Energy Resources, Economics and Environment
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Lecture 08
Materials for Energy

We have already looked at energy resources and we saw that we have stocks, fossil fuels and we have flows renewable energy. We saw that there is sufficient renewable energy to meet our requirement. Now the question is we have sufficient renewable energy to meet our requirement but each of these renewable energy sources needs technologies, those technologies materials, do we have enough materials to meet the energy requirements or will be end up in problem related to materials.

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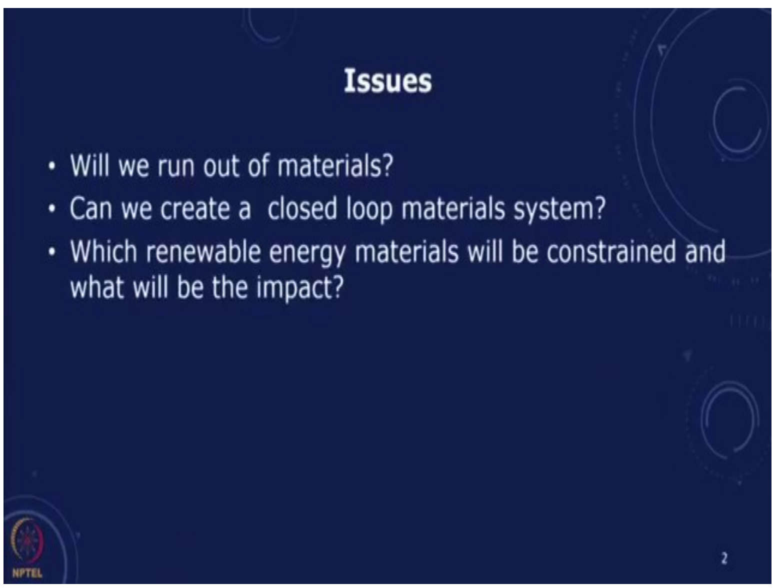

So, the question that we would, the issues that we would like to address, one is will we ran out of materials? Can we create a closed loop materials system? Which renewable energy materials will be constrained and what will be the impact? You are not going to completely answer all these questions but we will look at the way in which we can analyze this and what are the typical types of material and how they are looking at it.

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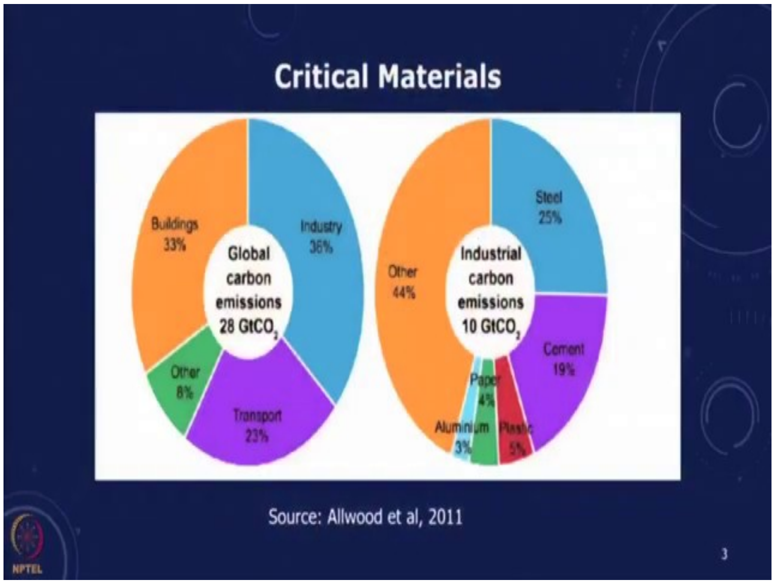

So, if we look at the materials, we find that of the significant amount of our CO_2 emissions are accounted for by some of the most energy intensive and carbon intensive materials. If you look at materials we are looking at steel, we look at cement, we look at aluminium, paper, plastic and these accounts for the largest chunk of the carbon emissions its about 10 Giga tons of CO_2 out of the total 28 Giga tons of CO_2 in a particular area I think it is 2008. And this is from the paper by Allwood you can look at this paper for more details.

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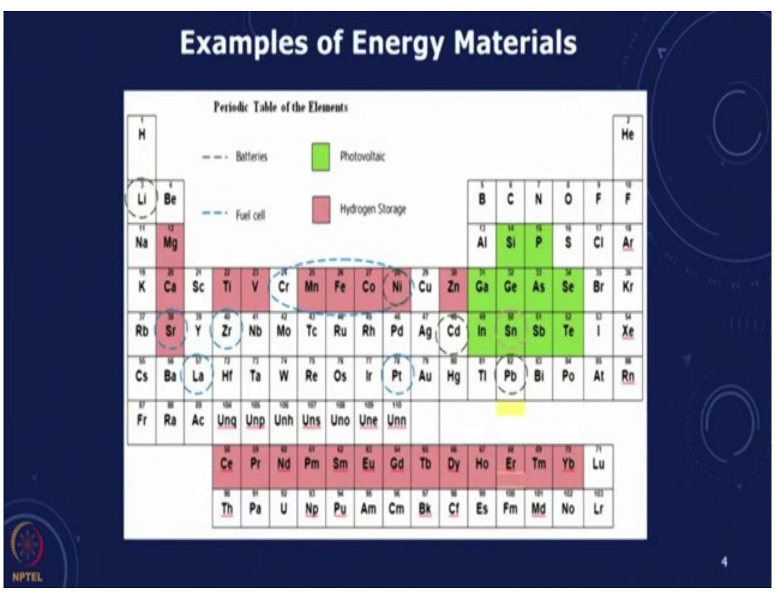

So, if we look at the periodic table which I am sure all of you are familiar with you have studied it at some point of time either in your school or our college and you can see that there are several of these materials including some of these rare earth and some of now these materials which are being becoming important for batteries, for storage, for photovoltaic you have this whole set of material which are coming in for the photovoltaic, for the lead acid batteries, cadmium telluride then you have the other chromium, nickel, cobalt.

Then you have lithium, then you have these materials which are used for hydrogen storage and many of these materials involve our located in some regions and in a few countries and they also involve significant amount of energy used in their extraction. So, when we look at materials, we can think in terms of material efficiency and this is from the paper by Allwood, We can try and design so that we use less materials. So, we can this is called dematerialization.

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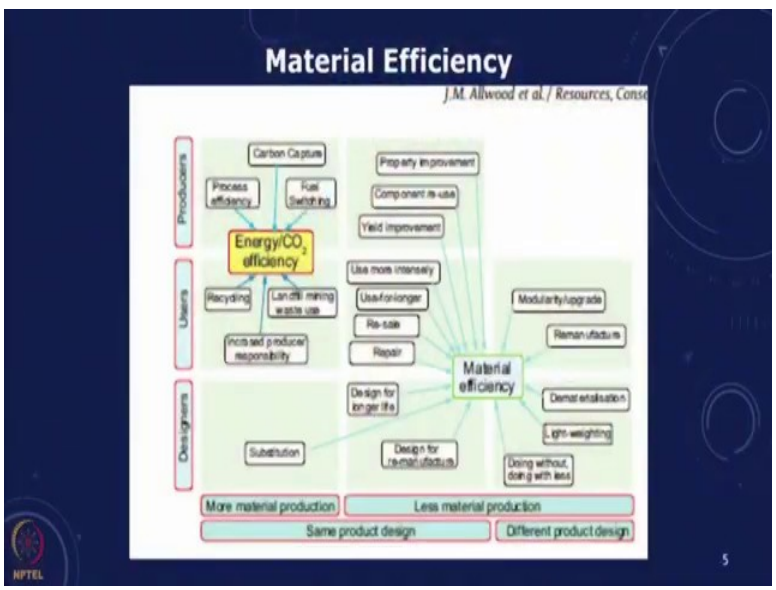

You know look at your cellphone or look at your motor see how much steel and how much metal is going into it, see if you can have the same functionality using less metal, we can also replace the substitute, energy intensive materials by less energy intensive materials. Materials that are less carbon intensity, so this that is we can do dematerialization, we can do light weighting and now with nanotechnology we have the advantage that we can actually have design a material which have the properties that we require.

For instance, it is being told that if you look at Eiffel tower and you look at the weight of the Eiffel tower today if you have designer steel which nano-composites and engineer steel you can actually we could reduce the quantity of steel that is require with the same strength and we can get a much more light weight Eiffel tower using less materials.

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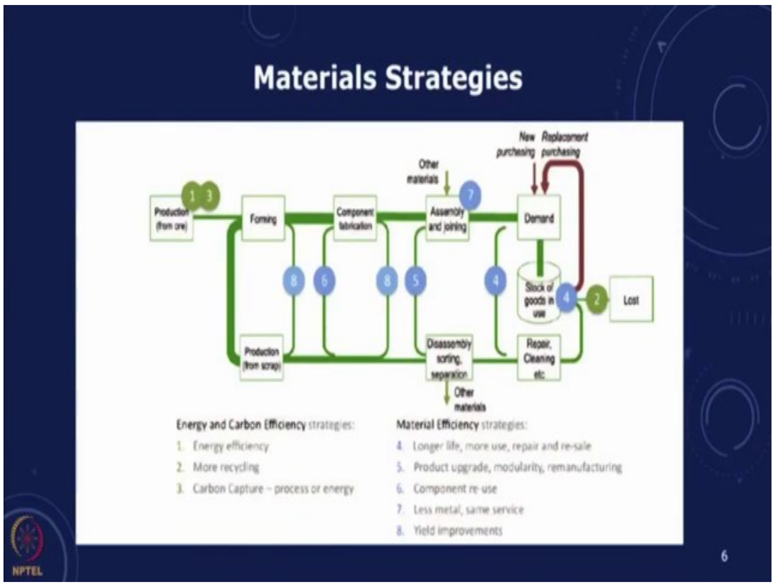

In general when we look at the production of a material we can look at the production going to the and you have the at each stage of the production there would be some scrap we can recycle that scrap that when we look at the demand and then the after the post demand when it is used it can be recycled then some part of it, so we can try to see if we can have this entire thing as entire loop as a loop which is closed and we use relatively less amount of virgin material and we can try and recycle at each of these stages.

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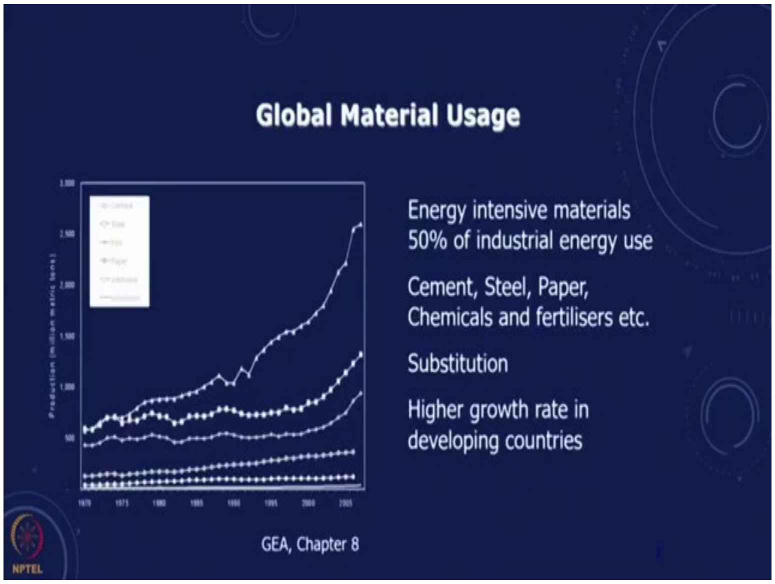

If we look at the global materials used you will see that energy intensive materials account for about 50% of the industrial energy used, cement steel, paper, chemical, fertilizers and also the interesting thing is that most of these now these materials are being consumed by the developing countries, there are much higher growth rates in the developing countries.

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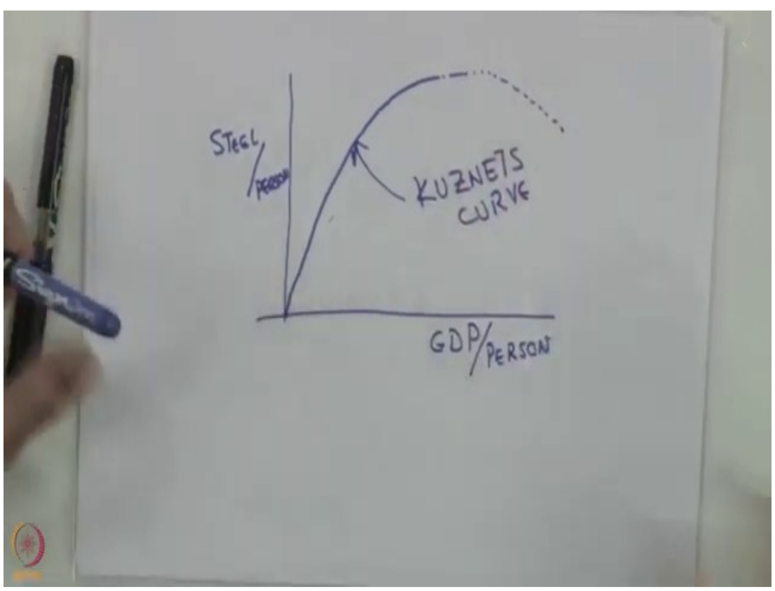

We have if we look at any of these materials we can plot. If you look at let us say steel used per person and we look at the status of the country in terms of GDP per capita or GDP per person. You find that this increases with income to a point where it stabilizes and then may be declined, this is something like the, this is called the KUZNETS curve, so most of the developing countries are at this stage where there is this growth, developed countries have already gone where you have already produced all the steel you have of your infrastructure is already created. You have the number of cars and the kind of things which is there and then the number of it starts declining and so that is the kind of I will just show you some of these trends.

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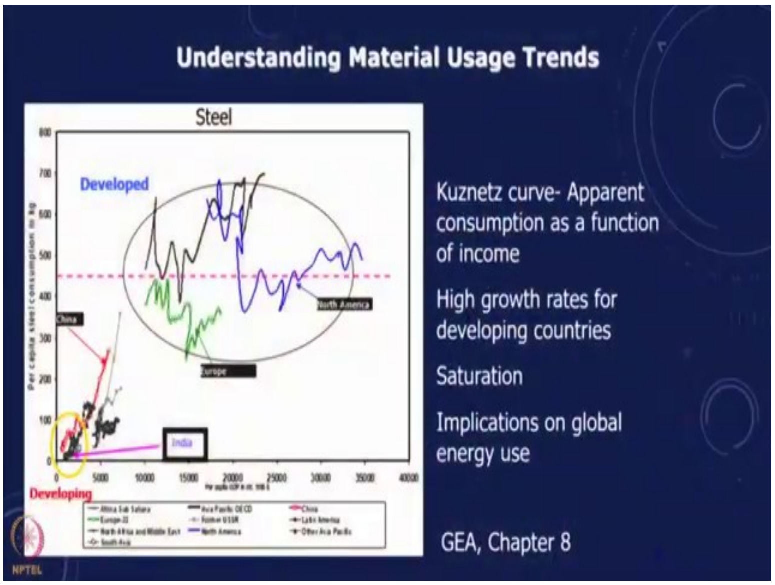

So, if you look at steel we see different countries North America, Europe, you can see China and Indian over here and you can see that this is corresponding to something like we go to a stagnation level which is of the order of about 450 kg / person /year. So, it is an apparent consumption as a function of income high growth rates for developing countries and it goes to saturation, there is an implication on the global energy used.

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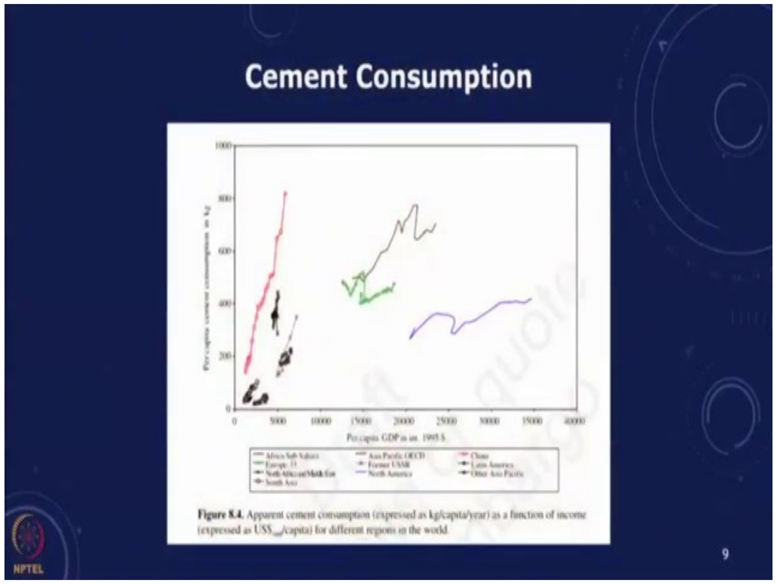

Similar thing you can see for instance for cement, you can look at the kind of different levels at which you have these developing countries, which are growing in these cases it is more or less saturating of course it is saturating at different kind of levels.

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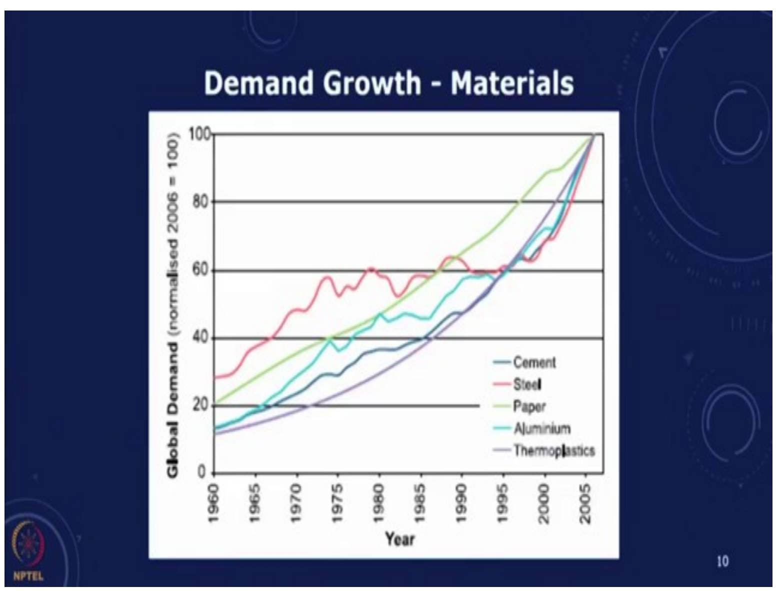

And this is sort of global demand normalize you can see that there is an overall growth.

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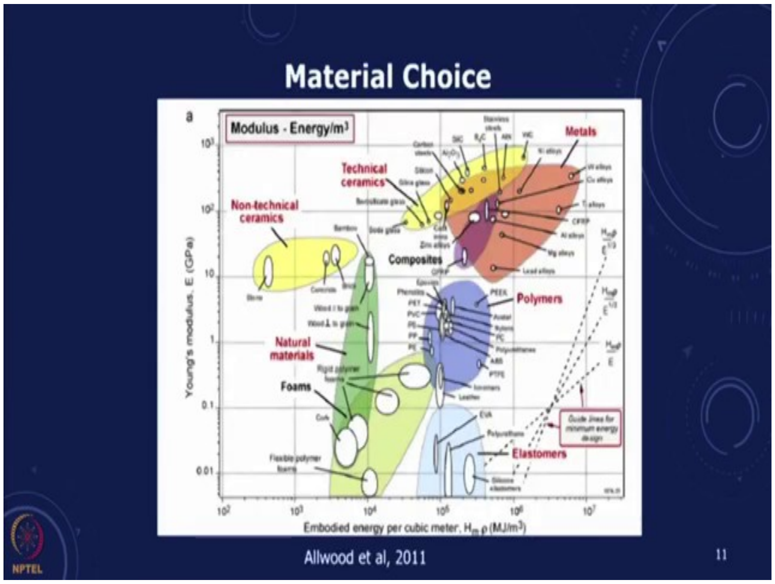

Ashby has come up with this scientist in UK whose created this kind of design plots and this these design plots are extremely interesting in terms of when you look at a particular characteristic for instance you look at the Young's modulus energy per meter cube and if that is the requirement which is for a particular application and we are choosing between the metals, polymers, ceramics and you have the embodied energy, which is the total energy required to create that material and to extract it and to make it available from nature per cubic meter.

So, based on this we can use with this we can decide between different materials and see what is the implication when we are making a particular choice in terms of what is the amount of energy that is being used. So, this could be used and we can have similar kinds of lots giving the carbon intensity of these.

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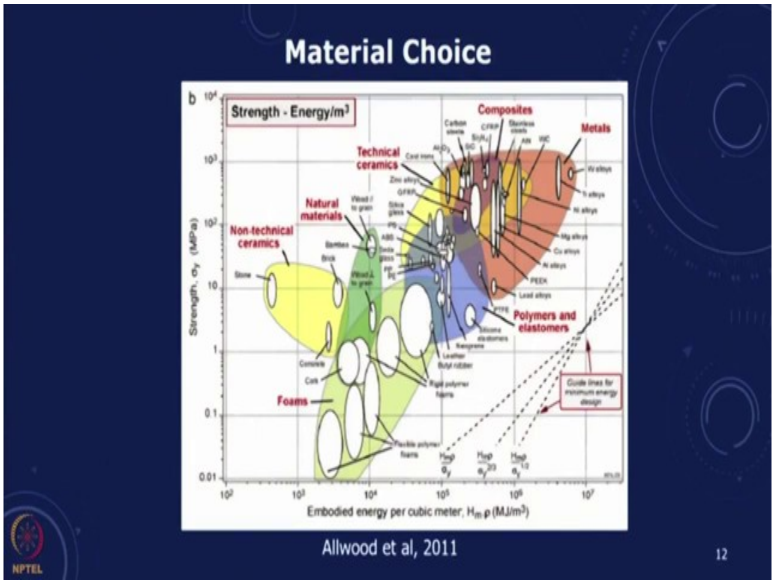

This is another plot which is will be talking about the strength and the strength in terms and the embodied energy. So, these are interesting design age which can be used for us to choose less energy intensive materials and less carbon intensive materials for a particular application.

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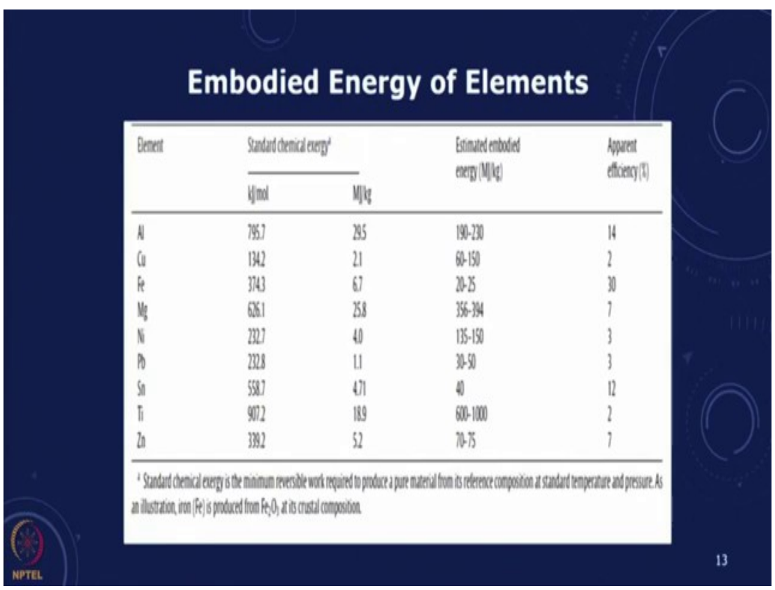
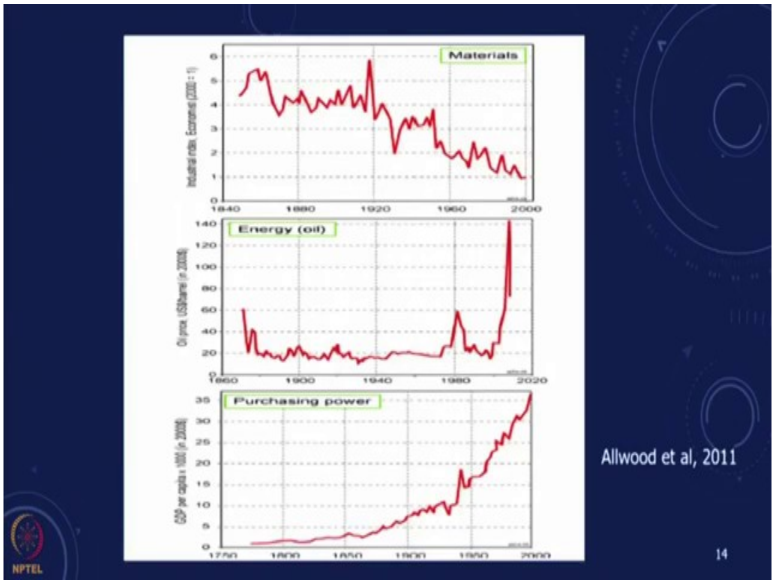


Element	Standard chemical exergy[a] kJ/mol	Standard chemical exergy[a] MJ/kg	Estimated embodied energy (MJ/kg)	Apparent efficiency (%)
Al	795.7	29.5	190-230	14
Cu	134.2	2.1	60-150	2
Fe	374.3	6.7	20-25	30
Mg	626.1	25.8	356-394	7
Ni	232.7	4.0	135-150	3
Pb	232.8	1.1	30-50	3
Sn	558.7	4.71	40	12
Ti	907.2	18.9	600-1000	2
Zn	339.2	5.2	70-75	7

[a] Standard chemical exergy is the minimum reversible work required to produce a pure material from its reference composition at standard temperature and pressure. As an illustration, iron (Fe) is produced from Fe_2O_3 at its crustal composition.



And so, you know the we will when we talk about embodied energy and we do the lifecycle we will look at this is little more in detail but one can look at different types of elements and see what kind of energy is embodied and what kind of efficiency is there.

So in general what has happened is that one expects that with materials as the demand increases and if the in most of the material we are looking at a finite stocks, so these are the stocks but then there are possibilities of substitutes and with technology improvement it is possible that we can have less use of the material but in general what one expects is that materials will, we will run out of materials and so there was this debate and you can see this there is a very interesting bet which was there in literature.

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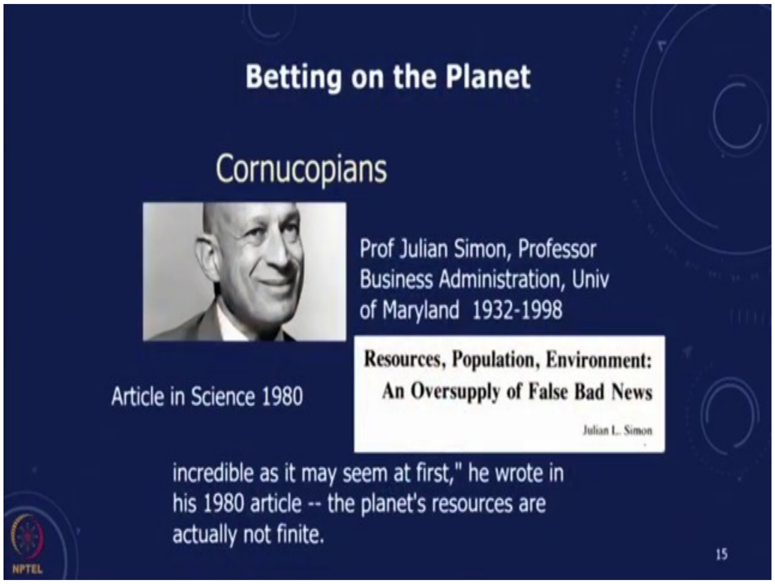

And you can see in science in 19, there is a general article published by Professor Julian Simon in 1980 and he basically felt that planets resources are not finite, there has been ecologists and environmentalists were saying that we need to look at material getting over we need to look at resources and he said that planets resources are actually not finite,

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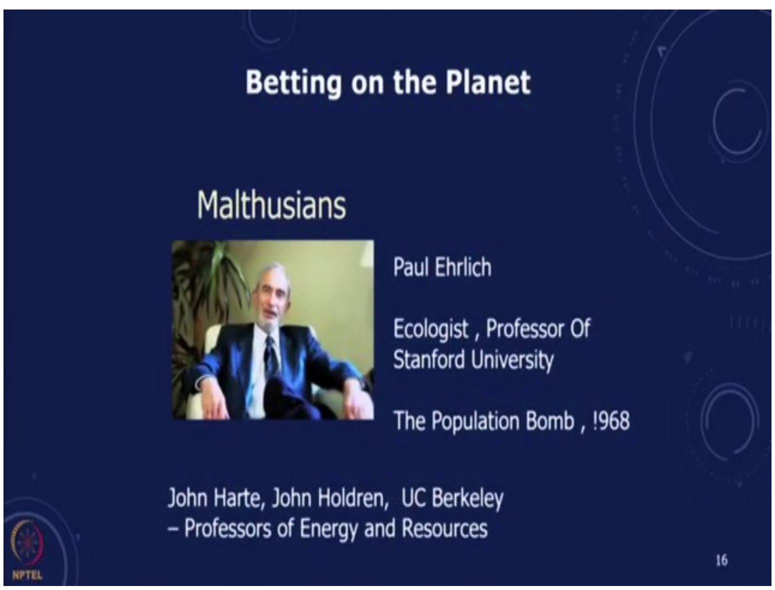

On the other side of the bet were Malthusians, Paul Ehrlich, John Harte and John Holdren and they have been saying that the we have one world, one earth and finite resources and we need to conserve and use our resources efficiently.

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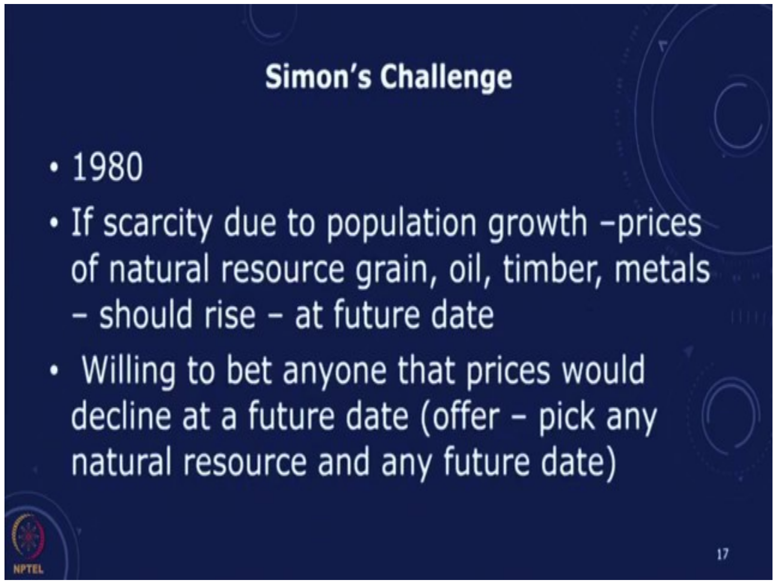

So, Simon challenge through an open challenge saying that if the scarcity is due to population growth and the prices of all natural resources grain, oil, timber, metal should rise at any future date and he said that he is willing to bet anyone because he believes that technology and human innovations is such that there is no scarcity cause by human efforts and he said that he was willing to bet anyone that prices would decline at any future date. And he made an offer that any natural resources can be picked at any future date. So, when this challenge was issued Paul Ehrlich and John Harte and John Holdren took up the challenge.

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Ehrlich, John Holdren, John Harte accepted the challenge in October 1980 and the choose the following materials. Chrome, copper, nickel, tin and tungsten and they bet a token amount of 200 dollars each at 1980 prices on these 5, so total of a 1000 $ and the idea was that in 1980 at 1000 $ they bought a certain amount of this and idea was the future date of 1990 was picked and it was said that whether these would the value would be more than 1000 $ or less than 1000 $?

If this was more than 1000 $ then Simon lost the bet and Simon has to pay that difference to them, if the prices actually declined if it is less than 1000 $ they have lost the bet and they have to pay Simon. So, what did you think happened? In this particular case actually Ehrlich, John Holdren and John Harte actually lost the bet.

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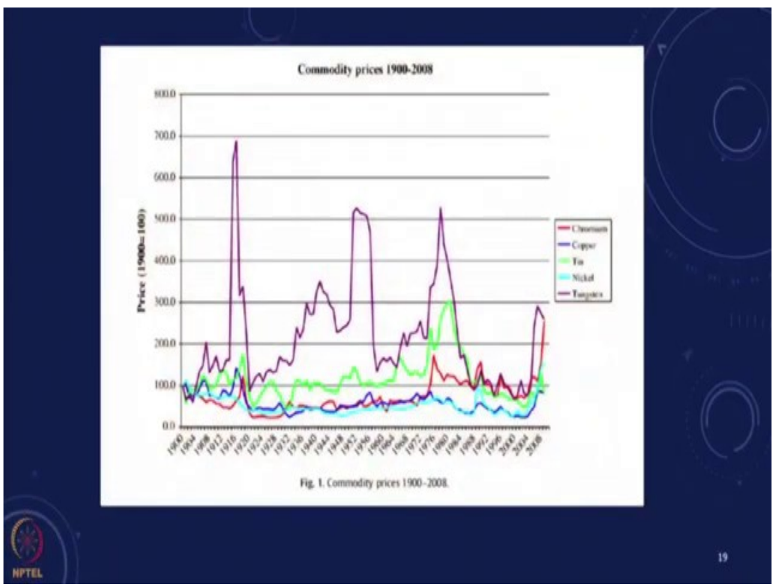

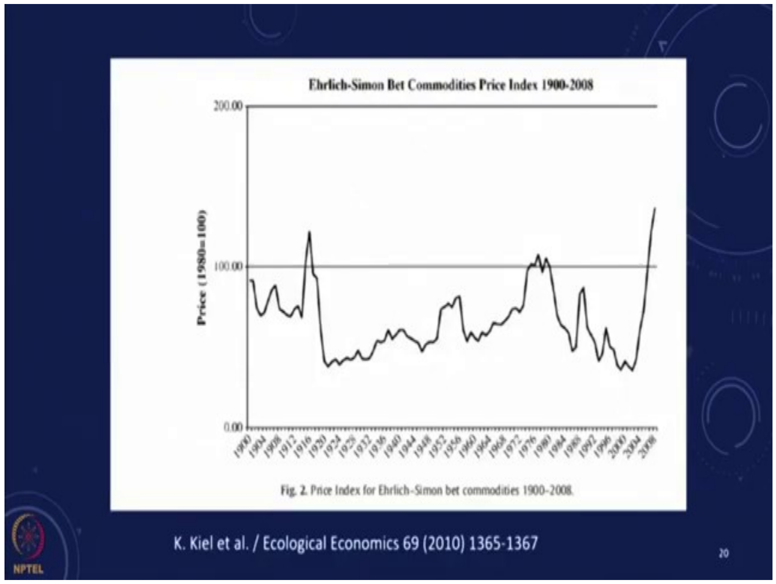

And you can see this, these are the commodities which were mentioned, the you can see that this was the in the 1980 and even you can look at 1990 you find that actually the prices went down.

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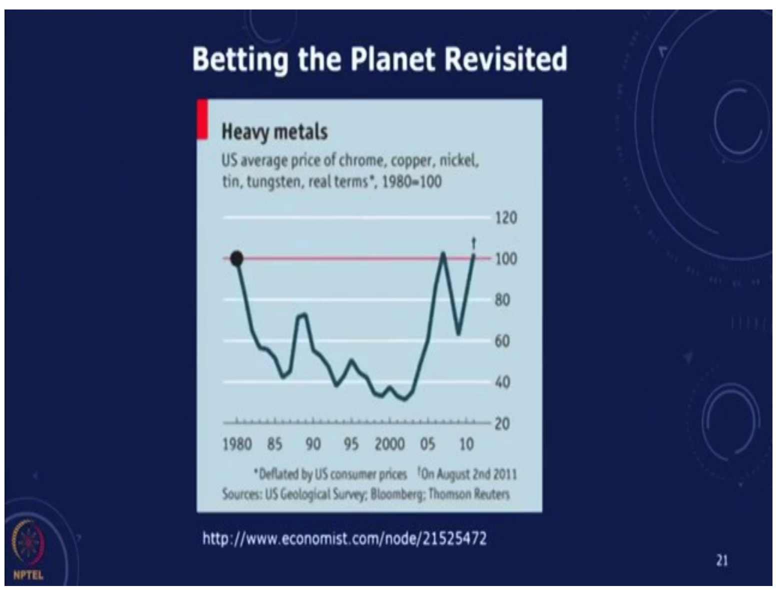

So, essentially what happened is that you can see that this is what happened in 1980, this is the situation in 1990 and so with result that they this of course this did not prove it conclusively because this goes through ups and downs and there was an economists article recently which said that just so happened that he was unlucky to choose the years if it had been some other years then this would bet the kind of situation.

But the fact remains that overall there are 2 trains which are there, one is that there is a problem in terms of scarcity but also with technological innovation and volumes the cost reduction are there, so over a long time period we have seen very significant reductions in cost of materials.

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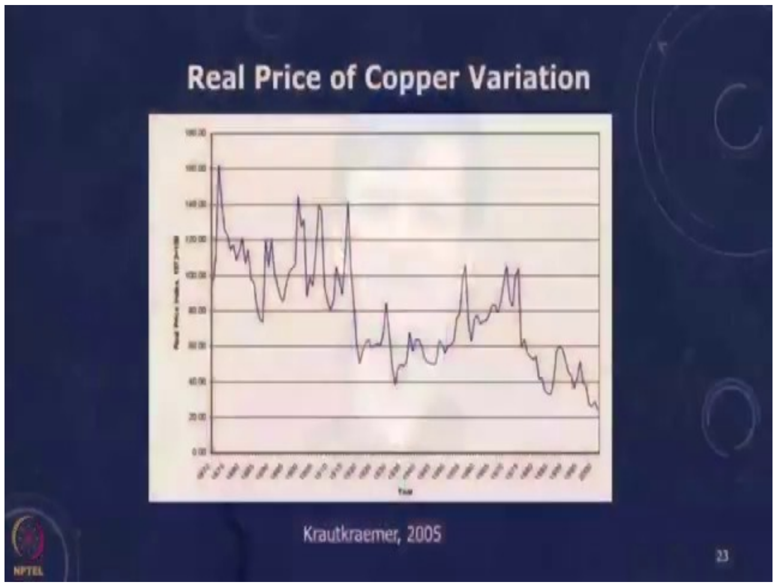

So, you can see for instance if you look at copper, real price of copper has been going down and so it is not clear there is any issue of scarcity but there is also innovation and possibility of technological improvements and so when we talk in terms of materials we have to be aware of scarcities in the short term.

But it is not completely apparent that this will necessarily result in extremely high prices, there could be back stop technologies another option which are available. So, for all these materials we can use the same static R by P ratio or we can use something like the Hubbert's curve if you want to estimate time periods.

In many of these cases, these are all this price trends. In many of the cases, if you see we can actually look at what kind of where is the distribution of this materials, so sometimes regionally some countries have for instance if you look at lithium it is only available in a few countries of the world.

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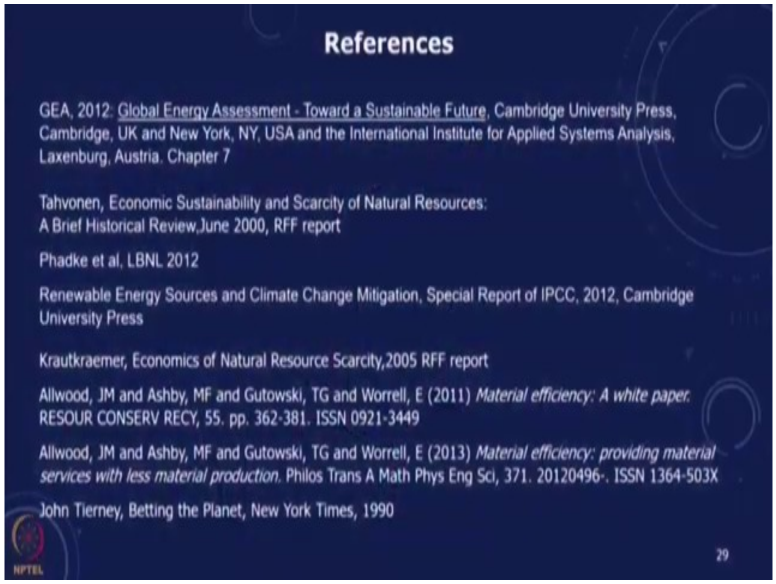

So, the control of this materials and this could involve getting an advantage and then they are taken industry and development may be affected by it. So, we need to look at substitutes, so with this we have seen we have got a quick introduction of the kind of materials that are used for the energy sector.

We looked at over with development that material used per capita will increase and then saturate and may be then decline and then there could be possibilities in terms of substitution by more energy efficient and low carbon materials and then we can look at it is not essential that scarcity of materials always results in increase of price, historical trend show that there is also scope for innovation and technology improvements where prices may actually decline with time.

With this we end the portion on materials for those who are interested there are more details in some of these papers you can look at the GEA, you can look at the papers by Allwood and about the bet you can look at John Tierney original article in New York Times which gives you about the Betting on the Planet.

In the next session we will start with looking at the historical way of the mine mangers problem, if you own a mine how much of that mine should you allow to be used every year and we will cast this as an optimization problem and see how a resource, a coal or oil or gas how it should be mined and distributed over future generations, thank you.