Solar Energy Technology

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Lecture - 1
Energy and Dependence on External Sources and Sun, Physical Discription and Reactons

These lectures are meant for the curricular course, Solar Energy Technology. And the material that, I am going to present, shall be appearing in the form of a book soon, principles and performance of solar energy thermal systems.

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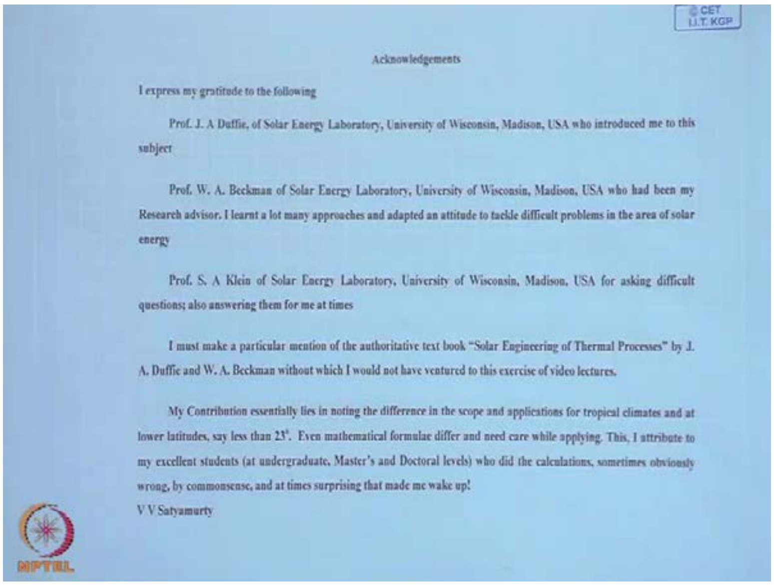

And at the same time, I must do little bit of my duty in acknowledging Professor Duffie of solar energy lab, University of Wisconsin, Madison, who introduced me to the subject. Again Professor W. A. Beckman of solar lab, University of Wisconsin and who had been my researcher by there, and I learnt a lot many approaches and adapted an attitude to tackle difficult problems in the area of solar energy. Of course, in the same group is professor S. A. Klein of solar energy laboratory, University of Wisconsin, he was asking very difficult questions, some of them he was answering also.

I must make a particular mention of the authoritative text on solar engineering of thermal processes by professors J. A. Duffie and W.A. Beckman without, which I would not have ventured to undertake this exercise. My contribution essentially lies in noting the difference in the scope and applications for tropic climates and particularly, at lower latitudes so say, less than 23 degrees. Even, mathematical formulae differ and need care while applying these things, this achievement I attribute to my large number of undergraduate master's and doctorate students, who did the calculations, sometimes obviously, wrong and at times surprising that, made me wake up and take note of the material.

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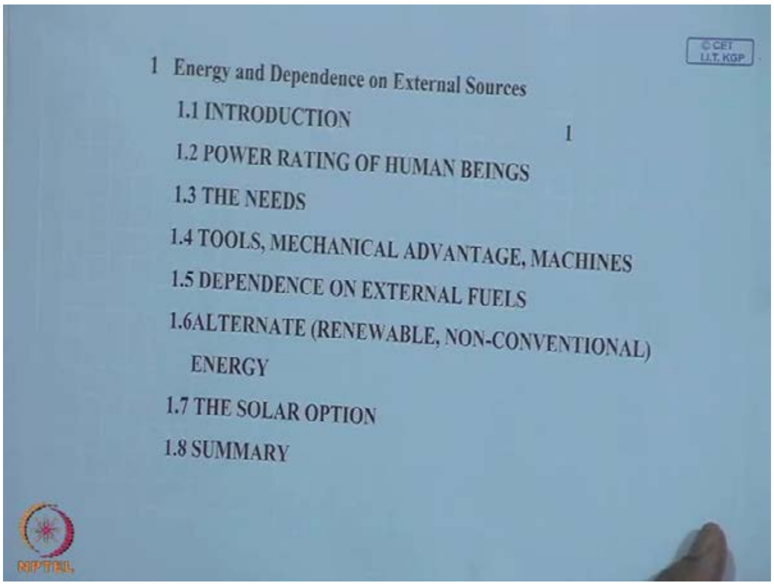

So, first lecture, we devote to energy and dependence on external resources, many of us feel that, the energy crisis of 1973 was responsible for a relook by scientists and engineers into developing your or alternate energy sources. However, a question comes to our mind, whether there is any intrinsic need, for the man to be dependent on external sources of energy. So, this part of the lecture, I organize as a introduction and power rating of human beings and his needs to advantage and subsequently machines, which made him depend on external fuels.

Similarly, we define, what is meant by alternate or renewable or non-conventional energy sources, of which solar energy is one option. And why it is promising, we shall have a little bit of justification for going through this course and this material, and that is the summary of the first lecture, at the end of the lecture.

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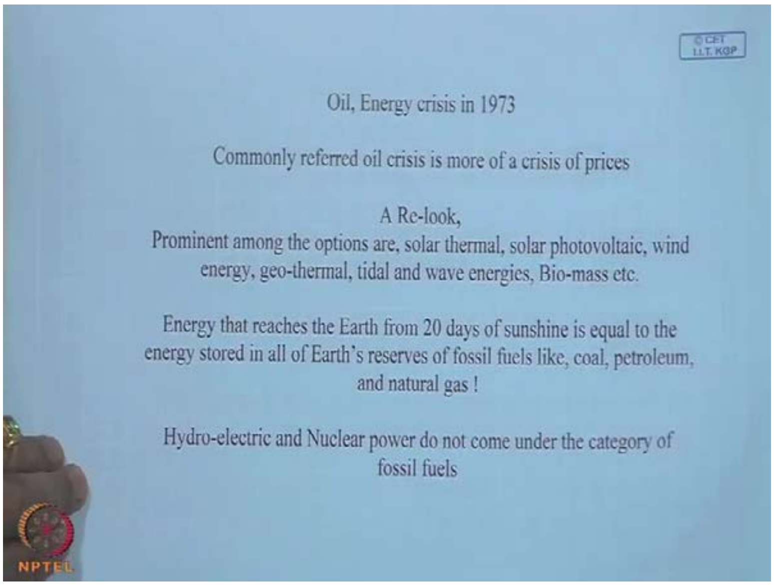

So, this I gave a historic perspective of oil energy crisis in 1973, it is really one says an energy crisis and an oil crisis but, it is more of a crisis of the prices. Because, the opaque countries increased the price of the fuel and particularly, America and other countries, which heavily import the oil, are started feeling that, there is a need to develop alternate sources instead of, depending only on the conventional fuels, fossil fuels particularly, coal, natural gas or petroleum.

So, prominent among the options are solar thermal and solar photovoltaic, and wind energy, geothermal, tidal and wave energies, bio mass, etcetera. So, all these things were given attention by scientists and engineers, and an interesting fact is that, energy that reaches the earth from 20 days of sunshine is equal to the energy stored in all of earth's reserves of fossil fuels like coal, petroleum and natural gas. Hydro-electric and nuclear power do not come under the category of fossil fuels, though they have a good share in meeting the energy requirements in the world.

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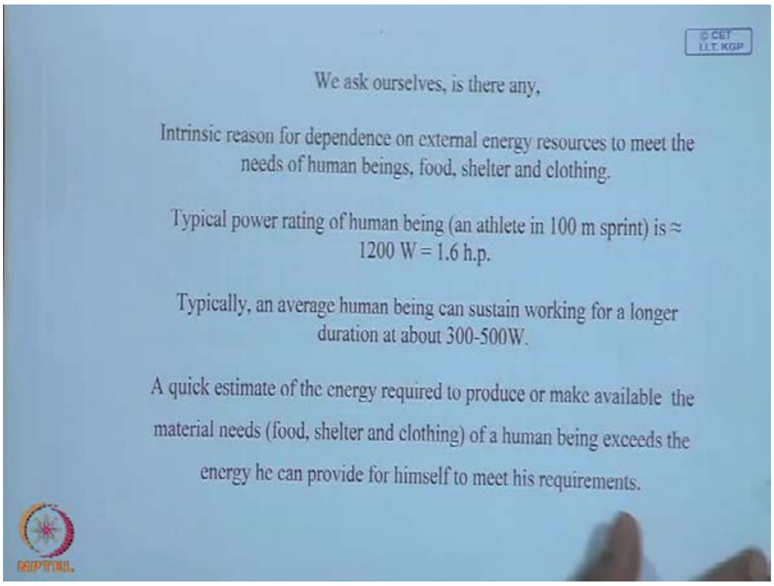

So, the crisis is some sort of manmade and the other thing is the best estimates of the results that are available, will make us tell that, the last 20 years or 30 years, the estimates widely vary. It could also depend upon, how much increase in the rate of consumption is going to continue, to happen or we are going to decrease our consumption rates by any means, by either alternate sources or by conservation, there could be a reduction in the consumption or dependence on fossil fuels.

So, there is an intrinsic reason for dependence on external energy sources, to meet the needs of human being’s food, shelter and clothing. Typical power rating of a human being for an athlete in 100 meter sprint is about 1200 watts, which comes to about 1.6 horse power. An average human being can sustain working for a longer duration, at the rate of about 300 to 500 watts at best. A quick estimate of the energy required to produce or make availably material needs like food, shelter and clothing of a human being exceeds the energy that, he himself can produce in trying to produce whatever he needs.

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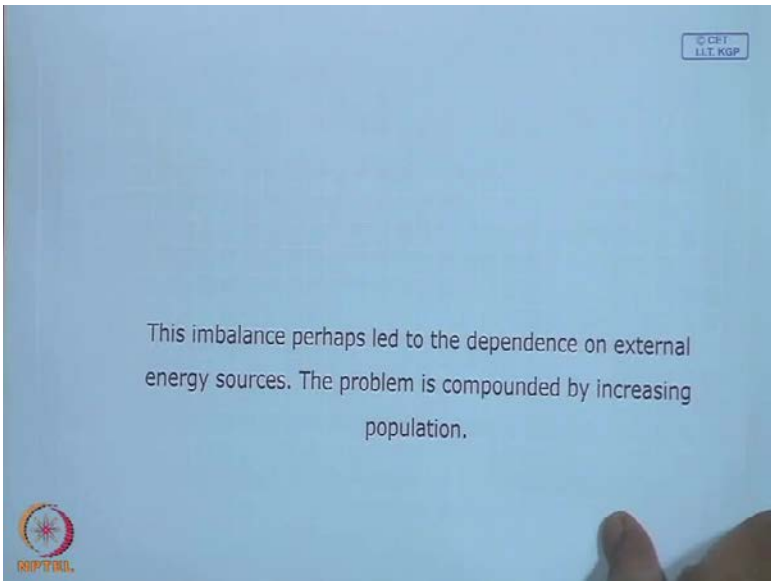

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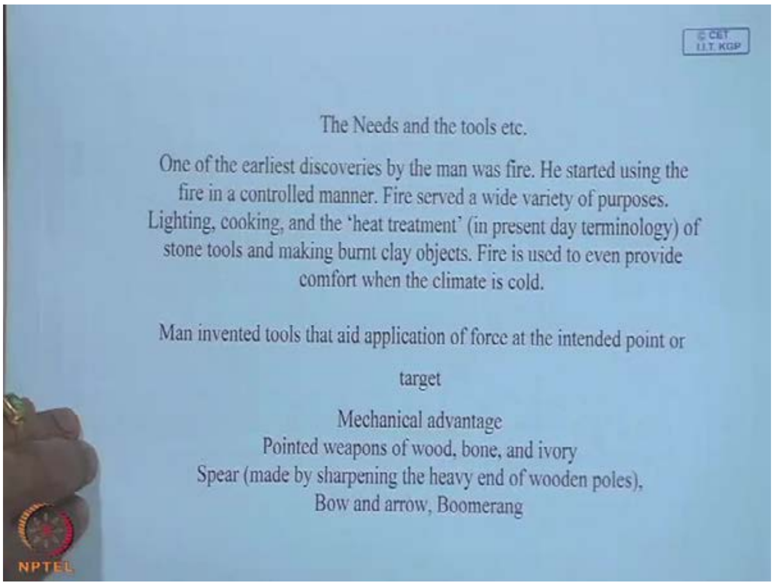

Consequently, there is an imbalance, this imbalance perhaps lead to the dependence on external energy sources, the problem is further compounded by increasing population. Because, we have got limited sources and a larger number of people dependent upon that so consequently, instead of, himself producing this, he had to use some power, animal power, machine power or whatever. And then, to make life little more comfortable, first he invented the fire, which made him feel little more comfortable, even in a cold climate.

And then, also to ward off wild animals then, subsequently, he started using the fire for what we call, in the modern day technology as heat treatment. Then, various tools have been invented, for use of convenience including killing the animals or protecting himself upto mass destruction, weapons of the present day. Then, in this process, mechanical advantage has been harnessed in other words, if you have got the lever principle, you can take a crow bar and lift the earth, provided there is space to stand and a strong enough foundation to hold the bar.

So, pointed weapons of wood, bone and ivory then, spear made by sharpening the heavy end of the wooden poles, bow and arrow, and boomerang are the very early tools and weapons that the man was using.

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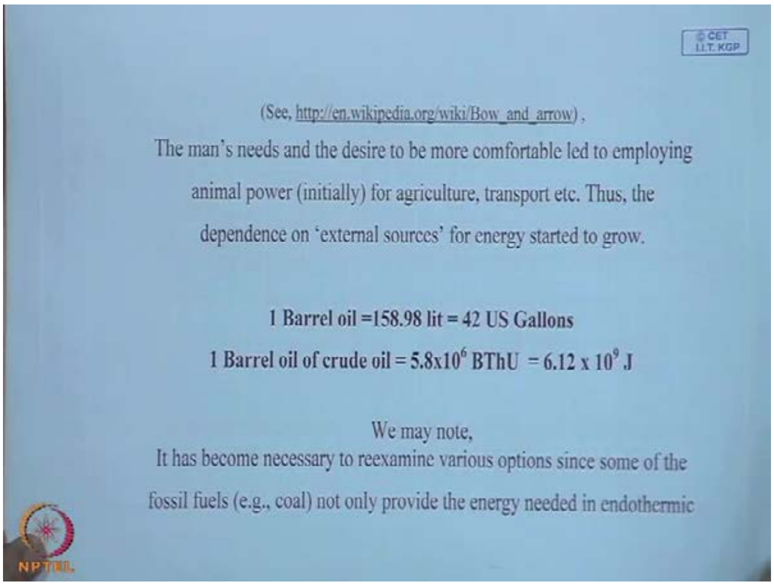

And some of this material is taken from Wikipedia, the websites I have given particularly, in the notes there are many more websites I have mentioned. So, you can check for yourself and look at the depth and details, that are provided on these materials. The man's need and the desire to be more comfortable, lead to employing animal power initially for agriculture, later on for using the transport so that, they can move quickly from one place to the other.

Thus, the dependence on external sources for energy started to grow and it would be interesting because, you may be going through different books American-oriented or British-oriented. A barrel of oil is a common unit, a barrel of oil contains 158.98 liters, which is equal to 42 US gallons and produces an energy of 6.12 into 10 to the power 9 joules. We may note, it has become necessary to reexamine various options, since some of the fossil fuels example, coal, not only provide the energy needed in endothermic reactions but, they also participate in the process.

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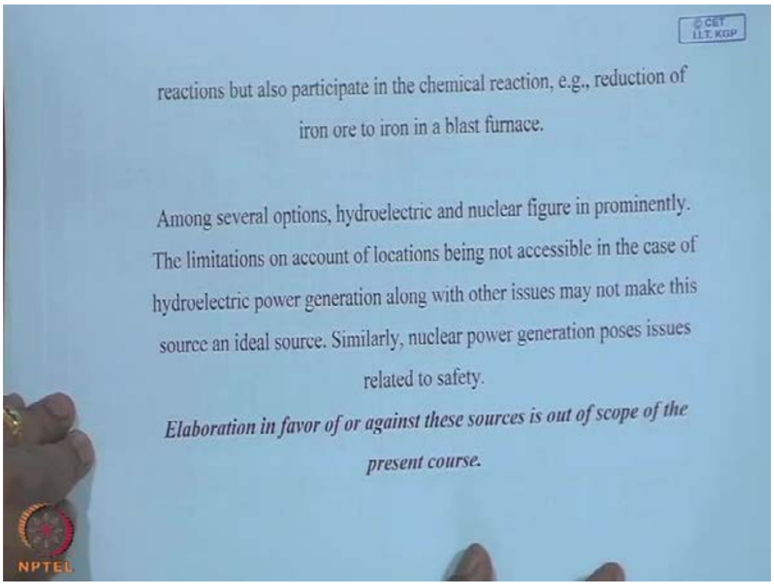

In the technological route for example, for producing iron in the blast furnace, coal is not just an energy source, it participates in the chemical reaction. This particularly, I am mentioning to point out that, if the dependence on coal for power generation is reduced, it will be available for a longer period, for producing like iron and steel. Consequently, there will be a chance to think of a new technology, which may not depend on coal, for producing iron and steel or any other, one can think of.

So, the hydroelectric power generation and nuclear power, they strongly occupy pretty important role however, they are all not easily accessible, not easily available at the location, that you need. And there are issues like submerging or the surrounding areas and safety issues, as far as nuclear power is concerned and elaboration in favor or against these sources, is out of scope of the present course.

We will not enter into a debate, whether nuclear is better or hydroelectric is better or solar is the only option as far as, this is concerned. But, we do consider solar to be one of the options, in trying to reduce the dependence on fossil fuel.

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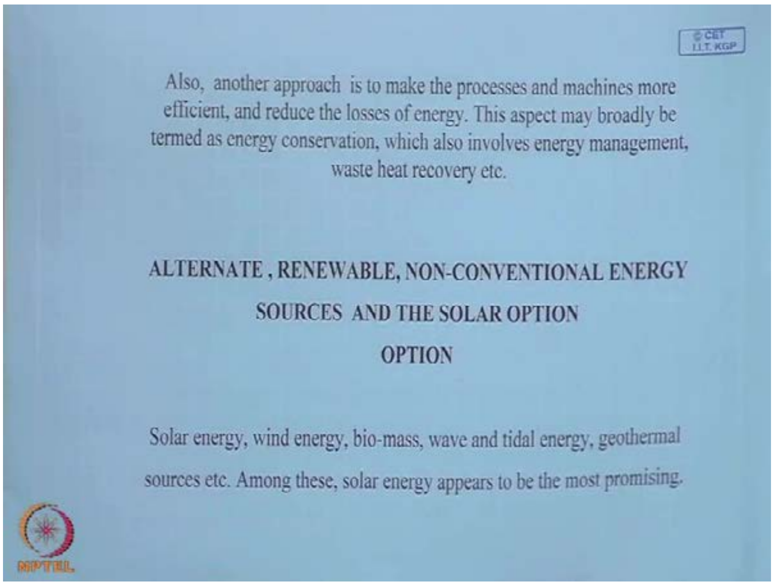

Another approach is to make the processes and machines more efficient and reduce the losses of energy, this aspect may broadly be termed as energy conservation, which also involves energy management, waste heat recovery, etcetera. So, by this method, if actual dependence on the fossil fuel consumption is becoming less then, the resources last longer. It is not essential that, you added power generation but, you have reduced your consumption by alternate means or efficient means.

In fact, I shall give you one example, in early 80's any two wheeler giving about something like, about 40 kilometers a liter is considered to be a very highly efficient machine. Whereas, now it goes to 80 to 100 kilometers per liter with the same or may be more power and more comfort this is because, the direction that the research has taken over, in trying to reduce the consumption. Consequently, I mean you can run 2 two wheelers instead of, 1 two wheeler earlier.

There are alternate, renewable, non-conventional these are all the terms, that are being used synonymously, quite often they are not exactly synonymous, we may have to differentiate slightly. An alternate energy if you say, it is an alternate to something so, what is alternate today might have been existing, it may be existing in future. Similarly, renewable energy is expected to last perennially, time immemorial but, even if you consider solar radiation, we read it with, sun is having a nuclear reaction, nuclear fusion reaction, it will have a finite life, when it may become a dwarf.

Consequently, nothing is really infinitely long and non-conventional also has this misnomer in the sense, what is non-conventional today, might become conventional after 50 years or 100 years. So, these are all used in a synonymous sense but, we would like to have characterized the ideal source of energy and what can go in meeting the requirements of the man and at the same time, reduce the dependence on the fossil fuel results. So, solar energy, wind energy, biomass, wave and tidal energy, geothermal sources or some other things that were, that are being considered actively, among these, solar energy appears to be the most promising.

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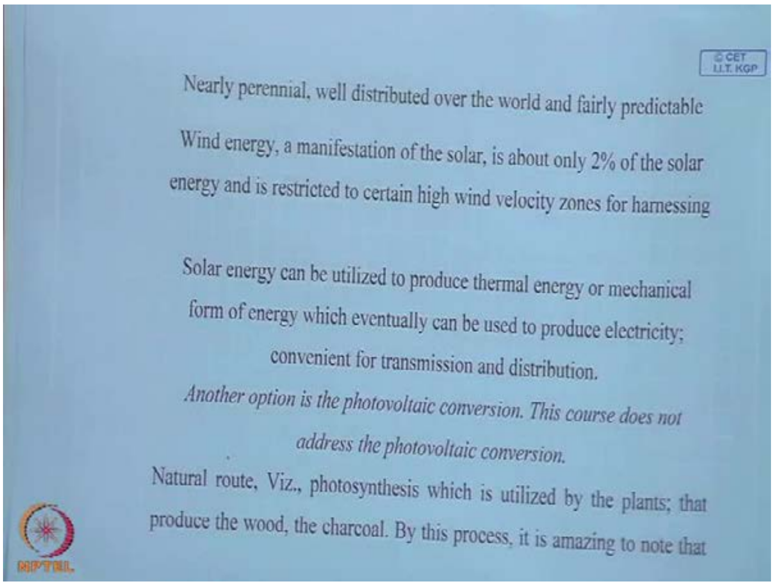

It is not that, we are giving this course and hence, we worked for solar, the distribution of solar energy throughout the world is more or less uniform. It does not favor a rich country or unfavor a poorer country, the second part is, it can be fairly predicted, i may not be able to guess, what will be the solar radiation tomorrow morning at 7:30 to 8:30. But, a pretty good average for the month of August or for the day, typical day in August can be predicted, can be calculated or measurements are available.

Whereas, wind energy is more erotic at the same time, it is most of the time available at places, which are not easily accessible. So, there are and wind energy, one should note is a manifestation of solar energy, which is approximately about 2 percent of the solar radiation. But, at the same time, we should also note, wind energy is a high grade energy source since it directly provides mechanical power, from which you can generate electricity. So, consequently wind also can play an important role in meeting the energy demand and reducing the dependence on fossil fuel resource.

So, solar energy can be utilized to produce thermal energy or mechanical form of energy, which eventually can be used to produce electricity, which electricity we take it for granted these days because of, the convenience in the transmission and distribution. If you generate mechanical shaft power, you cannot transfer more than a 100 feet, even if you have a very long shaft and earlier old workshops used to have a common shaft, and to which the number of blades or machines used to be connected.

So, that type of the thing, one cannot think of in kilometers and hundreds of kilometers of distribution for transmission. In the solar route, photovoltaic conversion is there where, directly solar radiation is converted into electric energy. This course does not address the photovoltaic conversion so, we will read restrict ourselves to solar thermal energy and various types of either producing thermal energy as thermal energy or mechanical energy or electric energy. The most natural route was the photosynthesis, which the plants do fairly efficiently essentially, it is a method of storing the solar energy in the form of wood.

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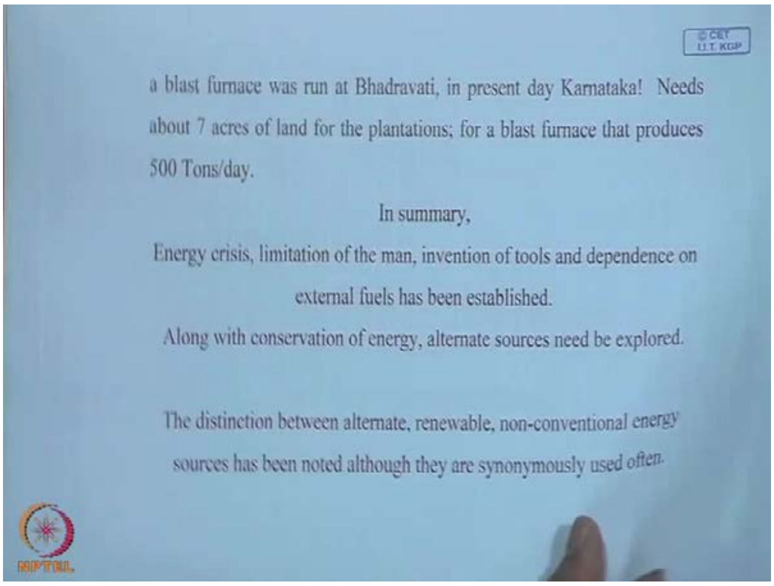

And by this process, and I was told and I happened to read that, one of the iron and steel companies in Bhadravati, in present day Karnataka, a blast furnace was run by the charcoal, that was produced by a forest grown around that. The area of the forest was about 7 acres and it is a blast furnace capacity is 500 tons, which is small by modern terminology. Nevertheless, it has been shown that means, you cut off about 100 trees, plant 100 trees, the cycled time is some 5 years or 6 years.

Again they will become ready for next time use so, in a way, we might summarize saying that, energy crisis and limitation of the man, invention of tools and dependence on external fuels, we have established. Along with conservation of energy, alternate sources need to be explored, the distribution between alternate distinction between alternate renewable and non-conventional energy sources be noted, although they are synonymously used many times.

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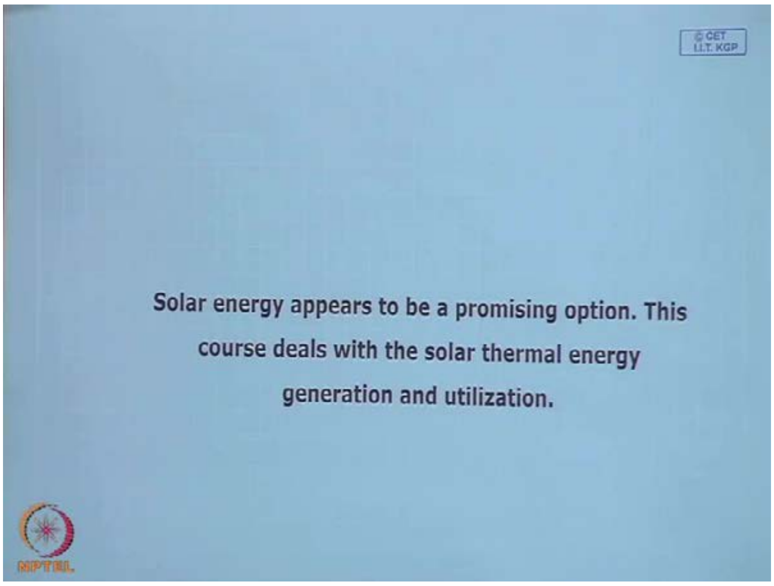

So, at the end of this lecture what we can say is, solar energy appears to be a promising option and this course deals with solar thermal energy generation and utilization. So, the next lecture will be a shorter one, just we should try to provide the sun, physical description and our reactions. Now, if you look at, what we had been speaking rhetorically all the time is that, there is a good case to reduce the use of fossil fuels and to explore alternate energy sources, and solar seems to be a good option.

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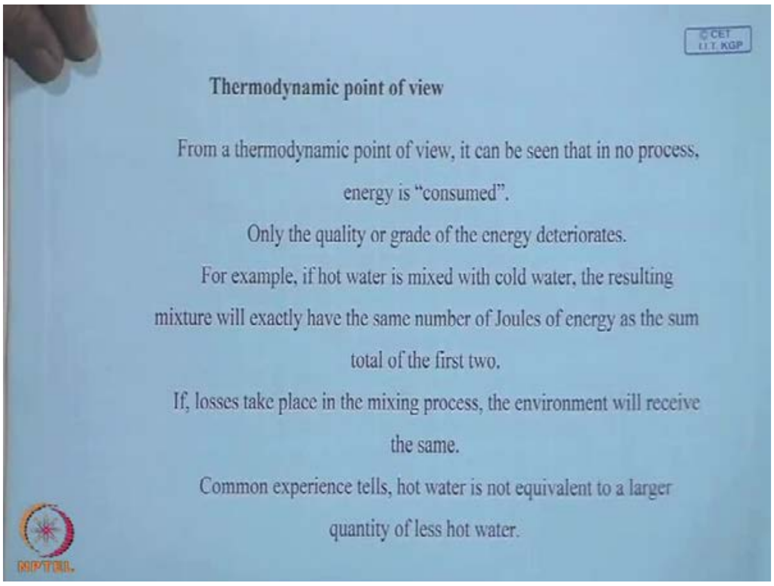

And if you look at it from a thermodynamic point of view, it can be seen that, in no process energy is consumed, energy is not at all lost, the form of energy changes from one form to the other form, only the quality or grade of the energy deteriorates. Now, if you have got a air conditioner for example, so, many kilowatts of energy is used and then, a hot air is thrown out but, nevertheless the total amount of energy comes out in the form of hot air. Because, it is around the ambient temperature, may be few degrees more I cannot get a useful work out of it because, of the Carnot's limitation.

For example, if hot water is mixed with cold water, the resulting mixture will exactly have the same number of joules of energy, as the sum total of the first two. But, in this process, the temperature might have gone down, if I had mixed it with cold water or it might have gone up, if I had mixed it with hot water, thereby the quality of the energy is changed.

And if you look at the Carnot cycle efficiency, which says that efficiency is T 1 minus T 2 by T 1 where, T 1 and T 2 are the temperature of the source and the sink respectively in Kelvin, if higher the source temperature, higher is the conversion efficiency. Essentially, whenever you have got thermal energy and trying to convert it into mechanical form of the energy, the disorderly thermal energy is tried to be put into orderly mechanical energy.

Thereby, there is a price that, you have to pay and hence, the efficiency will be lower at the lower temperatures and if the temperature is higher, the efficiency will be higher. common experience tells, hot water is not equivalent to a larger quantity of less hot water.

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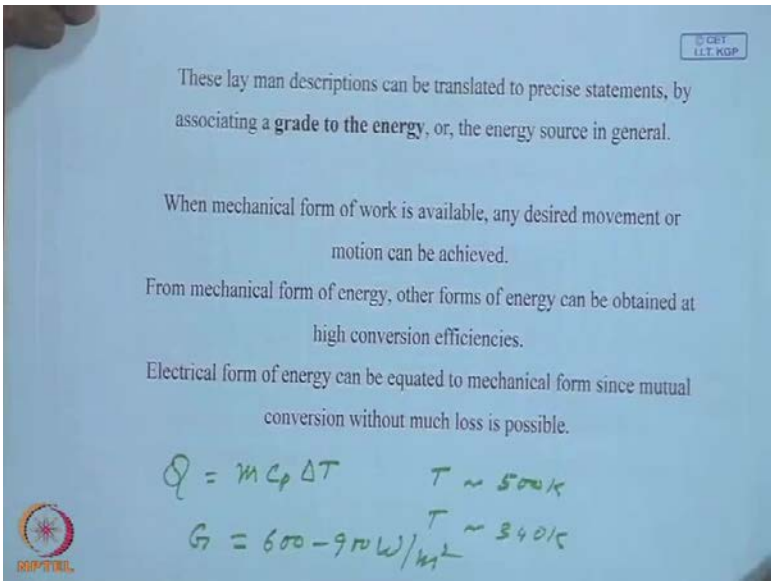

So, if you calculate m's of m into specific heat C p into delta t for example, i may use it here, is temperature is with respect to some reference temperature and it is a specific heat C p and m is the mass of the water. Now, I can convert this into a less cold less hot water, containing the same amount of joules right m is increased, delta t is decreased. But, at the same time, if I have got T 500 Kelvin or the capability of the hotter fluid is higher in converting into mechanical energy rather than, that of the colder fluid.

So, whatever we are saying less cold and more hot, these layman descriptions can be translated to precise statements, by associating a grade to the energy or the energy source in general. So, we might qualify them as high grade sources or low grade sources and if you have wind energy, it is a high grade source, hydroelectric is a high grade source, nuclear though it is thermal route, also is a high grade source. Because, the temperature, at which the reaction can be maintained or the steam can be raised, can be very high.

Now, if you look at solar energy, it is typically a diffuse sources of energy and you have got something like, you may have G is about 600 to 900. The intensity of solar radiation that, you receive typically during the better part of the day, not early morning, not cloudy days 600 to 900 watts per meter square, multiplied by the surface of the area, of the earth, it is quite a lot. But, 600 watts is small and typically a boiler will have about 3000 watts per meter square of heat flux.

So, compared to that, this is only one fifth or one sixth and in addition, you have got intermittency, it will not shine all the 24 hours. So, when we talk about, most of the time mechanical form of work is available, any desired movement or motion can be achieved in the direction that you want. Essentially, if you have shaft work, I can make it move a wheel or i can make it move a another reciprocating mechanism and produce an ordered directed movement. And from mechanical form of energy, other forms of energy can be obtained at high conversion efficiencies.

Now, why we talk about mechanical form and not just the thermal form is, when once you have got mechanical energy, you shall be able to produce electricity with a reasonable efficiency of, generation of 90 percent, 95 percent. When once, you have got again electrical energy, mechanical energy can be produced again with a high efficiency and also thermal energy at the temperature that, you desire also can be produced at a higher efficiency but, the reverse is not true.

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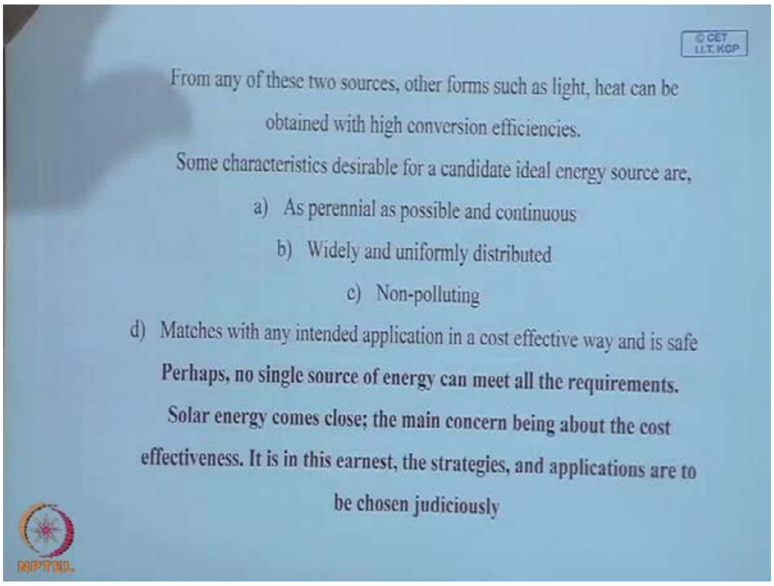

So, now, if we ask ourselves, what are the ideal characteristics that, we would like to have for a new energy source. So, we would like it to have as perennial as possible and continuous, widely and uniformly distributed and it should be non-polluting right. So, by having it as perennial, as long as the man exist, the energy will be available and if it is continuous, I would not have to store the energy in any form.

And if it is widely and uniformly distributed, I can set up a power producing plant anywhere I want then, similarly, it should be non-polluting, which is a serious issue these days, with number of vehicles increasing and the power generating units increasing. The other thing, that you would like to have is, matches with any intended application in a cost effective way and it is safe. So, if I want to produce say for example, hot water what is the cost of the hot water produced, if you use solar.

Similarly, if I want to generate mechanical power or electrical power eventually, what will be the cost of the system. Because, the moment we talk about electric generation or power generation, you go to a higher source, the higher temperature then, that may be less efficient in the conversion, from heat losses point of view. Consequently, that cost will be entirely different, if I am using a solar collector for that matter, just to heat water upto 60 degree centigrade.

Now, if you try to see all these things, perhaps not a single source of energy can meet all these requirements, solar energy comes close. The main concern being about the cost effectiveness and it is in this earnest, the strategies and applications are to be chosen judiciously. For example, if you take a tropical climate like India, water heating is not a burning problem in the sense, you would like to have in winter, 3 months, 4 months right bearing water about certain temperature and most of the time you need cooling, which is again a high grade application, if you try to provide a air condition.

Whereas, if you got to a cold climate and typically at high latitudes like the USA, the northern part of the USA, Canada then, the ambient temperature is about 11 degrees, 10 degrees or even sub-zero temperatures. So, if you can provide a house with 20 degrees C and water at the tap at 20 degrees C, it requires a lot of heating from the ambient temperature, which is normally set by the government as mains temperature.

Unfortunately, this type of an application, we cannot have but, there may be other fortune applications, see here heating is not the problem, cooling is the problem right. And though we will come again in detail, towards the end of this course, a lot of solar energy research has gone in during the last three decades with some of the demonstration plants being successful, some not so successful.

And some applications, water heating, green house effect, there are solar cookers, these are all popularly used and at the same time, you have to be concerned about this solar energy, why it is not being widely used in all parts of the world. One of the issues is that, if you look at the type of work, that is going on, people classify sometimes in a light hearted manner, as solar-solar application and solar-nonsolar application. That means, we use a solar energy for generating energy, which you call a solar-solar.

Whereas, if you take for example, architecture and take the sun power diagrams, and calculate how much of a shading, it should provide to the windows or how much it should not provide in a cold place like Kashmir or Srinagar then, this is a non-solar application, which is applied on architecture. But, this type of research, with the algorithms and the research, that has become available during the last 15, 20 years has become more widely being used in the non-solar applications.

Another simple example that, I can give you is your for example, cold storage ideally, cold storage is maintained at a certain temperature and if you can reduce this solar radiation, falling on the cold storage by choosing a, b, c, the three length, width and height dimensions properly. Which are the purpose say, for example, the height should be minimum of 6 feet, whether it is south facing, north facing or which side it is facing more area.

Thereby, you can reduce the total amount of solar radiation deceived by the cold storage thereby, you reduce the cold storage requirement on the air condition load or cooling load. So, some of these applications have become I mean, this calculations have become available with the advent of better methods and better algorithms.

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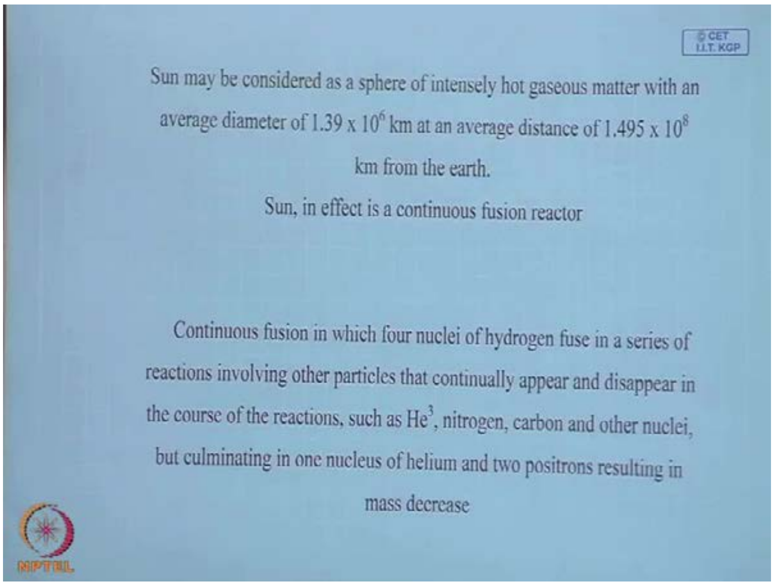

Little bit about sun, sun may be considered as a sphere, intensely hot, gaseous matter with an average diameter of 1.39 into 10 to the power 6 kilometers and it is at an average distance of 1.495 into 10 to the power 8 kilometers from the earth. Sun, in effect is a continuous fusion reactor and we on earth, try to simulate fusion reaction but, unfortunately the success is limited. Because, we cannot contain the high temperature plasma in the containers of the materials, that are known to us.

However, in the sun, the hot gases and the plasma are contained by gravitational forces without requiring the external use of a vessel, to hold the material. And the continuous fusion, in which 4 nuclei of hydrogen fuse in a series of reactions, involving other particles that continuously appear and disappear in the course of the reactions such as, He 3, nitrogen, carbon and other nuclei. But, culminating in 1 nucleus of helium and 2 positrons resulting in a mass decrease so, when this fusion reaction goes, there is a reduction in the mass.

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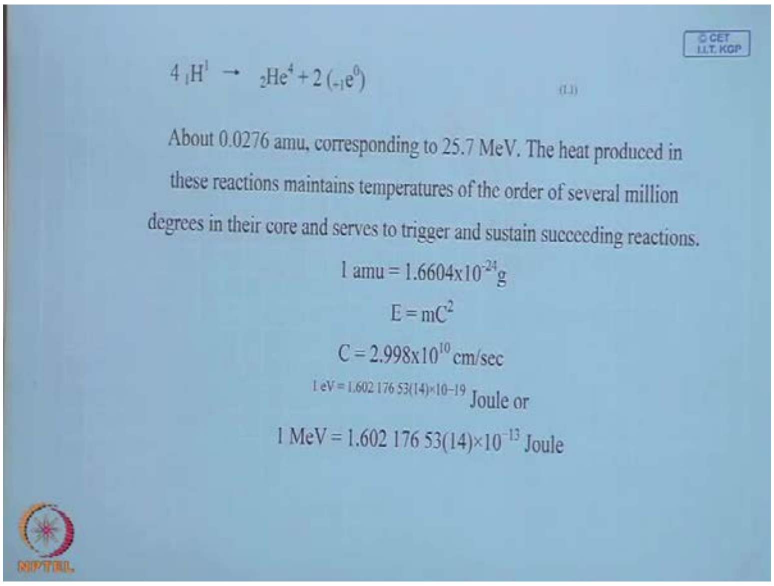

So, that reduction the mass is converted into energy and about 0.0276 atomic mass unit of mass deficiency corresponds to 25.7 billion electron volts and the name is very profound million electron volts but, the quantity of energy that, you will see of MeV is equal to very small. The heat produced in these reactions maintains temperatures of the order of several million degrees in their core and serves to trigger, and sustain succeeding reactions.

One atomic mass unit is, for your information 1.6604 into 10 to the power minus 24 grams and the rate of conversion is, according to the Einstein's relation, E equal to m C square where, C is the velocity of light 2.998 into 10 to the power 10 centimeters per second. And 1 electron volt is of the order of 10 to the power minus 19 joules or 1 milli-electron volt is of the order of 1.6 into 10 to the power minus 13 joule. So, so called milli-electron volt is a very small amount of energy however, the fusion reactions are the efficient reactions in nuclear reactors are plenty per second, producing sufficient energy.

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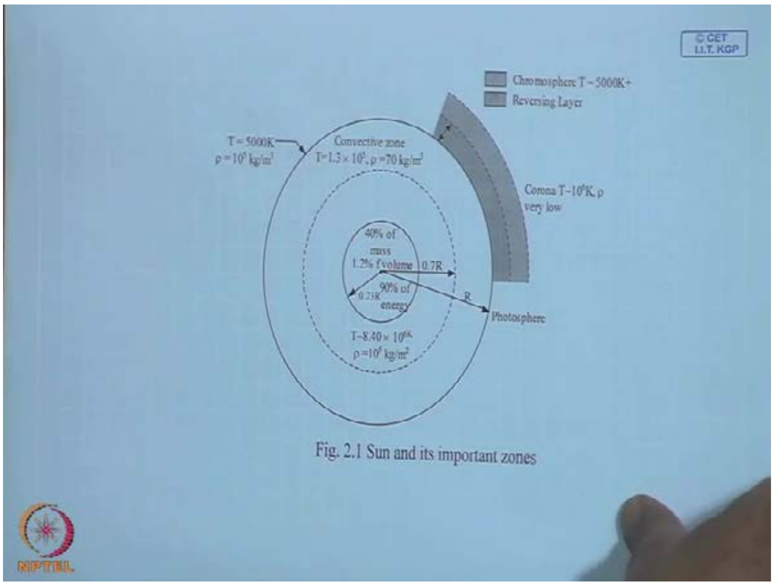

Fig. 2.1 Sun and its important zones

So, this is the schematic representation of the sun about 90 percent of energy is produced within 0.23 of the radius and it occupies a 1.2 percent of volume. But, 40 percent of mass at the center, there is corona, there is a reversing layer, there is a photosphere and then, a convective zone and effectively, sun is at about 5000 Kelvin. So, in another words, it is not that, we have measured the temperature by any thermocouple or thermometer, taking it near the sun.

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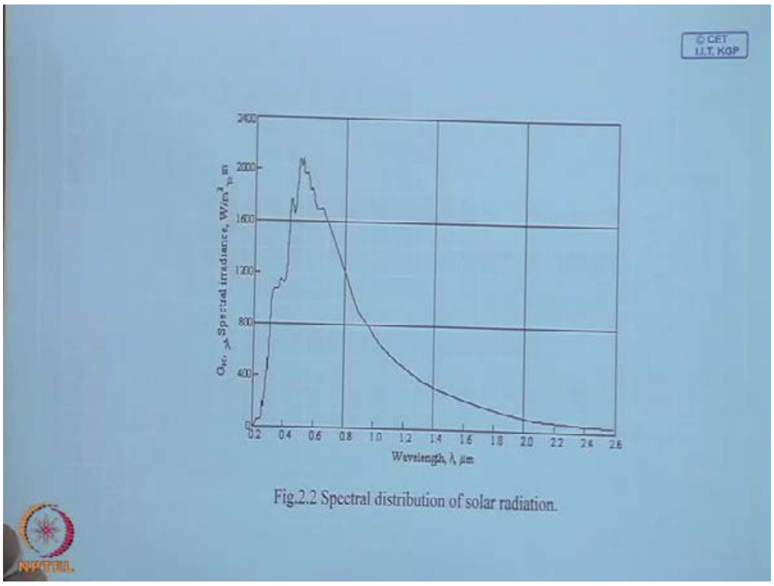

Fig.2.2 Spectral distribution of solar radiation.

But, effectively, by virtue of the solar radiation that, you receive on the earth, if you back estimate, the effective temperature transferred to be 5000 Kelvin. This is the spectral distribution of solar radiation, 95 percent of energy is between about 0.0 to about 4 microns

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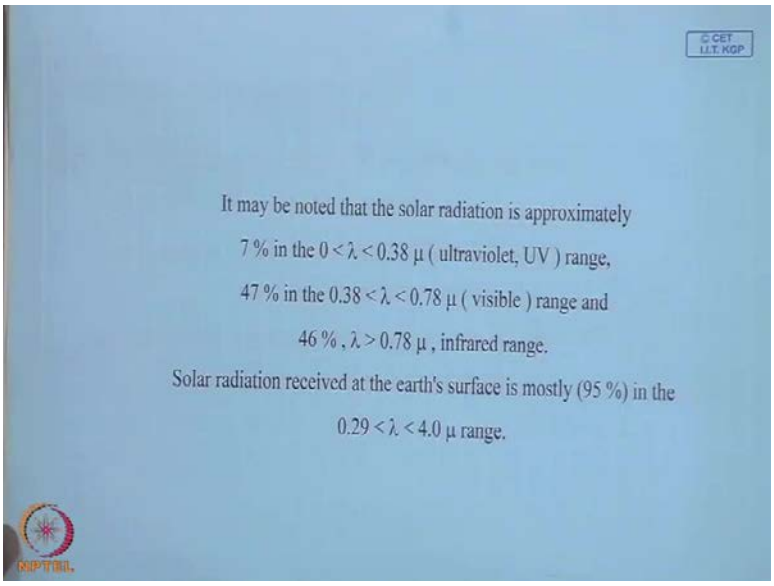

And the other percentages are 7 percent is between 0 to 0.38 microns, which we properly call, the ultra violet. And about 47 percent is in the range of 0.38 to 0.78 that is, a visible range and about 46 percent of lambda, greater than 0.78 microns is the so called infrared range. Solar radiation received at the earth’s surface is mostly in the wave length band 0.29 to 4 microns range now, interestingly this visible range is one thing which is utilized by the photovoltaic.

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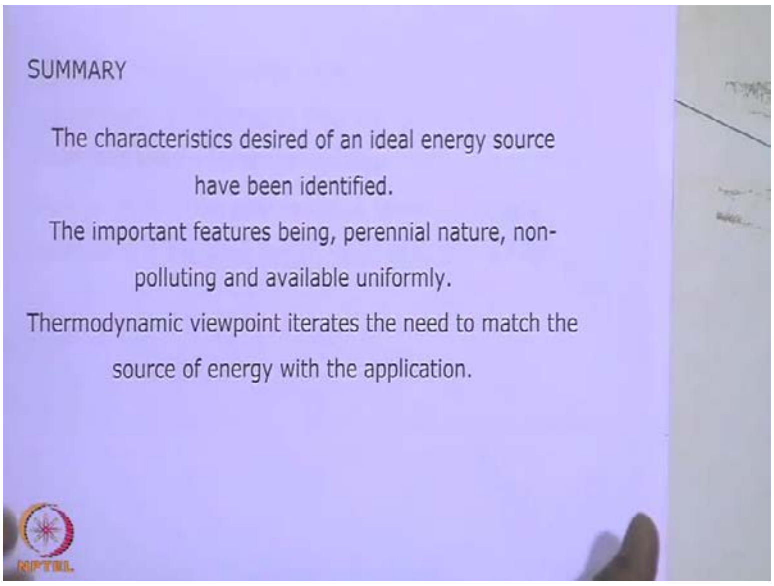

So, though photovoltaic produce direct electric energy, only part of the solar radiation spectrum is available for it, to convert into energy that is, one thing we have to take into account, when we calculate the efficiency of solar energy device, working on a photovoltaic principle. So, what we have done in this part is, a little glimpse of, what sun does, it is basically a fusion reaction producing energy.

And in a particular wave length range and what we receive on the earth and the characteristics desired of an ideal energy source have been identified, the important features being perennial nature, non-polluting and available uniformly. Thermodynamic view point iterates the need to match the source of energy with the application so, this I have not elaborated but, it will be interesting to know.

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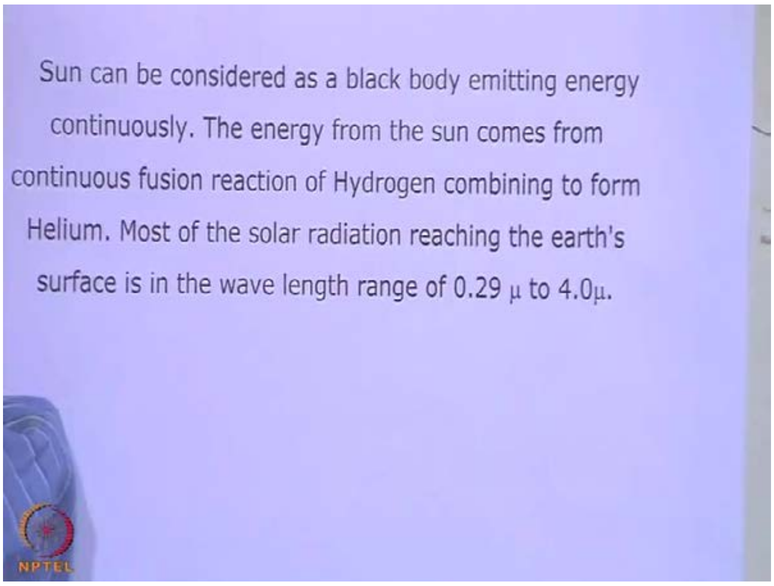

How many of you know, at what temperature you take the bath, hot water bath, I know previous classes, people came out with answers ranging from 50 degrees to 60 degrees to 45 degrees, like that. But, the fact is, you use about 5 to 6 degrees above the body temperature, 41 to 42 degrees centigrade right and skin cannot sustain more than 45 degrees C and do not think that, you take bath at 60 degrees C.

But, invariably, there is a small model I want to draw, you produce hot water in a geyser or even in the conventional method of heating, at about 60 degrees or more than 60 degrees. Then, mix it with cold water to bring it to 40 to 45 degrees centigrade, in thermodynamic's language it is a entropy generation. So, you are taking a high grade energy at 60 degrees and converting into a lower grade energy at 45, 42 degrees.

So, if you need hot water at 45 degrees, just heat it only up to 45 degrees centigrade of course, there are economic issues, which you have to study, which in the course of time, we will find out, what is important. Then, if you have water at 45 degrees centigrade then, the tank size will be larger then, your economics will be affected because of, the size of the tank. And now, it is an issue, whether the heat loss will increase because of, the surface area of the tank or decreases because, the temperature is lower.

So, though it is a very simple example, it can be set mathematically and go to an optimum size of the tank and optimum temperature, at which you generate the energy. With these calculations, solar energy device and particular application, as we will be noting, as we go along the course and what purposes, it is ideally suited and what if, what are technologically have become feasible and we note, whatever conclusions we draw at the end of the course, we will draw at the end of the course.

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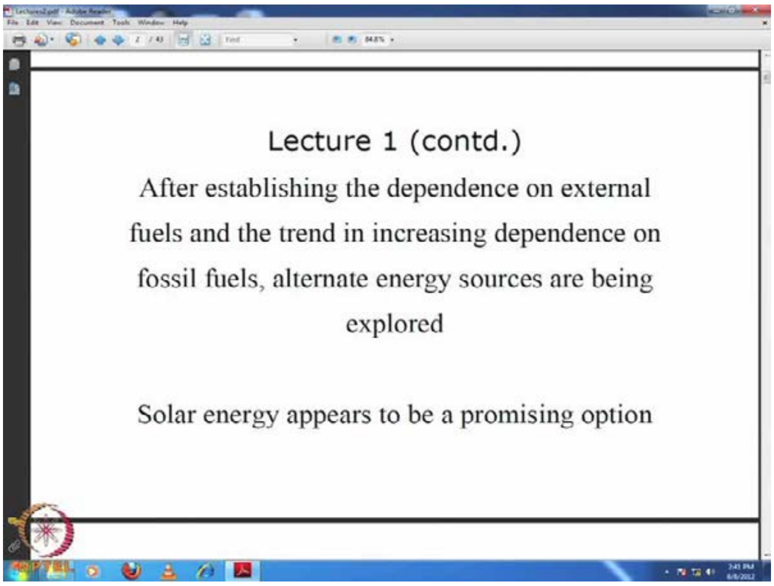

Last time we established, the dependence on external fuels and the trend in increasing dependence on fossil fuels, alternate energy sources are being explored. And we also considered different options, which are called popularly, the alternative energy sources, of which solar energy appears to be a promising option.

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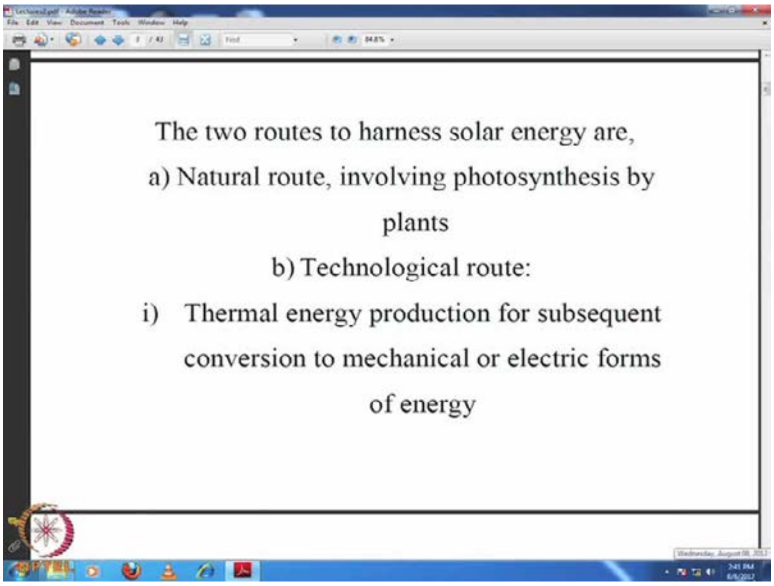

In harnessing solar energy, we have two routes, one is the so called natural route, which is a plant's implement by the process of photosynthesis and stored the energy in the form of wood, which can be later on used for number of applications. On the technological route, involves thermal energy production for subsequent conversion to mechanical or electrical forms of energy.

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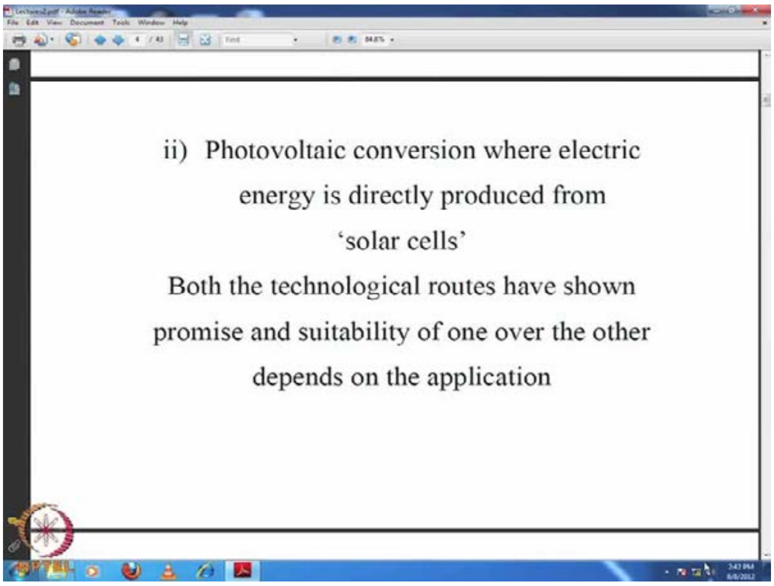

And also, you may have photovoltaic conversion where, electric energy is directly produced from solar cells. Both the technological routes have shown promise and suitability of one over the other, depends upon the specific applications.

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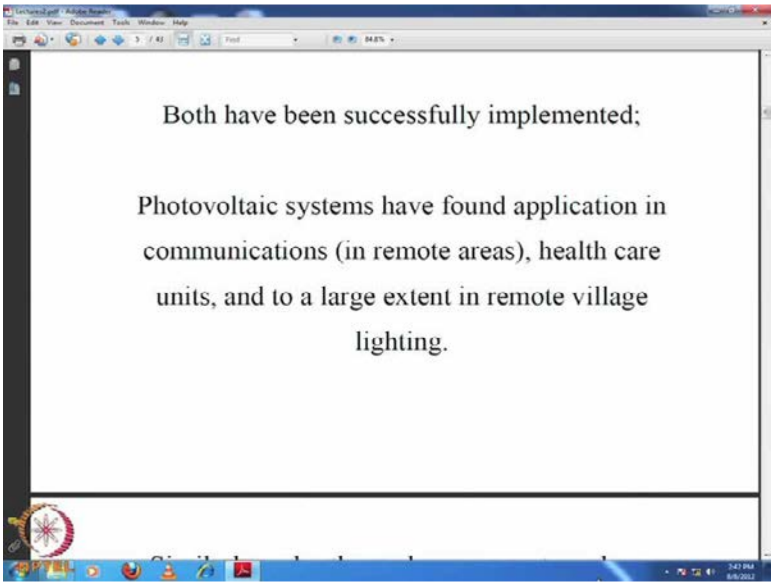

If we for example, consider a remote area, for communication purposes, etcetera solar cell appear to be a good option. Similarly, remote villages where, lighting is required, solar cells operated systems also appear to be promising. Whereas, there are a large number of systems based on the thermal energy, that have been established throughout the country for production of hot water, for production of steam and even power generation. As I was pointing out last time, basically the idea is, we have to match the sources of energy to the application.

The example I was talking about was simple, taking the bath with hot water and you as a matter of fact, you use water around 40 to 45 degree centigrade. And most commonly, it is heated upto 60 degrees and then cooled, which is a wasteful process, which is an entropy generating wasteful process. Photovoltaic systems have found application in communication, etcetera, which we have already seen and both have been successfully implemented. There is not much doubt in the technological feasibility of, either the photovoltaic route or the thermal energy route.

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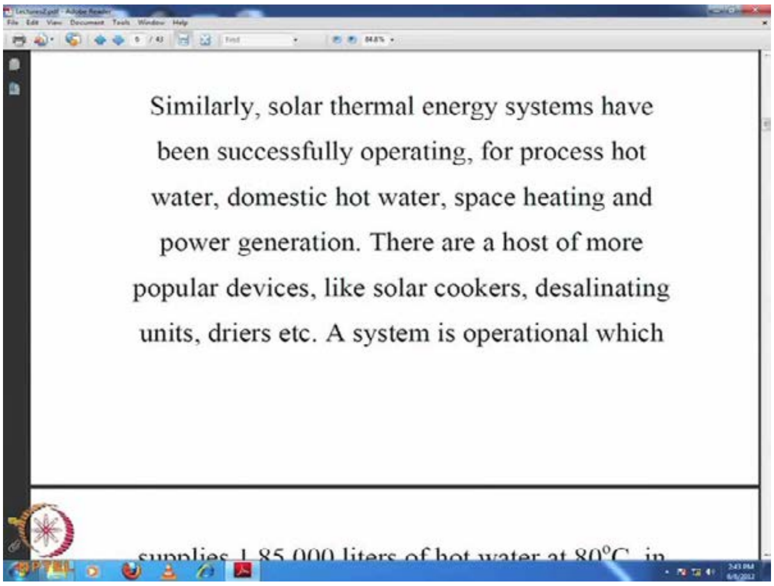

However, the issues remain those of economic viability, longevity and monitoring in remote areas for a long period of operation so that, we will know the reliability like for example, transformer that is, kept outside right. We know, depending upon the quality of the steel, it lasts for 20 years or 30 years, same statement we cannot make about a solar collector. The reasons being, such has not been the case earlier, we did not used those appliances in addition, it is subject to thermal cycling. Normal environmental degradation processes may be accelerated, which need, which can be established only through long term experimentation and monitoring of the energy systems.

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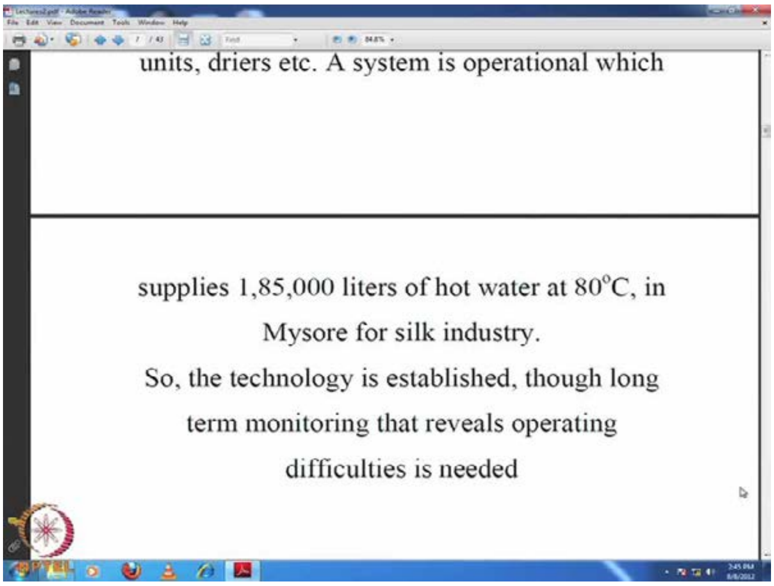

And I knew a one of the, one of the operation systems in India supplies about 185000 liters of hot water, at 80 degree centigrade, in Mysore to meet the requirements of the silk industry. So, the technology is established though long term monitoring that reveals, operating difficulties is needed.

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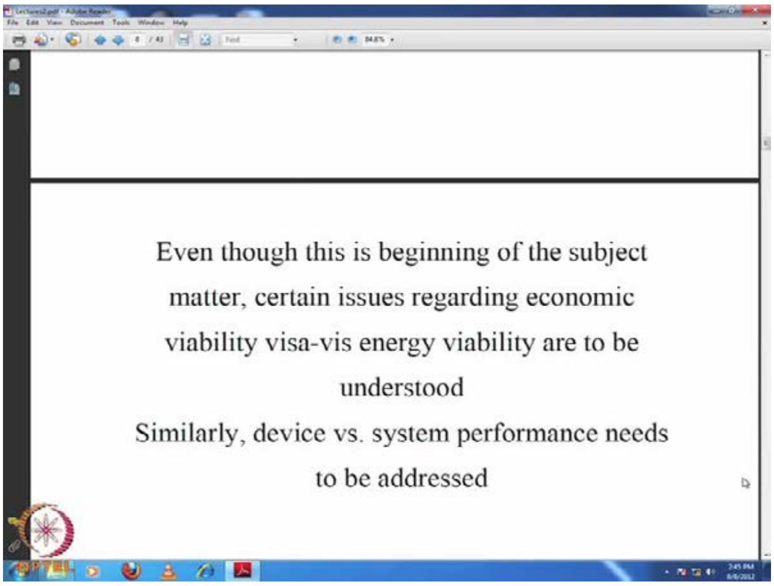

At the same time, before you appreciate the subject and the difficulties, we have to carefully distinguish between economic viability and the energy viability. Most of the time, what is the energy saved by producing hot water or power generation by a solar energy system or any other system is, compared with the conventional energy sources. And if the payback period is a reasonable period like 2 years or 3 years or 4 years, we call it economically viable however, there is one basic issue, economics and in general, cost is somewhat artificial.

In the sense for example, if you take it LPG is subsidized and if you compare with the cost of petrol, there is no reason, why LPG should be less costly than petrol. So, if you analyze the system based upon LPG, it appears to be economically viable but, in reality the price is paid by someone else. More basic issue is, if you have an energy system, which definitely makes use of materials like steel, copper or aluminum, or glass, insulation material that, material itself consumes certain amount of energy in producing the article.

So, in its own lifetime, unless it is going to save that much of energy, that has been really used in producing the material, whether or not economic viability or not, chances are we are going towards bankruptcy faster as far as, energy depends on other sources concerned. If you carefully analyze, a take 2 squares meters area of a solar collector, thermal ordinary flat plate collector that, requires some 5 kgs of steel, 2 kgs of glass one can put down and then, find out what is energy has, that has gone in, in producing these elements.

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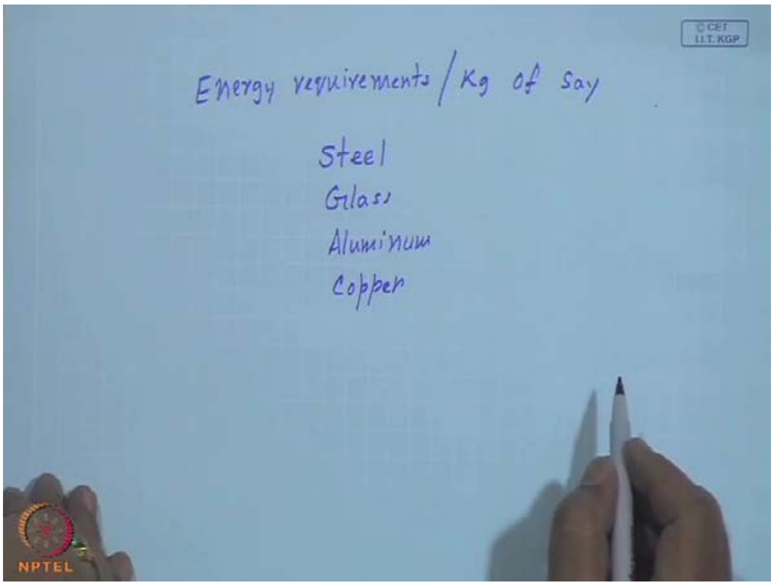

So, one exercise people can do and take up even will be available from the net, because these are the materials that are common used in various solar applications. And in fact, number of other applications so it is worthwhile knowing, what is energy consumption per kilo of the material produced.

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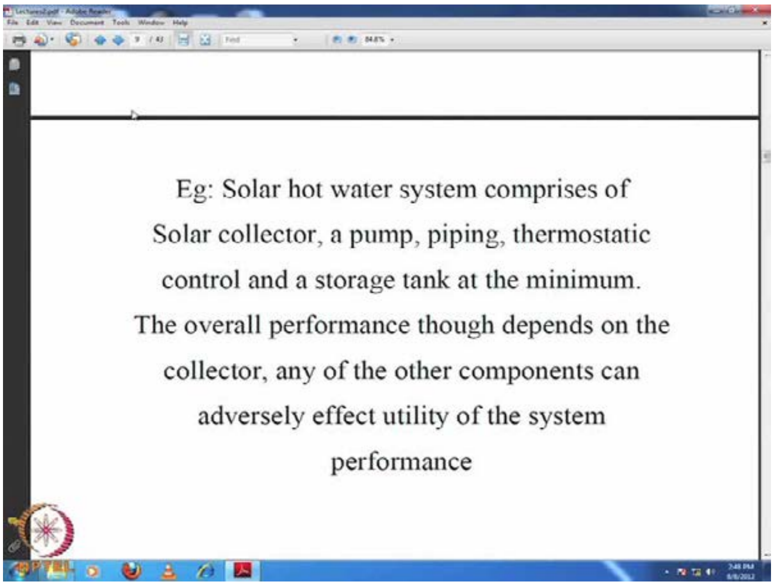

Again, we try to make a distinction between a solar certain device and a system.

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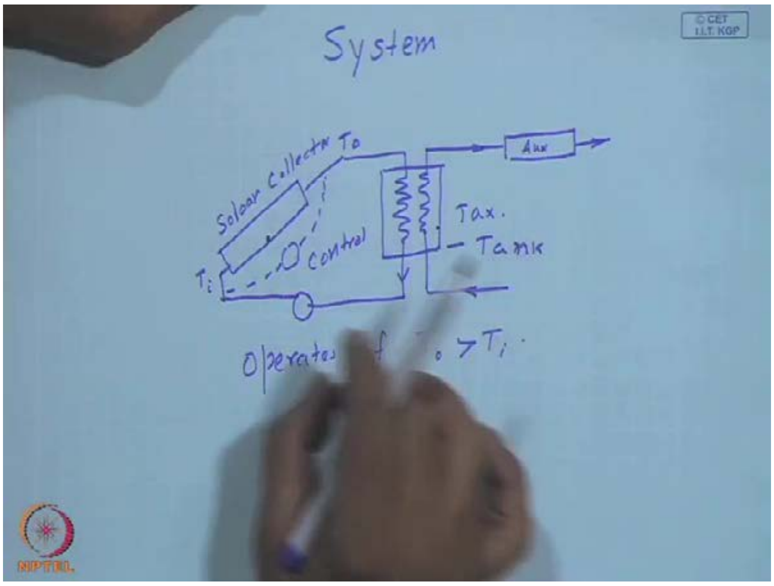

This has not been sufficiently emphasized in many of the books that are available, if you are talking about even hot water production, the simplest system one can think of, will comprise of a solar collector, from which hot water goes to a tank exchanging energy. You may draw the water through a heat exchanger so that, the fluid need not be only water, it can be any other heat exchange fluid.

You may add even an auxiliary to make up for the quality or the quantity of the water required, there will be a pump circulating water into the solar collector or it may be operating on thermosiphon system. You may have a control, which measures outlet temperature and the inlet temperature, and operates if T o is greater than T i. So, otherwise the pump is shut off of course, you cannot have a perfect control so, there will be a bandwidth, it may be accepting outlet temperature plus minus 5 degrees, 3 degrees, depending on the accuracy of the control unit.

Even if you consider the simplest conceptual system like this now, the delivery temperature ultimately after or before the auxiliary, will depend upon, how effective is the heat exchanger. Similarly, if the control is ineffective, it may be throwing out lot of cold water or if it is too stringent, it may not be sending it, unless the temperature increases much more than the set temperature or required temperature and one can also expect the failure of the pump.

Now, this is a auxiliary tank, just to give emphasis of example I have taken, somebody designs for a family of 4 that, about 60 liters of water or 120 liters of hot water are required per day. So, solar collector sizing has been found to be about 3 square meters roughly and pump everything is put in place but, forgot to put tank. So, unless the requirement matches with the solar radiation, you take little water, when it is in the morning and the sun is not so hot and more water around 12-o-clock then only, the utility of the system can be felt.

But, if anyone everyone wants to have bathing between 8 and 9, there will be no water available however, if you put the solar energy tank right then, the water collected the previous day is available in full to you, when on demand the next day. So, then the sizing issue of the tank comes, those are all details but, the effectiveness of the entire system will not only depend upon the so called, collector efficiency. But, also on the combination of the components that are put in this, this is one part, which this course tries to emphasis the system versus device component.

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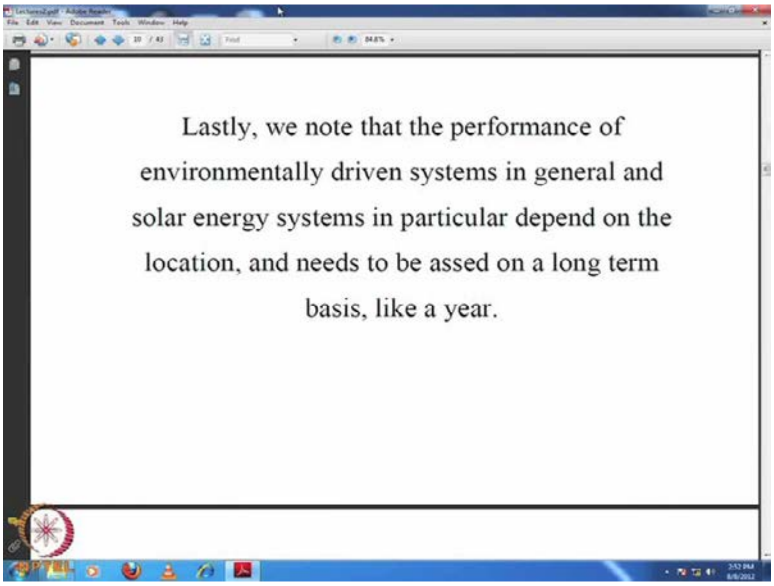

So, the matching of the components in the entire system, along with the collecting device and the conversion device is an equally important task. Now, we might categorically say, the performance of environmentally driven systems is a collective term that is, given for wind energy systems, solar energy systems that, depend upon the environment, in general. And solar energy systems, in particular depend on the location and needs to be assist, there is a spelling mistake on a long term basis like a year.

Depending on the location say, for example, if you have got a fan, as long as the supply voltage is 220 volts well, it is put in Kharagpur or Madras or New Delhi or somewhere abroad, which operates on 220 volts. It will give us exactly the same performance whereas, the same solar energy collector will not give the same output, if it is operating in Chennai and if it is operating in Delhi. So, if you want to size a system, you have to know the local meteorological features, and then consequently performance of overall system is highly location dependent. Making thereby not possible to have a unique design for every system and every location that is, what makes the subject interesting as well as challenging.

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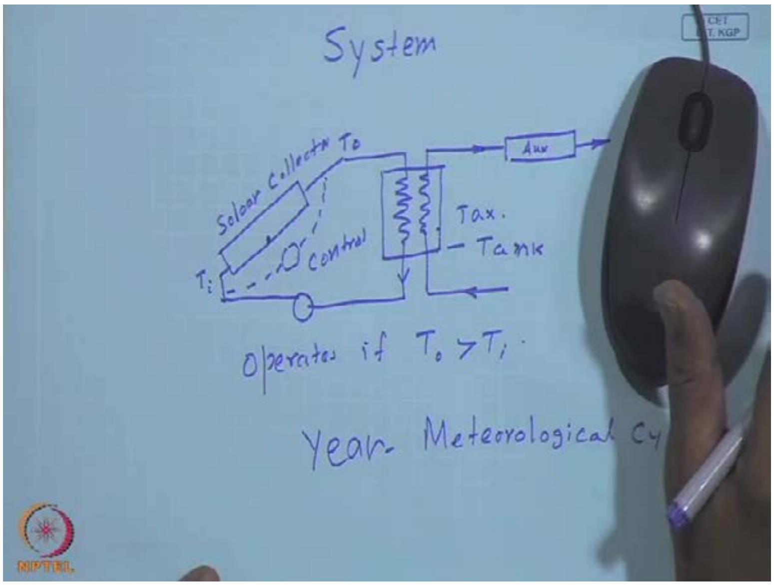

Now, the other thing, I was telling a long term basis like a year particularly, for solar energy system, a year is chosen, because the meteorological cycle repeats every year, though January first may not be identical to the next year’s January first, the fare amounts of averages are reproduced. Consequently, whatever is the output that you expect in a typical year can be predicted but good enough number of simulations over a long term average meteorological data.

Not only that, invariably your economic analysis also is based on yearly analysis consequently, long term performance becomes necessary. Just to emphasis again this point, if you have got a particular solar collector and your requirement is let us say, at 60 degree centigrade water, if you operate it in the month of December, you may have to heat it from 15 degrees to 60 degrees; whereas, if you operate in summer, it may be 35 degrees to 60 degrees, ambient temperature being the inlet temperature. So, delta d is almost one half in I mean, in summer compared to what it is in December.

In addition, you have a solar radiation decrease by a third portion, at least one third in December to June. So, if you size for requiring, rather meeting 60 liters of water, at 60 degrees in December, it will be a grossly overdesign in June; at the same time you have to make a compromise. So, in other words, equal additions of areas will not be resulting in proportionately higher increase in the overall year, yearly production. So, that is where, the non-linearity comes into the picture, which also gives us an opportunity to optimize the objective need not necessarily be replacing something for your entire system needs. But using the system at an optimum level so that, your benefits are per rupee investment is a maximum.

So, that is what, we learn so basically we tried to build up a case, why this deficiency in the energy has come about. And particularly, the need to look at alternate energy sources of the several options, solar appears to be one, which can directly produce electricity or thermal energy, which may be converted into heat energy or electric energy, depending upon the need. Subsequently, the challenge lies in, it has to be a location based design, a unique design will not work and thoroughly, a long term performance has to be accessed. And system performance, though critically depends upon the solar collector, will equally well depend upon the other components wherein, you have a lot of meteorological data and interactions, you have to choose optimal size that yields the maximum energy per rupee invested on the system.