**Energy Conservation and Waste Heat Recovery**
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**Lecture - 62**
**Energy Economics – I**

Hello. Good morning and welcome back to the next lecture of Energy Conservation and Waste Heat Recovery. Today we are going to talk about a topic which is a little different from you know the topics that we were discussing. So, far this topic is called energy economics. So, this is not. So, much about hardware, but its more about how do we decide if an energy installation if a plant if that is viable if it is worth going for that energy production if you are planning to set up an energy plant or how much energy do we need for the economy to sustain. So, a lot of these questions are going to be answered in this section on energy economics.

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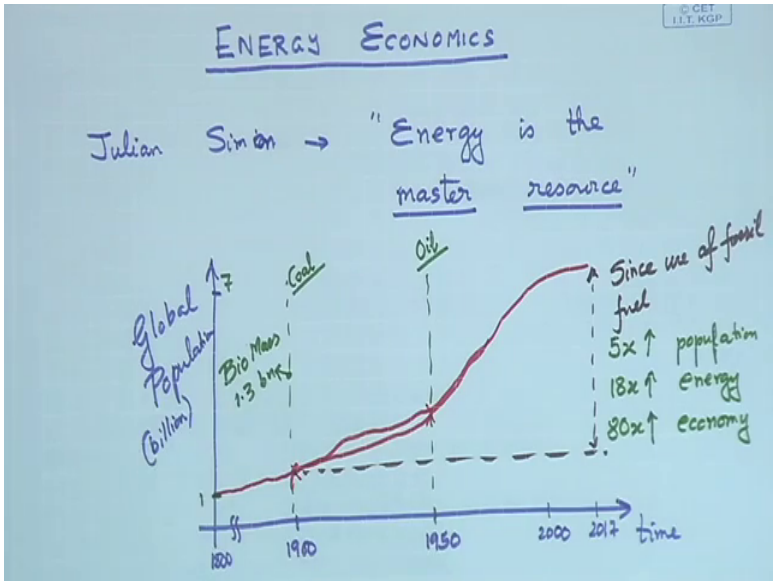


So, let us write down the name of the topic then the topic is energy economics all right now when we talk about energy economics there are roughly I would say or at least what I am going to present there are 2 different ways of looking at this its I mean they are not like alternate ways energy economics can mean 2 different things the first one as I was saying is the economics related to an energy installation. So, you do the accounting you see how much is the cost of setting up a plant and if you set up a plant what is the benefit

that you are going to get in terms of energy product additional energy production in terms of cost savings over a period or over its lifetime and so on and so forth. So, that is definitely one part of energy economics.

The other part with which I am going to start is to look at energy and economy how is energy and economy related to each other what is the relation are they are they even related when we talk about the economy of a nation let us say economy of India does it depend on energy. So, that is the question that let us try to answer that. So, to do this what I would say is let us imagine a hypothetical situation where I leave you on an island it is a deserted island and over there I give you a lot of things I give you money I give you gold I gives you silver a lot of other things, but I do not give you any energy and when I say energy I am talking about coal I am talking about wood I am talking about natural gas oil and. So, on and even sunlight let us say is the north pole during winter you do not have sunlight.

So, what will happen? So, if I am stranded in an island like that I will survive for the amount of time that my body energy stored in my body is going to let me survive, but beyond that I will not be able to survive and nothing in the on; that island is going to survive. So, if nothing survives on an island what happens to the economy the economy also dies. So, there is no economy left on the island, but think about it I had given you a lot of other things. So, there is no economy left on the island even though you are surrounded with enormous wealth.

But that wealth that money that gold the silver the bullion is of no use, all right. So, that is what I am trying to say there is a famous economist his name was Julian Simon; Julian Simon. So, what he said is energy is the master resource mark by words energy is a master resource. So, all things depend on available energy the plants grow because they get energy from sunlight from the soil through the nutrients and. So, on the population grows because of energy and the growth a limit of population growth will be dictated by how much of energy resources a nation has.

If there are situations where when the economies have stumbled have fallen because the population growth was more than what the economy could sustain and which in turn was related to unavailability of energy resources. So, every unit of production of anything you think about it anything that you want to produce requires energy we cannot deny that

fact everything whatever you want to produce every unit will depend on energy and that energy has to be available to us and available in an affordable manner. So, therefore, I would like to further state that the growth of a nation which is growth of the economy of the nation depends on adequate supply or availability of affordable energy I repeat the growth depends on adequate supply of affordable energy and why do I say that if you think about it.

Let us try to plot the global population. So, I would say the global population in billion people and this is time. So, let us say till I will put a break here I would put this as 1900, I would put this as 2000, I put this as 2017 which is where we are today and somewhere in the middle, I will put this as 1950, today we know the population is around seven billion and let us say this was one. So, around 1900 if I plot this it was going growing up like this, all right and then today we are at around seven point 3 billion or something I think here also there was an increase sorry and then there was an increase like this.

So, remember if I say this is 1800 and I have put a break here. So, what happened was that what we see is after 1900, there is a steep growth and after 1950; even another steep growth. So, let us put these 2 points. Now these 2 points actually denote something, these 2 points in time approximately denote something; this one coincided with coal becoming an available source of energy economically viable. Therefore, affordable source of energy and this one coincided with oil before this was more like the biomass; biomass was the energy source here and the population was around at 1900 was around 1.3 billion.

So, as you can see that with the availability of coal and oil liter; a oil what has happened was the population really searched. So, this further denotes or what further sort of underlines what I just said that the growth of a nation and this is being denoted in terms of population the growth depends on the availability of adequate amounts of affordable energy, right. So, if I look at some numbers. So, from where we were in 1900 to where we are today this one; what it means it means that since the why would say since use of fossil fuel, what have we seen we have seen 5 x increase in population sorry what is not shown here is an 18 x increase in energy and around if I look at the global economy an 80 x increase in economy.

Look at these numbers I am talking about 1900 which is a little more than hundred years. So, in this short period of time if you if you look at it this time period is a short timeframe if you look at the history of mankind, but what we see is in a little more than 100 years the population has increased by 5 x, not just 5 yeah of course, 5 x, but more than that from 1.3 billion to around 7 billion, today the energy resources in the world has increased by 18 times and the economy has therefore, jumped by 80 times. So, this further again I am trying to underline the fact that energy is the master driver that is a master driver for economy.

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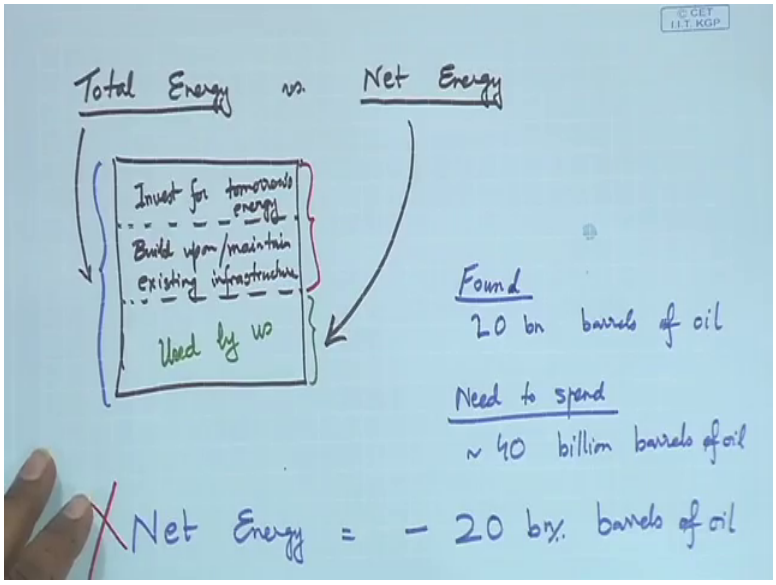


So, what we are going to do next is we are going to look at something called net energy total energy and net energy. So, total energy versus net energy. So, what is total energy that is the amount of energy that is available to me now is that the energy I can use right away let us say for lighting my home no, all right. So, if I look at the total energy if this is my total energy let us say I would say part of it I have to invest for tomorrows energy I have to think of the fact that my energy requirements are going to go up in time with time and therefore, I have to make way for you know for installing new plants new energy sources and so on in new energy production units and so on.

The second one is you have to use it to build upon or maintain existing infrastructure all right and after this. So, after this is gone what is left over here is what can be used by us and even what can be used by us can also be further broken down let us say into essential

use like for example, water electricity etcetera which are life needs. So, that is essential use and also discretionary use for example, I want to you know drive an SUV, do I have the energy to do that again we are not talking about affordability in terms of money here which is also important, but what we are trying to talking about here is the availability of energy resources to us as a nation.

So, if you look at this; this is like you know if you if you think about your paycheck, right. So, part of it is like taken away for tax and then the rest of it is used is available to us for use right. So, this is something that we have to keep in mind. So, therefore, this is this one this net energy. So, this total is the total energy I would say this is total energy, but net energy is this one and it is net energy is what that matters, all right.

So, what do we mean by that what do we mean by that what I am trying to say is if you have to generate energy if you think of it if you need to generate energy we also have to use some energy let us take the simple example of a power plant right power plant yes I need to generate energy I generate electrical energy, right, but for that I also need energy to be used right. So, that is the thing and when I said I mean I need energy I need energy for the available energy that is to that is available to us or part of the energy that is produced is me is required to run the plant right I am running that power plant, but I need electricity to run the plant, right.

If it is a gas turbine plant I need part of the turbine work to run my compressor exactly and the rest of it is available to us. So, let us take a step back and this was we are talking about already an existing energy installation when we are talking about power plants, but let us think about just to get a source of energy what is the amount of energy that we need to spend, all right. So, let us say I tell you today that I have found an oil well that can give you like let us say 20 billion barrels of oil, right, I can get 20 billion barrels of oil from a new oil well that has been this is a hypothetical situation by the way I found a new oil well somewhere where I have seen there a enough oil reserves to give me 20 billion barrels of oil.

So, that is a lot of oil it is a great news right for mankind because we know that the fossil fuel or we are we are running shortage there is a shortage of growing shortage of fossil fuel we are running out of resources and. So, on, but then I tell you that you know what the problem is that this oil well that we have found is really deep its almost close to the

center of the earth and to dig this oil or to explore and get this oil out of out of there will cost me an energy which is equivalent to 40 billion barrels of oil.

So, what is it I am spending energy worth 40 billion barrels of oil equivalent to 40 billion barrels of oil to get energy which is 20 billion barrels of oil. So, again let us write down this hypothetical situation I would say found 20 billion barrels of oil, but need to spend 40 billion barrels of oil or equivalent of; so, what is my net energy total energy yeah is 20 billion barrels of oil, but what is my net energy, it is minus 20 billion barrels of oil minus 20 billion barrels of oil. So, what is the use this is a losing proposition.

The net energy is actually negative, all right. So, this one this energy proposition is rejected this is a losing proposition because the net energy or the surplus energy is negative here and that is what matters a society runs on the surplus or net energy clear. So, always keep that in mind the society runs on surplus or net energy if you look at highways if you look at roads if you look at the aircrafts on the sky everything to build everything we needed energy.

So, energy actually is very important it is kind of influencing us in every moment in such a manner that we do not even realize.

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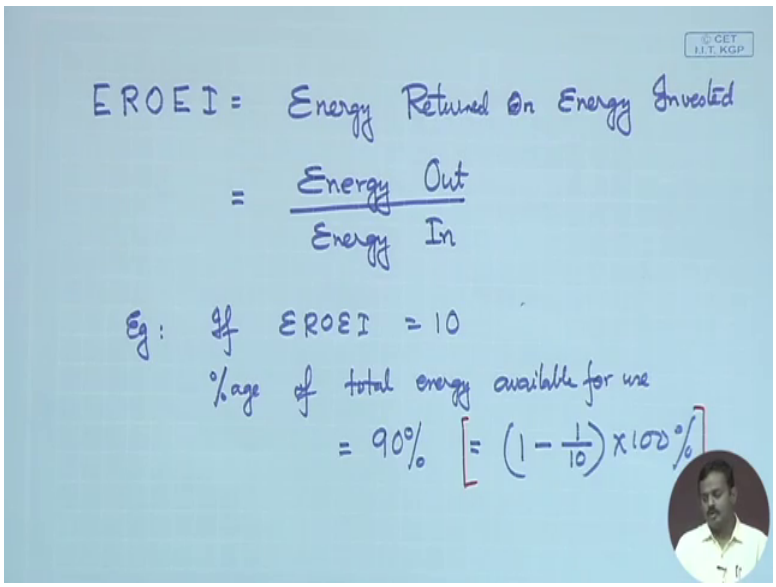


So, with that what I will do is I will come to the first metric of energy which we which sometimes is called net energy it is also called energy returned on energy invested. So, I

will call it EROEI stands for energy returned on energy invested and this is again defined as energy out over energy in right this is equivalent to like your take home salary over the tax that you paid on your salary.

So, this is what it is. So, this term is energy return on energy investment or energy invested. So, let us say I would say as an example if EROEI is equal to 10 what does it mean it means that the percentage of total energy available for use will be how much it means that if I let us take the example if I produce if or if I use energy equivalent to one barrel of oil I can get 10 barrels of oil. So, 10 percent of the energy that I am getting is lost in producing that energy. So, therefore, percentage of total energy that is available to us is ninety percent why because it is one minus one over 10 times hundred percent clear, all right.

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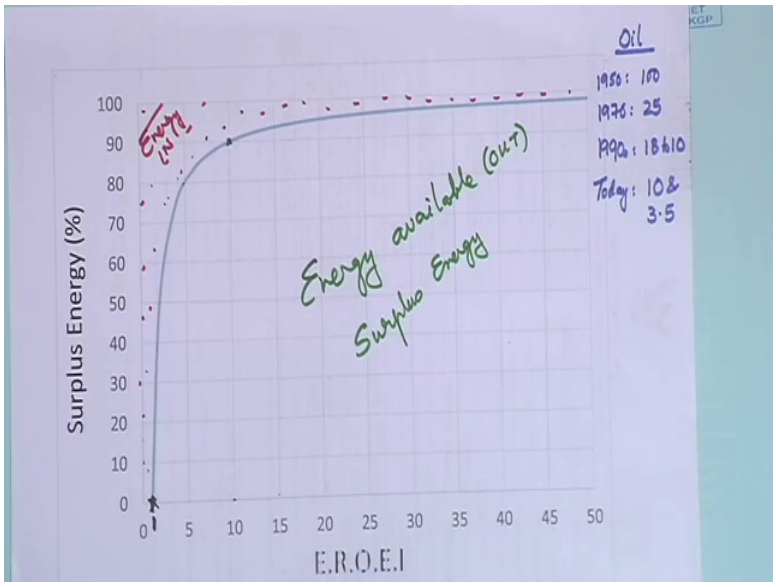


So, what I have with me now is a plot which I made using this formula again let us see if it is I will I will try to explain what it is on the y axis on the x axis sorry is EROEI, this is at 0, 50, 45 that 10 is something that we were talking about and as you can see this is a surplus energy percentage or the available energy to us and as we were seeing at 10, it is at ninety percent. So, let us think about the this entire plot area which is this is equivalent to like your total energy whatever is above the line if I sort of mark it in or in red this is the energy that is lost, right.

This is something that I do not get this is the energy in, but and what is then under this plot this is the energy available or surplus energy, right. So, this for example, this again is like energy in and this is energy available or energy out all right. So, as you can see at fifty at fifty of EROI of 50 what happens is only 2 percent of the energy that I get is actually used up for producing that energy and the rest 98 percent is available right at 15 it is still quite high right at 15, it is like ninety 3 percent or so on.

At 10 90 it still, but this is where the hockey stick starts and if you look beyond 5, we are really on this on this part of the curve which is called the energy cliff right what it means is beyond let us say beyond 5, if we go a little towards the left towards the lower numbers what happens is most of the energy that is produced is lost and till we reach this till we reach this value which is equal to one what does one mean that whatever we get is used up for producing that energy.

So, there the surplus energy available hits 0 at the value of EROEI equal to one. So, their energy out is equal to energy in right. So, that is the point. So, let us now look at this curve and try to see where we stand if we look at the different sources of energy that we know of let us first talk about oil which is important which is something that has been you know one of the prime drivers of our economy today in 1950 when the oil extraction was first done you could do that at almost an EROEI of hundred which is way toward the right of the curve, right.

So, for one energy spent which is equal to one barrel of oil I was getting hundred barrels of oil. So, because at that time it was largely unexplored the wells were you; you could get oil at low depths and. So, therefore, oil was abundantly available, but what we as greedy humans did was since it was available to us we extracted it as much as possible and used it up unfortunately and so, with time what happened was the oil production started going down this curve at around 1950 that is let me write down some of these, if I talk about oil in 1950, it was around as I said is; it was 100 right, by 1970, it had come down to around 25 why because whatever was readily available easily available has been extracted.

So, now in order to extract oil we were having to go deep we were leading larger; larger oil wells and. So, on right then what happened by nineteen nineties we were somewhere between 18 to 10, all right and today we are between 10 and 3.5; let us say depending on

where the oil field is why because as I said the easier sources have been extracted and what is remaining are deep into a are re really deep wells which we have to really dig deep to get them, the oil fields to extract a certain sizable amount volume of oil the fields have become large and the machinery is also the third thing we should not forget the machineries used for drilling for excavation has also become much much bigger much more complicated and it requires much more energy to build those rigs today than what it used to take in 1950, right.

Therefore, from 1 is to 100 which is way to the right of this curve today we have come to around this point we are somewhere here and here very sad, but that is the reality because the low hanging fruits the easily available oil is no longer available to us we have used it up.

So, that is the scenario of oil today. What we will do next is in the next class we will wrap up this discussion and look at other sources of energy where they lie on this curve.

Thank you very much.