2 CONCEPT OF THE SOLAR CREMATORIUM

The basic concept of solar crematorium is to ignite the dead body locally anywhere and anyhow with the help of a huge concentrating reflector having very high CR and to maintain the combustion of dead body by supplying the fresh atmospheric air with the help of blower. Once combustion of dead body starts within the cremation chamber, it also releases heat which automatically in combination with solar energy obtained from concentrating reflector maintains continuous burning of dead body until complete dead body gets converted into ash.

With a huge 197m^2 parabolic reflector, the system can achieve temperature up to 1200° C. This temperature is sufficient for burning human or

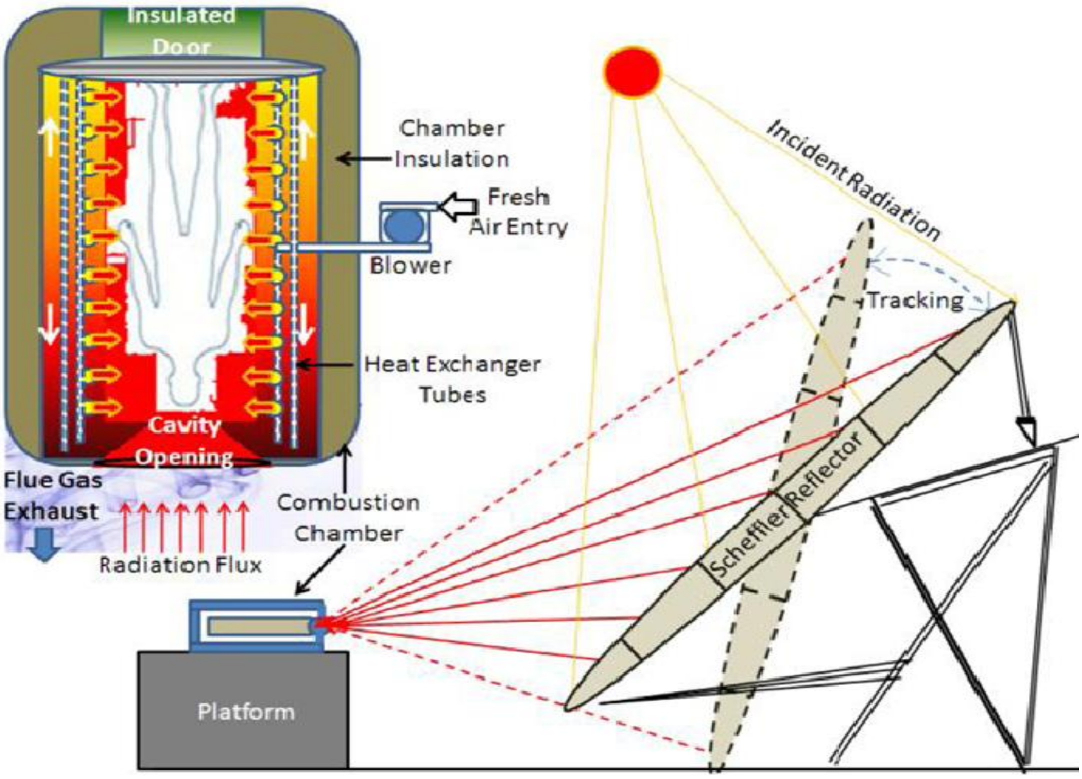


Fig. 4.1 : Block Diagram of Solar Crematorium

animal body. The reflector concentrates all the energy received from the Sun on a chamber where the body is kept, hot air is blown through the blower in chamber, which helps to acquire uniform temperature across the chamber. Chamber is designed in such a way that the solar radiation gets reflected from its inner wall and concentrates on the plate where dead body is kept, thus making full use of the Solar Energy and increasing the overall efficiency. Backup system is provided by Biogas/Biomass/LPG/CNG fired furnace.

In order to successfully procure and operate a solar crematorium, specifications and recommendations for the (a) system design, and (b) guaranteed performance parameters are given. The system design specifications primarily include controllability, stability and accuracy of the support structure; well-specified reflectors; and insulation and operation of heat exchanger in the cremation chamber.

The parameters requiring guarantees include thermal efficiency of the cremation chamber; time taken to reach cremation temperatures and complete cremation process; limit of system degradation; and guaranteed service life of the system at 5 years.

Based on above discussion, system of solar crematorium can be divided into following four components. All these components are described in forthcoming subsections.

- **Scheffler Reflector**
- **Tracking System**
- **Cremation Chamber**
- **Backup system for non sunny hours**

Further, a broad SOP (Standard Operation Procedure) and System Validation Method are recommended. These procedures are supported by sensors which are also recommended. In conclusion, it is established that a well-designed and maintained system is capable of solar cremation. Utmost care should be taken in maintaining such a system and operating at appropriate weather conditions. It is finally recommended that such systems should be highly promoted to conserve energy and foster a cleaner environment.

4.3 SCHEFFLER REFLECTOR

Parabolic Scheffler Reflectors can provide (you with) high temperature heat for all types of cooking, steam generation and many other applications. **Their speciality is a flexible surface curvature and a nonmoving focal area**. Therefore their use is now becoming increasingly popular in many parts of the world, especially in India.

4.3.1 DESIGNING THE SCHEFFLER REFLECTOR

The **size** (Aperture Area) of Scheffler reflector is determined by reverse design procedure. Which is described step by step as following :

- First of all "**E**" (total energy) required to burn completely a single dead body is calculated. Since a traditional Hindu funeral pyre takes 2-3 hours and consumes 500–600kg of open wood pile to burn completely a corpse. But Mokshda, a Delhi-based non-governmental organization has created an alternative cremation system that reduces heat loss. With it, it takes up to two hours and 150–200 kilograms of wood to burn a corpse. According to Vinod Kumar Agarwal, the founder of Mokshda, with proper and complete combustion, 22 kg of wood is sufficient to burn down a body. Considering above facts, 100kg of wood is used for cremating a single corpse in 1 to 2Hrs if heat loss is optimized to minimum value by effective insulation of combustion chamber. Since calorific value of wood is 19700kJ/kg. Therefore

$$E = 100kg \times 19700kJ/kg = 1970000kJ = 1970MJ$$

- Now "**P**" power (in MJ/hr) required to burn completely the body in combustion chamber is determined. If we design a reflector to cremate a dead body in 2hrs then this (total energy) "**E**" required to burn completely the dead body must be obtained/captured by the reflector within 2hrs. Therefore

$$P = \frac{1970MJ}{2Hrs} = 985MJ/Hrs$$

- Finally "**A**", **size** (Aperture Area) of Scheffler reflector is determined. Since DNI (Direct Normal Irradiance) is 5MJ/m^2hr (≈ 4.9212 MJ/m^2hr = 1367W/m^2 X 3600sec). So Aperture Area "**A**" is obtained by dividing "**P**" (power) with DNI.

  i.e.

$$A = \frac{P}{DNI} = \frac{985MJ/Hr}{5MJ/m^2\,Hr} = 197m^2$$

4.3.2 MATERIAL OF SCHEFFLER REFLECTOR

The Scheffler reflectors are made up of several small double sided (two plane mirrors are joined on their each other silver coating sides) plane mirrors. Theoretically single sided mirror is sufficient for the Scheffler reflector, but double sided mirror is used to protect the silver material which is coated on the almost completely transparent glass. Because of intense heat and temperature of solar energy there is possibility of silver coatings to melt away from the rear surface of the glass. Therefore the rear side mirror protects the silver coating to melt away by reflecting back the sunlight if any from rear side, and simultaneously by avoiding the erosion and corrosion. This rear side mirror also provides the additional strength to the front mirror.

The efficiency/reflectivity of several plane mirrors in the Scheffler reflector ranges 90-95% when new. Though it is not important much more, because efficiency is greatly considered where we pay money for energy/fuels which (solar energy) is free here. Here efficiency/reflectivity of mirror is only considered to determine size (aperture area) of the Scheffler reflector.

4.4 TRACKING SYSTEM

Since the speciality of Scheffler reflector [*Refence-20*] is flexible surface curvature and a nonmoving focal area. Their use is now becoming increasingly popular in many parts of the world, especially in India. Almost all concentrators have a rigid structure and the focus, the hot area where all light is concentrated, moves along with the direction of the sun. This makes its use a little bit impractical.

This is a paraboloidal mirror which is rotated about axes that pass through its centre of mass, but this does not coincide with the focus, which is outside the dish. If the reflector were a rigid paraboloid, the focus would move as the dish turns. To avoid this, the reflector is made flexible, so it is bents as it rotates so as to keep the focus stationary. Ideally, the reflector would be exactly paraboloidal at all times. In practice, this cannot be achieved exactly, so the Scheffler reflector is not suitable for purposes that require high accuracy.

4.4.1 STOPPING THE SUN

The sun gives us the impression of movement basically because the earth is revolving under our feet. One way to stop moving while rotating is to locate yourself in the center or axis of the rotation. Imagine a carousel. When you go to its center, you will still rotate, but will not move sideways any longer. The same way, the hot focus of the Scheffler Reflector is placed in the axis of rotation of the reflector. Thus it remains in a fixed place, giving maximum convenience.

4.4.2 MOVING WITH THE SUN

Just as the earth spins around an axis through the North Pole and the South Pole, the Scheffler Reflector spins around an axis parallel to that, just in the opposite direction. (It counteracts the earth's rotation, cancel it out.)

This is called polar mounting or mounting on a polar axis. The speed is one revolution per day, or, better, half a revolution in half a day, since we do not use at night. This way the reflector keeps facing the sun in a constant manner. The constant speed is controlled with mechanical clockwork. For practical reasons, the shape of the reflector is such that the hot focus is outside of the reflector, either on the north side or the south side. This way the hot focus can be even inside a building while the reflector remains outside.

4.4.3 BENDING AND FLEXING, THE MOST UNIQUE FEATURE OF THE SCHEFFLER REFLECTORS

This is the most important point of the design of the Scheffler reflector, and is normally completely overlooked by people who see the reflector. In winter, the sun is low above the horizon, while in summer it moves high up into the sky. Under these changing conditions, having a different angle of the sunlight everyday, it is difficult to maintain a small and hot focus in a fixed place during all the four seasons. The design of the Scheffler Reflectors provides the only widespread solution to this demanding situation. First it sounds almost unbelievable, but the reflector is made to change the shape of its entire surface to adapt itself to the different angles of the sunlight.

This way, a small and hot focus is achieved during all seasons. This sounds very complicated to make and to handle, but it turns out not to be so.

If you take a round or elliptical piece of orange peel and slightly squeeze it in your hand, you get a similar change of shape as it is required for the reflector. When you squeeze it, in one direction it will become more curved, while in the other direction it flattens out a bit. When you pull it apart instead, it will flatten out in this direction and curve in the other one. This gives you the basic idea on what type of shape change is required for the reflector to achieve a small focus at

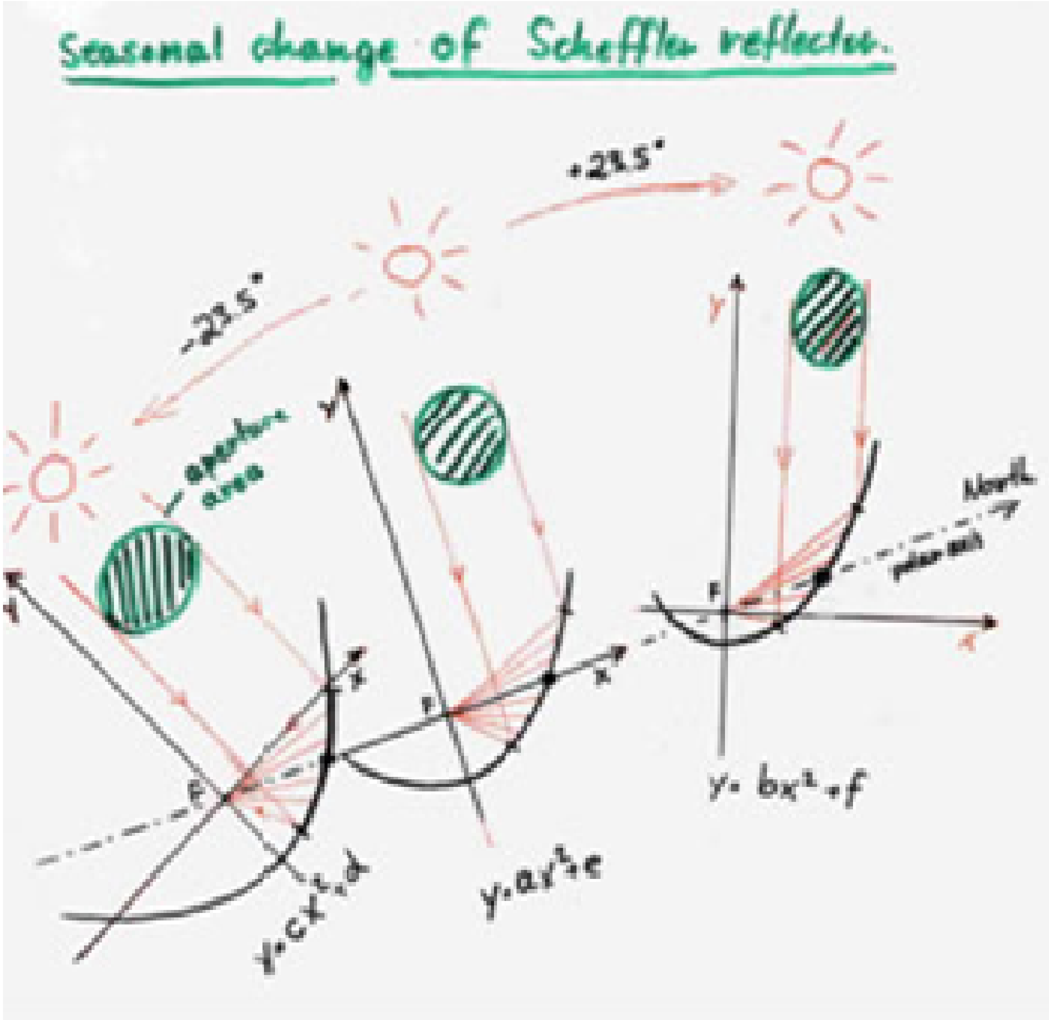


Fig. 4.2 : Different parabolas focus the sunlight at different seasons. The incident light has to be parallel to their y-axis. Note the seasonal change in the aperture area, focus "F" and the center of the Scheffler reflector (black dot) remain stationary

all seasons. For the real reflector all these shapes are of course calculated first. A scientific pocket calculator and your school math are sufficient to do this job. It's all based on the equations of a parabola and straight lines and calculating their intersection points.

It also uses the fact that whenever you cut a paraboloid with a plane, you get an ellipse; in school we used to learn this only for a cone. That is why the Scheffler reflectors have this typical elliptical shape.

The small straight section of the frame near the focus improves the flexing behavior in that section. This is found by trial and error method. Reflectors like the SK-14 (used for cooking or, steam generation) are circular. This is because their plane of cutting is perpendicular to the paraboloid. In that special case the short and the long diameters of the ellipse become of the same length and we get a circle. After a lot of observation done on Scheffler reflector it is found that five points are sufficient to support the reflector frame. And, very important, only two of them needed to be adjusted in order to create all different shapes required during the whole year. These two are adjusted manually after every few days, just pushing or pulling them until all light enters the hot focus again properly.

It is very important to keep the number of adjustments to this minimum; otherwise it is felt that handling would be too cumbersome for the user. Actually a third adjustment in the center of the dish would have been necessary, but after studying the geometry for some time, it is found that it could be designed this adjustment as an automatic lever. The lever pushes the center of the reflector forward or retracts it automatically when the reflector is set for the seasonally lower or higher sun. At that time, the angle of the reflector towards its mounting along the polar axis changes, and the lever is activated. The whole structure is well balanced and easy to turn. It is made from light iron tubes and bars, which are softer in the places which require more bending (like near the focus) and stiffer where less bending is appropriate (the areas far from the focus).

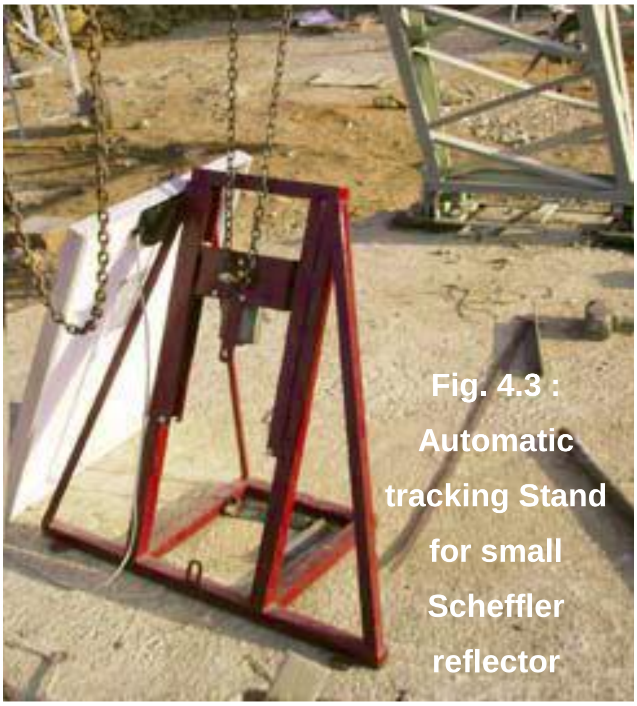


Fig. 4.3 : Automatic tracking Stand for small Scheffler reflector

Fig. 4.4 : Crematorium tracking stand aligned with back crane and reflector frame

The power output varies with the season (see Fig. : 4.2). The Sun which shines more from the front into the reflector sees a larger reflector (large aperture), and thus more power is collected. In the same way, a sun shining more from behind sees a smaller reflector and less power is collected. A 2.7 m² reflector can typically bring 1.2 lts of water to boiling point within 10 minutes. The circle in figure 4.5 at the center highlights the position of the lever for the seasonal shape change.

Fig. 4.5 : Manual changing of length of the reflector's rear support for seasonal adjustment

4.5 CREMATION CHAMBER

Within the chamber where the body is placed is called a *retort* and is lined with heat-resistant refractory bricks. Refractory bricks are designed in several layers. The outermost layer is usually simply an insulation material, *e.g.*, mineral wool. Inside insulation is typically a layer of insulation brick, mostly calcium silicate in nature. Heavy duty cremators are usually designed with two layers of fire bricks inside the insulation layer. The layer of fire bricks in contact with the combustion process protects the outer layer and is required to be replaced from time to time. Refractory bricks are typically replaced every five years, because thermal fatigue gradually introduces fissures that reduce the insulating strength. For heavy duty cremators having an inner sacrificial layer of refractory material, often cracks, slagging, bulging and dislocation can be seen on this layer shortly after the cremator is put into use.

The coffin or container is charged (inserted) into the retort as quickly as possible to avoid heat loss through the top door. The container may be mounted on a charger (motorised trolley) that can quickly insert it, or on a fixed or movable hopper that allows the container to slide into the cremator.

First the chamber will be heated without air blower. When the temperature of the chamber reaches about 800°C, then the body can be inserted into the cremation chamber and the well insulated door can be closed. About 150kg of air per hour is required in the combustion chamber. This air first passes through 15 heat exchanger tubes (above the body) from the back to the front of the chamber, then it enters into the preheated chamber through many small holes. For this optimal combustion, an air blower (maximum 0.75kW, 220Volt AC) is needed. The hot flue gases leave the chamber through the focal area which results in a secondary combustion and like that no smoke should be in the exhaust gases. The calculated time for cremating a 60 kg body, is about one to two hours.

Concerning the airflow for combustion, we have two arrangements. First one has already been discussed. In other arrangement; we may use a counter-flow heat exchanger to preheat the fresh air with the hot exhaust gases. A suction blower pulls the hot exhaust gases from the back of the chamber through the heat-exchanger and out through a chimney. At the same time a second blower provided the fresh inlet-air, which also passed the heat-exchanger and then entered the chamber. During operation, the flow of both blowers was balanced so that there was almost no net-flow through the opening of the chamber at the focus.

Fig. 4.6

Flue gases leaving the chamber through focus opening, A long flame is seen burning off without visible smoke

4.6 BACKUP SYSTEM FOR NON-SUNNY HOURS

The actual harnessing of the solar energy can happen unless you're in a very hot sunny climate days but the need for energy is often greater in rainy, cloudy or, colder climates. So it can be unreliable. On the other hand we are intended to investigate the possibility of employing solar energy for Hindu ritual of cremation. This arise a concern regarding sentiments connected to the cremation process. **As per Hindu ritual practice, there is an established sentimental fact of cremating the corpse completely at one goes. And there must not be left any un-burnt portion of the body. Otherwise the soul of that person will remain unsatisfied, and it will be converted into the devil or imp which will victimize or terrorize the concerned relatives for his/her satisfaction**.

Therefore there must be an arrangement of suitable and sufficient backup system to mitigate the above situations. So the cremation chamber must be designed in such a way that other alternate fuels like Biogas/Biomass/LPG/CNG can be fired if required.

4.7 DEVELOPMENT OF SOLAR CREMATORIUM

As the main challenge is to have a very small focal area, the whole frame has to be adjustable for exact positioning during the different seasons of the year. Electrical DC motors with gear boxes have to be installed and tested for an improved seasonal adjustment (+/-23.5 Degree). All the parts have to become very precise in order to have minimum mistakes in the focal area.

A place near a river is chosen as place for the new crematorium. The correct geographic North-South alignment is marked and so we are able to prepare the layout for the foundations on this piece of land belonging to village. The focus should be around 240mm diameter but in morning and evening positions the frame is twisted which results in a bigger focus. The stand, the rotating support and the wings of the frame and small parts got sandblasted and primer was sprayed twice as anti-corrosion measure. Finally painting is applied at the new place of erection (income

Fig. 4.7 : Foundation for stand: Reinforced concrete

generation in rural areas). The frame parts are mounted to the rotating support on the ground. As soon as the concrete is hardened, the stand and the back-crane of the stand (for lifting the stand up and down) got installed with the help of a mobile crane. The exact alignment of the stand (bearings parallel to polar axis) was adjusted. During the different phases of the project practical education is integrated in order to make the operator able to use the system properly. After the mirrors are all mounted on the crossbars of the frame (see Fig. : 4.9) we needed again a crane to lift the finished frame with the rotating support into the bearings of the stand. Before lifting up the stand with its back crane, all electrical installations have to be tested. The seasonal adjustments are now regulated so that the frame has the correct paraboloid for the day. On the right height and in the correct instance we prepare a provisorily stage for measuring the focal area because the platform for the chamber is not ready then. As mentioned in the Summary, the focal area has a diameter of 240 mm. In order to correct the twisting in the morning and the evening position, 8 instead of 4 wire ropes are connected to the 4 edges of the frame with an elastic telescope column in the middle of the frame.

Fig. 4.8 : Aligned Stand & Back Crane

Fig. 4.9 : Top View of the Cross-bar Stand

Fig 4.10 : Platform 6.3 X 9 m^2 under construction Where chamber will be placed

As soon as the platform is ready, the chamber can be tested. If the temperature inside the chamber is reaching at 800 degree Celsius, then small animals like e.g. dead dogs can be cremated in order to see, if the system can start to benefit human families soon.

Fig. 4.11 : Chamber (front) arrives in; Focal-opening 240 mm diameter, Connection for air-blower at the side

Fig. 4.12 : Chamber (back-side) with wooden bier on trolley & insulated "Closing Door"

4.8 FURTHER STEPS

- Finishing platform
- Putting the chamber in correct position (Focus)
- Testing temperature in chamber. How much time is needed to heat the chamber? What is the maximal temperature? Is it needed to expand the opening of the chamber from 240 mm to 260 mm diameter? Testing combustion

Fig 4.13 : Dead body being inserted in Crematorium

with dead animals like e.g. dogs. What is the optimal quantity of air per hour for a good combustion? Etc.

- Stronger motor
- Mounting and testing Automatic tracking system
- Making all motors movable from central control panel. All the positions of the moving parts must be readable on the digital control boards from the control panel.
- Painting all before next monsoon

- Rain protection for chamber and other equipment like blower, control panels (reflector; chamber) etc.
- Correcting glass mirrors which are not in correct position between crossbars
- Caring, that the environment around the solar crematorium is respected (waste management; no cars or trucks if not necessary; not allowing to pollute the ground or the river)
- Organizing backup system, for reliable crematorium procedure unstable weather)
- Maintaining the system

Chapter – 5

FEASIBILITY STUDY IN INDIA

Contrary to popular perception, electric crematoriums also lead to more pollution than the traditional Hindu style of cremation, involving burning the body on a pyre. The UNDP report informs that electric cremation is nearly seven times more intensive in terms of emission of green house gases as compared to the traditional Hindu style. Solar crematorium also appears to be a viable option, suggests V Ramesh of Karnataka Renewable Energy Development Limited. India is the front runner in this regard, with Baroda, a city in Gujarat equipped with the world's first solar crematorium. It was developed by Wolfgang Scheffler, a Swiss national and Ronnie Sabbawala of Rashron Energy and Auto limited. The body is burned exclusively using solar energy. The second solar crematorium is to be erected in Patna, Bihar, by 2013.

But this method also has certain disadvantages. Solar crematoriums are impossible in many parts of India during the winters and monsoons. Also, they can be used only during the day as long as the sun shines. Built with an investment of ₹75 Lakh, the solar crematorium does not need electricity or gas. It makes it an energy and cost efficient.

Applications in Remote villages where wood is scarce and no electricity; Solar Crematoriums have high potential to be used in Gram-Panchayats & municipal corporations.

In north India, solar crematorium can be constructed at Yamuna Ghat near Nigam-Bodh Ghat in Delhi, at Bass-Ghat near Ganga in Patna and in Banaras as well as Haridwar and other places.

5.1 DEMANDS OF CREMATION FACILITY

Key factors affecting demand for burial and cremation facilities are:

- **<u>Population</u> :** Running cost of crematorium will be relatively low where there is large population. Here in India, there is no problem of population as India is the second most populous country of the world. And the population too is increasing at very high growth rate.

- **<u>Age Structure</u> :** The general mortality rate conceals great variation according to age. Hence there is very high importance of examining the age structure of the given area (locality). Whilst the population is projected to grow, particularly in the pensionable age groups which have the highest death rates, the reducing death rates will result in a relatively small rise in the number of deaths. Mortality rates are highest amongst the elderly, who will represent and growing proportion of the population of India.

- **<u>Mortality Rates</u> :** Mortality rates have fallen considerably over the last hundred years and will continue to fall because of improved medical facilities, resulting in falling numbers of deaths.

- **<u>Religion and Ethnicity</u> :** Religious belief can play a significant role in people's choice between burial of cremation. Demand for burial and cremation facilities is thus influenced by the religious beliefs of the residents of an area. Ethnic origin, like religious belief, can influence people's choice of burial or cremation. For example, Black Caribbean people tend to prefer burial; Bangladeshi people tend to prefer burial as they are generally Muslim. The following Chart summarizes religious attitudes to cremation:

Chart 5.1 : Cremation in Various Religions

Necessary	Permitted	Forbidden
Hinduism	Buddhism	Muslims
Sikhism	Roman Catholic	Baha'i

Jainism	Jews – Liberal	Jews – Orthodox
	Roman Catholic	Greek Orthodox
	Church of Scotland	Russian Orthodox
	Church of England	Zoroastrians
	Church in Wales	Parsees
	Church of Ireland	
	Presbyterians	
	Methodists	

- **Availability of Cremation Facilities :** People mind set are changing from burial to cremation. The same may be improved depending upon the available facility of cremation.

5.2 FACTORS INFLUENCING PEOPLE'S CHOICE OF CREMATORIUM

5.2.1 LOCATION

A new crematorium has an opportunity to compete with existing crematoria on the basis not only of location, but also the quality of the facilities and the service it provides. Since as per religious ritual some burnt part of the dead body is allowed to flow in the water, therefore ideally, the new site should be located near the river, canal, pond, lake or sea. The main customers making the decision to use a particular crematorium are bereaved (whose relative is dead) people and the funeral directors. The influence of religious ministers is insignificant in my view, as the funeral location is usually chosen prior to their appointment to lead the service.

5.2.2 BEREAVED PEOPLE

They may be arranging their first funeral and, in any case, may be guided strongly by the funeral director's recommendations. Alternatively, they may have arranged funerals previously and have a sense of loyalty to a neighbouring crematorium where the cremated remains of family members have been placed and where they may already have an existing memorial and focal point for their grief. Responsibility for the arrangement of a cremation is an unusual event in most people's lives. Unlike regular shopping trips or visits to the sports centre, they do not have many opportunities to assess the quality of the service and make comparisons between crematoria. The close relatives of the deceased are often so stressed that they notice very little about the crematorium during the funeral.

5.2.3 CREMATORIUM MARKETER

Supermarkets pay keen attention to buyer behaviour, but there have been no comparative surveys carried out into customer's attitudes to the quality of the service and facilities of crematoria. It is increasingly common for individual cremation authorities to issue questionnaires, but they do not seek customer's views on crematoria apart from their own. However, based on experience, we can say that a new crematorium can attract additional customers on the basis of the quality of its facilities and service. A new crematorium can be designed with the benefit of experience of mistakes made at other crematoria and using modern technology to make the building economical to operate and maintain. Contemporary, clean lines and a good site would give a completely different new crematorium. Factors in favour of such a crematorium would include:

- adequate driveways and car parks
- comfortable modern furnishings
- adequate protection from inclement weather
- segregation of different funerals
- good toilet facilities

- good choice of memorials

5.2.4 FUNERAL DIRECTOR

Whilst the funeral director can charge mileage for the journey to the crematorium, a short journey to the local crematorium may mean that he can carry out more funerals per day and increase overall profits. Funeral vehicles have long wheelbases and funeral corteges may consist of numerous vehicles. The new crematorium may provide an opportunity to serve roads and car parking facilities that helps rather than hinder the funeral director. Unlike the bereaved, funeral directors visit crematoria often and do make comparisons between them. The basis of these comparisons is usually:

- ease of access and use
- segregation of different funerals
- staff attitude

A common problem at crematoria is the disturbance of one funeral by the noise of another preceding or following it. Once mourners have left the chapel, they congregate outside to chat.

The numbers of people involved and the design of buildings usually means that the people who have entered the chapel for the next service can hear this loud hubbub (noise) of conversation. Funeral directors get particularly annoyed when it is their funeral group affected.

5.3 CASE STUDY OF A SOLAR CREMATORIUM IN GUJARAT

A spiritual hermitage in Gujarat state, in the northwest of India, has become the home of the world’s first solar-powered crematorium. The historic village of Goraj near the town of Waghodia, in Vadodara district of Gujarat state is located in our country where an existing, but non-operational, the first solar crematorium is installed near Ashram at the “panchayat land” under the authority of ecologically conscious *Muni Seva Ashram*.

The idea was first conceived in 2005, by Raman Panwala from the coastal city of Valsad when he visited the ICNEER (International Center for Networking, Ecology, Education and Reintegration) set up by solar thermal energy expert Deepak Gadhia. When Panwala was shown that a piece of wood starts burning while placed in the Sun, he wanted the same concept applied to human bodies being cremated according to Hindu mythology (who burn their dead bodies). The ceremony typically consumes an average of 500-600 kg of wood per corpse.

5.3.1 INTRODUCTION TO THE PROBLEMS

This installed crematorium is non-operational. I don’t know why: maybe faulty design of solar crematorium because of which required sufficient temperature is probably not achieved to completely burn corpses or, aperture of collector may be small to collect sufficient amount of solar heat energy for complete burning of dead body. Maybe people just don’t come there because of any proper connectivity of road transport from nearby big cities like Vadodra and Ahemdabad or, maybe cremating cost per dead body is too high. Probably that place is geographically not suitable according to solar map or, there is no proper solar energy policy.

5.3.2 GEOGRAPHICAL SUITABILITY OF THE PLACE

Today world is moving towards the sustainable energy sources which are renewable in nature and biodegradable because in this modern era, a lot of problems of pollution and global warming have been encountered in almost all developed countries. Gujarat is most developed state of our country so there is also problem of pollution and global warming. Since Gujarat state is situated in such a solar belt where average annual solar irradiance is 5.5 to 6.0 kwh/m^2/day (as seen in Fig. 3.5 and 3.6). This quantity of solar irradiance is more than sufficient for solar powered equipments.

Since as per religious ritual some burnt part of the dead body is allowed to flow in the water, therefore ideally, the site should be near the river, canal, pond, lake or sea. The solar crematorium installed by Mr. Deepak Gadhia at *Muni Seva Ashram* is on the bank Dev River which is basically a tributary of Dhadhar River. So this crematorium is suitable for performing religious ritual of *Antim-Sanskara*.

5.3.3 GOVERNMENT POLICY

Since Gujarat is most developed state of our country so there is also problem of pollution and global warming. This problem of pollution and global warming has been noticed by the state government of Gujarat. As a result, government of Gujarat has established the GEDA (Gujarat Energy Development Agency). Since Gujarat state is situated in such a solar belt where average annual solar irradiance is much more than sufficient for solar powered equipments therefore the GEDA have promoted installation of lot of solar powered projects in the state. Currently Gujarat is the state of most solar powered installations in the India.

5.3.4 DESIGN AND DEVELOPMENT

At the ecologically conscious Muni Seva Ashram, a 50m^2 Scheffler dish will heat the oven which burns the dead bodies. The project was developed in cooperation with Wolfgang Scheffler (who designed the Scheffler mirrors from Germany) and Ronnie Sabawala (one of the owners of Vadodara-based Himalaya Engineering).

Opening Diameter of cremation chamber = d = 24cm

Receiver Area = $\boldsymbol{A_r} = \frac{\pi}{4}\boldsymbol{d^2} = \frac{\pi}{4}(\mathbf{24|100})^2$ m^2 = 0.045238934 m^2

CR = $\frac{A_a}{A_r} = \frac{50}{A_r} = \mathbf{1105.24266}$

As per the above calculations of **CR**, the target temperature is above 1000°C which can burn the human body very easily within approximately 40 to 60 min during a bright sunny day. The crematorium has been built as a chamber with special scheffler reflector developed specifically for this concept. The special reflectors are designed to heat a 2m long crematorium chamber to above 800°C. The facility was made operational on an experimental basis only.

As per my observation, **size of scheffler collector is 50m^2 which doesn't suit as per my design of scheffler reflector described in subsection 4.3.1. Since size (aperture area) of solar collector must be equal to 197m^2 otherwise, collector won't be able to collect sufficient amount of solar heat energy for complete burning of dead body within 2-3Hrs**.

Mr. Gadhia told me, Chamber is designed in such a way that the solar radiation gets reflected from its inner wall and concentrates on the plate where human body is kept. Thus, making full use of the solar energy and increasing the overall efficiency. Efficiency of cremation chamber insulation is about 80%.

Fig. 5.1 : Solar Crematorium which is visited at Goraj village near Waghodia town in Vadodara District of Gujarat State

Test with small pieces of meat was proved to be encouraging. However, Ashram will not be able to put the solar cremation chamber to use until a biogas/biomass/CNG/PNG backup burner is installed. **People across the region made clear that they will welcome the chamber if a backup burner takes over operation during cloudy hours. Otherwise, a body may only be half burnt which will hurt the sentiments of concerned relatives**.

As per the conversation held with Mr. Deepak Gadhia, Ashram is now searching for an eco-friendly solution with biogas, which is produced in a farm within 30 km of place of solar crematorium. **As soon as the funds for the biogas backup are available, the bottled heat source can be delivered and the solar crematorium can finally start to operate**.

5.3.5 CUSTOMERS AND BUSINESS OPPORTUNITIES

The main customers making the decision to use a particular crematorium are bereaved (whose relative is dead) people and the funeral directors. The close relatives of the deceased are often so stressed that they notice very little about the crematorium during the funeral. They may be arranging their first funeral and, in any case, may be guided strongly by the funeral director's recommendations. Responsibility for the arrangement of a cremation is an unusual event in most people's lives. Unlike regular shopping trips or visits to the sports centre, they do not have many opportunities to assess the quality of the service and make comparisons between crematoria.

When Deepak Gadhia started to work on the concept and estimated the total project costs at around ₹5 million, Panwala did not had enough cash at hand. Deepak then chose Muni Seva Ashram as the site for the pilot project. Since this Ashram has a very large and world class **cancer** hospital and research center where there is a common phenomenon of death of many people. So Raman Panwala managed to gather funds from his village by convincing the villagers that trees can be saved if human bodies are burnt using solar thermal energy.

Since at the time of the cremation or "last rites", a "Puja" (prayer) is performed. The holy text of Rigveda, one of the oldest Hindu scriptures, has many Ruchas (also written and pronounced as Richas in form of small poems) related to cremation, which state that Lord Agni (God of Fire) will purify the dead body. Soalr Crematorium at Muni Seva Ashram has a platform on which the cremation chamber is placed; facilities were set up at which to carry out all the usual rituals for the dead body first.

To satisfy the human mindset, a special provision should be made to have wood burning arrangement in the chamber and if required the initial firing will be done manually and after that the system will be put under solar operation. Therefore special platform should be made to perform last rights for the body near the Solar System. Backup system will be provided in form of CNG fired boiler at an extra cost.

But as I observed, **there is no any provision of collecting the ashes after cremation, which is necessary to collect the ashes by relatives and to immerse them in open flow of water**. Another facility which can be incorporated there is to provide adequate driveways and car parking.

5.3.6 POTENTIAL ENVIRONMENTAL IMPACT

Solar energy is non-polluting. Of all advantages of solar energy over that of oil, this is, perhaps, the most important. The burning of oil releases carbon dioxide and other greenhouse gases and carcinogens into the air. It needs no fuel and produces almost no waste & no pollution. This energy is totally renewable or inexhaustible fuel source, as far as we know for thousands of years. Often solar energy is an excellent supplement to other renewable sources.

5.3.7 CONCLUSION OF THE CASE STUDY

Geographically, this solar crematorium is installed in such a Gujarat state of solar belt where there is very good average annual solar irradiance of 5.5 to 6.0 kwh/m^2/day. Cremation chamber is well insulated with 80% efficiency. This chamber is placed on such sufficient platform that all the usual religious rituals of *Antim Samskara* can performed on it. There is no any problem of customers and business as it is placed near cancer hospital where some death occurs on daily basis. And this place is also situated near town of Waghodia and a big city of Vadodara on 30km distance.

There are some minor issues but necessary to eradicate like provision of collecting cremation ash and back-up system for cloudy hours to satisfy religious sentiments. Only major problem is insufficient/faulty size of scheffler reflector which is actually $50m^2$ in place of $197m^2$. It seems that this scheffler reflector is installed without following any proper designing procedure.

It will be commissioned within two months and shall be free of cost for everyone using it," said trustee Deepak Gadhia.

Chapter – 6

ECONOMIC ANALYSIS

Although solar radiant energy is free, the equipment required to convert it into useful form (thermal or electrical) is not free. Therefore a cost must be assigned to solar thermal/electrical energy that reflects the conversion equipment cost pro-rated by no. of kwh delivered by solar equipment. If solar cost is less than that of other energy sources that can perform the same task, there is an economic incentive to solar energy. The purpose of economic analysis is to maximize savings resulting from use of solar energy.

It is rarely cost effective to provide all energy requirements of thermal or mechanical system by means of solar energy. If this done, solar system would be capable to provide 100% of energy demand for the worst set of operating conditions ever expected: inclement weather, maximum demand and no sunshine. A solar system capable of providing peak demand for lengthy period would be oversized for all sever conditions; it would thus be greatly oversized. An oversized system delivers more energy than the requirement. A solar system with such a low load factor is uneconomical and impractical. Therefore best use of solar equipment is in conjunction with conventional fuels which are used auxiliary source for special high demand situations.

Non solar systems usually have relatively small initial costs and high operating costs reflecting lower lifetime. Solar systems however are relatively expensive initially but have negligible running cost during lifetime. Therefore if selection of equipment is made on basis of initial cost only, solar system would rarely be selected.

6.1 FACTORS AFFECTING COST OF NEW CREMATORIUM

Chart 6.1 : Factors Affecting cost of new Crematorium	
Factors	**Influence**
Location	Cost of land Cost of access and internal roads Cost of installing new utilities
Design	Size Type of construction and materials Number of cremators and abatement equipment

Ideally, the new site should be 7 to 8 acres (2.83 to 3.24 hectare) and located near river, canal, pond, lake or sea as per religious ritual some burnt part of the dead body is allowed to flow in the water. The crematorium should have good connectivity to main roads. Land values vary tremendously, particularly where landowners hope to sell their land at some point in the future for housing development.

Installation of mains gas, electricity and water supplies can form a significant part of the budget, depending upon proximity to suitable supplies. For example, where suitable mains are available adjacent to the site, gas installation will costs in the region of ₹60000 and electricity ₹68000. However, costs can rise exponentially with distance: for example, an onsite electrical transformer can cost ₹216000. In broad terms, the construction costs of a crematorium would be grouped under the following headings with appropriate guide costs:

Chart 6.2 : Installation Cost	
Items	**Estimate in ₹**
Professional fees	800000
Site survey, ground works, roads and car parking	3200000
Building structure	6000000
Building furniture and fittings	800000

Cremation equipment (single cremator)	4400000
Net total estimate	**15200000**

This estimate excludes the cost of land and any exceptional utility installation costs. Sufficient land would likely cost at least ₹600000. Thus a reasonable round figure for the cost of building a new crematorium in India would be ₹2 crores.

Thus based on above discussions, cost of crematorium can be divided into following sub-parts :

a) Operating Cost

b) Cost of cremation equipments

c) Premises cost

6.2 OPERATING COSTS

The key operational costs associated with operating a crematorium are:

- Personnel
- Operation and Maintenance of cremation equipment
- Maintenance of buildings and grounds

The number of staff varies between crematoria, with generally less employed at privately owned sites. Clearly, the unit cost per cremation of the staff and any other cost item is reduced by greater cremation numbers.

In order to provide a high quality service, there must be sufficient trained staff. The conditions of employment and job descriptions for crematorium staff at a new crematorium would be different from existing practices that have established over many years. Flexibility amongst employees is the key to success.

The chart below shows the personnel that we may recommend for a new crematorium in big Indian cities like Delhi or, Patna :

Chart 6.3 : Operating Cost of Employee			
Position	**Annual Salary in ₹**	**Number**	**Total Costs in ₹**
Manager	360000	1	360000
Administration	300000	1	300000
Operator	240000	2	480000
Total			**1140000**

These costs equate to ₹1140 per cremation based on 1000 cremations per year.

6.3 COST OF THE CREMATORIUM EQUIPMENT

Traditionally, crematoria have installed the maximum number of cremators possible to enable the cremation of all bodies on the same day as the funeral. This has still reduced significant overtime working.

It is now widely recognised that a crematorium should operate as few cremators as possible in order to minimise the environmental impact of cremation. National codes of practice have been changed to enable the retention of coffins overnight to enable the most efficient use of cremators.

If the private sector is building and operating a new crematorium undertaking 1000 to 1200 cremations per year, they would likely install only one cremator. This would minimize the capital and operational costs as well as the environmental impact. Cremators work most efficiently and cause least impact to the environment if they are used continuously, rather than being allowed to cool down. 5 day operation inevitably means that a cremator cools over the weekend, but storing coffins overnight as appropriate enables the number of daily cremations to be evened out to assist in reducing temperature variations and consequent thermal shock on the refractories.

The difficulty that a single cremator installation poses is that roughly every 5 years the cremator needs to be taken off line for a full re-line of the refractory brickwork. This work takes up to 18 days, during which the cremator cannot be used for cremations.

One way around this issue would be to initially install only a single cremator, but with a twin abatement plant. In the 4th year of operation, a second cremator could be added, enabling the crematorium to continue operating during the re-line of the first cremator in 5th year.

This option would reduce the initial capital requirement and maximize the efficiency of the first cremator during the first 4 years. Once 2 cremators were installed, the most efficient operation could be achieved by using each for 2 weeks alternately.

The design of the building should allow for easy delivery, installation and future maintenance of the equipment. Management should have flexible staff rota systems to ensure the most efficient operation of the equipment. The costs associated with cremation equipment include:

a) Purchase costs
b) Operating costs
c) Maintenance costs

6.3.1 EQUIPMENT PURCHASE COSTS

Currently Facultatieve Technologies are the UK market leader in terms of the installation of cremators and abatement equipment. A single **FT111** cremator would cost in the range of ₹3832000. This includes:

- construction and installation of the equipment
- automatic cleaning of the boiler
- waste gas ducting
- hot plate heat exchanger
- electrical and mechanical installation
- commissioning and testing
- staff training

In addition to the above cost, the crematorium would need :

- coffin charging system
- cremated remains treatment equipment
- coffin storage

These items would cost in the range of ₹336000. The installation costs associated with the cremation equipment would therefore total be ₹4166960. If the intention was to fit a second cremator in 4th year, the initial abatement plant cost would be higher, giving an initial installation total of ₹4446960. A second cremator would cost approximately ₹1080000 at current prices.

6.3.2 EQUIPMENT OPERATING COSTS

Unit costs can be dramatically reduced by increased throughput, as much of the energy used in heating a cremator is lost through intermittent operation. Cremators that receive five or more cremations per day retain heat energy and as numbers increase, fuel consumption per cremation decreases. Based upon annual figures of 1000 cremations, 50 operational weeks (allowing for

Bank Holidays) and a 5 day working week, a crematorium would only receive an average of 4 cremations per day.

Cremation times using modern cremators can be on average between 70 and 90 minutes. Allowing for a 90 minutes cremation cycle, the cremator would be in use for 6 hours per working day. Certain days of the week attract more funerals than others and demand on the cremator could be evened out by the storage of coffins overnight, in accordance with national codes of practice.

Costs vary with the number of cremators and cremations and the way that the equipment is used. However, we may offer the following guide prices for the purposes of this feasibility study based on the efficient use of one FT111 cremator to cremate 1000 cremations per year. At today's rates, the operating costs of the cremator per cremation would be approximately:

Chart 6.4 : Equipment Operating Cost

Item	**Cost in ₹**
Gas	1200
Electricity	50
Reagent and disposal	100
Total	**1350**

6.3.3 EQUIPMENT MAINTENANCE COSTS

Excluding call-outs and all refractory repairs, the servicing of an FT111 cremator and abatement plant would be in the range of ₹112000 per year, i.e. ₹120 per cremation.

Refractory brickwork will require replacement from time to time due to wear from thermal shock and chemical erosion. A full re-line of the cremator currently costs in the region of ₹240000 and would likely be required every 5 years, with hearth replacements required twice as often. We can recommend an all-inclusive fixed-price maintenance contract for a 5 year period to facilitate budgeting and maintenance of the equipment.

6.4 PREMISES COSTS

The maintenance costs of a new building should be low by virtue of good design, controlled construction and planned maintenance. In my opinion, high maintenance costs are the result of poor design. As in any building, it is essential that sufficient thought has gone into the roof and rainwater issues.

At Wrexham crematorium, Flat roofs needed continuous maintenance and the main sloping chapel roof required replacement after 30 years due to poor design of gutters and use of copperised felt to create a relatively low cost roof. At Harwood Park, a state-of-the-art computerised central heating system failed to adequately heat and ventilate the main chapel whilst over-heating other areas: this was in my view as a result of poorly-informed design.

The use of abatement equipment will necessitate the cooling of cremator exhaust gases prior to filtration. This will be an opportunity to utilise heat-recovery equipment to use this surplus energy to heat the building. The greatest demand for heating is during the winter months when cremation numbers are at their highest. Whilst this option would increase capital costs, it would provide significant long term savings and accord with the Indian Environmental Policy.

I recommend separate meters to accurately monitor utilities consumption for cremation and heating. Careful planning of the grounds will enable cost-effective maintenance. The areas used for memorials must be maintained to a high standard. This is appropriate evidence of customer care and also encourages memorial sales.

6.5 EXPENDITURE SUMMARY

In simple terms, the operational costs per cremation of the crematorium undertaking 1000 cremations per year would be between the following figures :

Chart 6.5 : Expenditure Summary

Item	Cost in ₹
Personnel	1140
Cremator Operation	1350
Cremator Maintenance	120
Total	**2610**

Additional costs would include capital charges, central support charges, business rates, buildings and grounds maintenance

6.6 CREMATORIUM INCOME

Income is primarily received as charges for cremations and for memorials. There is variation in the type of provision and the charges made for these services. A new crematorium in India completing 1000 cremations per year could expect an annual income of ₹2610000 from a charge of ₹2610 per cremation. This fee would place India in a comparable yet competitive situation with other crematoria in the world. Some crematoria make a surcharge for cremations originating outside of their area, in the same way as many burial authorities impose higher burial fees. This system is not employed by the private sector and in my experience discourages funerals from outside the local area. This is self-defeating as there are fixed costs in operating a crematorium and the greater the number of cremations the greater the ability to pay off capital and make a profit. Cremation income is obviously proportional to the number of cremations. Each additional cremation represents the potential for additional income from memorials like book of remembrance, wall tablet, ashes retained, private gardens, tree, and columbaria.

Memorial income cannot be guaranteed. The legislation relating to the sale of memorials by local authorities in England was recently clarified by the Local Government Act 2003. It basically means that local authorities cannot lawfully make a profit out of memorial sales, whether at a cemetery or crematorium. However, the costs of providing memorials at a new Indian crematorium would include a contribution to the capital and operational costs of the facility. In my view, the Council would be able to sell memorials at a higher price than the simple direct cost of the memorial. It is possible for a local authority to engage with the private sector to provide memorials for profit on its behalf. I am not aware of this procedure actually being adopted at a UK crematorium. In general terms, memorial income is only likely from funerals where the cremated remains are disposed of within the crematorium Garden of Remembrance. People who choose to remove the cremated remains for disposal elsewhere are unlikely to see the benefit of having a memorial at the crematorium.

CONCLUSION

- While cremation is an established Hindu ritual practiced since ancient times and the Hindu religion permits the cremation of dead body in day-time only, there is much scope of solar crematorium in this ritual; as solar power is also available in day-time only.
- Between 500 and 600 kg of wood are used to cremate a dead body. So we are significantly contributing in global warming and atmospheric air pollution much more and forest are depleting day by day. The most sustainable energy source is sunlight that too is totally inexhaustible and available free of cost. It mitigates all the above problems.
- India is situated in high solar insolation belt with about 300 clear sunny days in a year and the daily average solar energy incident over India varies from 4 to 7 kWh/m^2. All these are an ideal combination for using solar power in India, So solar crematorium will be a viable option.
- We should never suggest of using solar photo-voltaic panels to obtain such a large amount of heat for cremation, as the sunlight has very little part, only 20% of its energy as lighting effect and large portion of 80% as thermal effect. So energy of solar radiation can be utilized more in solar thermal power generation than in solar photo-voltaic (which utilizes only lighting effect of sunlight) power.
- There must be an arrangement of suitable and sufficient backup system for non-sunny hours to meet the Hindu ritual sentiment of burning the corpse at one goes.
- Ideally the solar crematorium should be built near river, pond or lake and there must be facility to collect ashes for emerging in open flow of water.

- Building solar crematorium is very expensive, since solar reflector costs a great amount of money. But in solar cremation, since we don’t have to pay for fuels, as in conventional cremation large amount of wooden pile or electricity are required. So money can saved in the long run.
- Central and state governments have several policies which promote using solar power by providing various subsidies, incentives and interest free loans.
- Cost of cremating a corpse solar crematorium is very genuine of ₹2610 on the basis of 1000 cremations per year, though it doesn’t include land cost, capital charges, and central support charges.
- 800°C is at the low end of incineration temperatures, so this method would be more time consuming and adoption of this method may be difficult for families and operators. So to achieve high temperature, there is need of further research in the field of advance technologies for designing reflector and combustion chamber. Universities can be contacted in order to benefit students who want to work with solar energy developments.
- In conclusion, we will definitely be able to cremate a corpse through solar crematorium built with a well designed scheffler reflector and an efficient combustion chamber. The project may go through many stops and goes, but in the last we will be able to make working prototype Solar Crematorium.

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