Energy Resources, Economics and Environment
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Lecture - 21 P1
Net Energy Analysis –Part 1

In the earlier module, we have looked at primary energy analysis. Where we looked at different options from the point of view of how much primary energy they are using. We, now extend this and move forward to look at a new technique, the life cycle analyses and within life cycle analysis we are going to focus on net energy analysis.

So, we will look at some applications of these techniques, different criteria and how this can be used to help in decision making. We have seen earlier the decision making based on an economic analysis and at sometimes it is we want to look at the different options from the point of view of how much energy it takes over its life cycle.

So, the whole field of life cycle analysis or LCA as it is known started in the early 1960s 1970s. In the initial phase this was, there were multiple methodology and in the 1990s there were two different societies the SATAC and the ISO which tries to standardize and provide a set of methodology for carrying out life cycle analysis. So, let us look at what is life cycle analysis.

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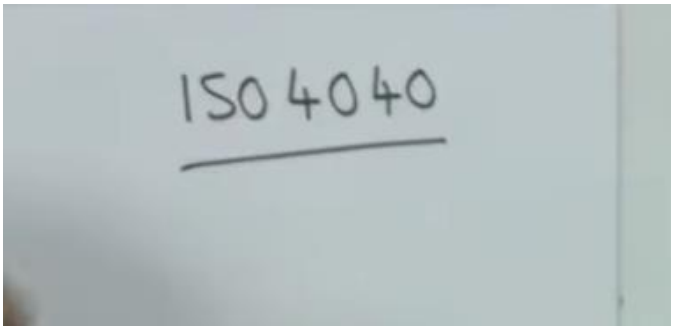

You may want to look at the International Standard ISO 4040, which sets out the methodology for life cycle analysis and you look at this. It is available in the public domain.

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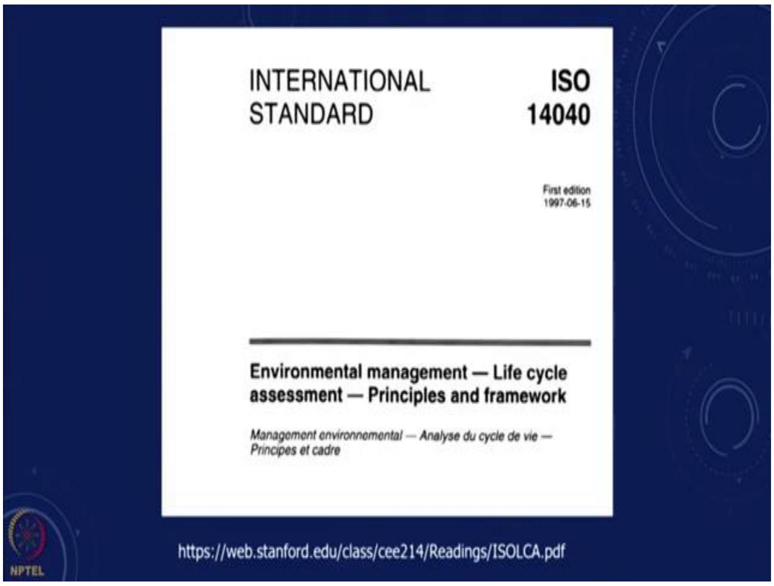

There are some addition values, this one is 1997 edition and this provides a framework for carrying out environmental management or life cycle assessment and the principles and the framework. This initially LCA was used to compare different products and mostly products for packaging.

So, we looked the entire life cycle from the point at which it was manufactured right from raw materials, to use and to the disposal. So, all of this constitutes the life cycle analysis. So, in life cycle analysis the basic steps involved are first we compile an inventory of relevant inputs and outputs. The different inputs, which are coming into the process and the outputs for the process. And then for each of this, we evolved the potential environmental impacts associated with these inputs and outputs and then we interpret the results.

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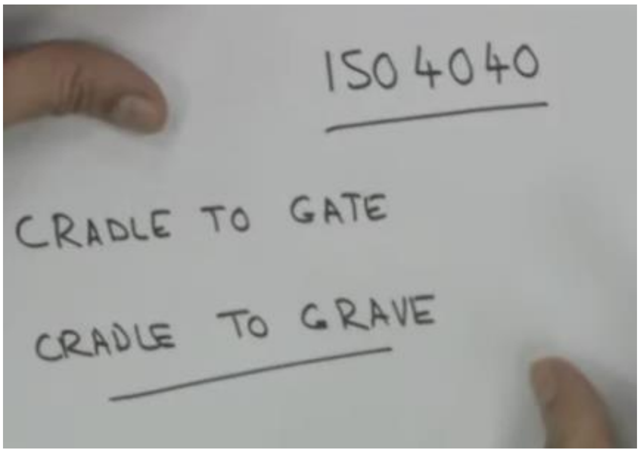

Now, there are two approaches here, we can do what is known as cradle to gate or cradle to grave. And this typically means that, we start with the initiation, the actual manufacture and then the to the gate where it is the produce and use. Cradle to grave means we also look at disposal the phase so the full cycle if you want to take it will be a cradle to grave analysis, in some cases we just do analysis till we get the end use and that the cradle to gate.

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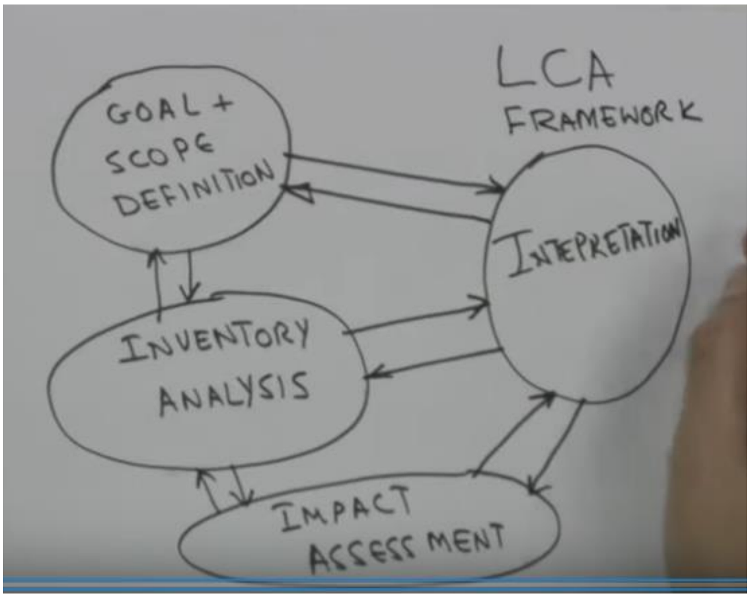

So, if we look at the different the mythology for life cycle analysis. The first step in the life cycle analysis is to identify the goal and the scope, define the scope and the goal. Once we define the goal and the scope. We can then look at, what is inventory what are the inputs and outputs doing in to the system boundary that we have. And of course, there is some iteration both ways between the goal and the inventory analysis.

Based on this we can then do an assessment of the different impacts again and then in all of this we would interpret the results. So, there is scope for interpretation we have these values which will there and there will be multiple different criteria. And then this will also. So, this essentially represents the framework for LCA.

Now, what you need to do is need to take some examples so that you know how to do this type kind of calculation and it will be useful in a whole variety of examples. And we take we will take some examples from literature this entire framework will then go for the, this will give us the direct applications.

And there are different types of application we can look at it for improving the current mechanism so that we can reduce the environmental impact. The second is we can look at it for decision for product development, we can look at if choices, we can look at it for strategies for companies, we look at it for policy analysis.

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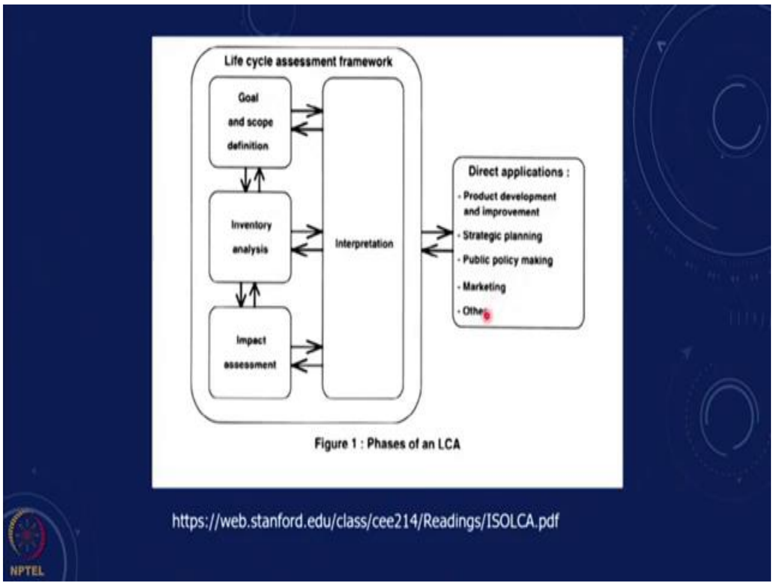

So, what we had just seen this is let me just put the pointer. This is what we have now just now seen this was the LCA framework this from the ISO manual and this give you finally the direct application that we are talking of.

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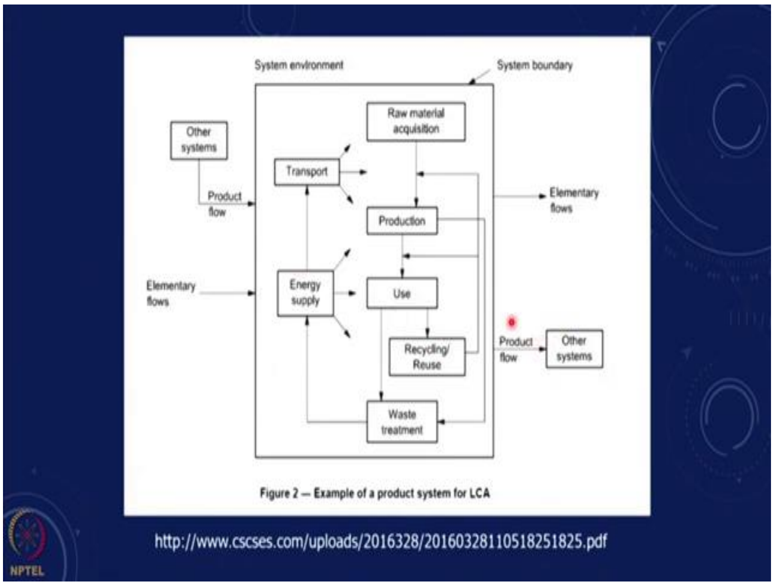

So, as we moving forward when we look at the products system we may want to decide in the system. The different kinds of flows, which are there in the systems. So, when we are creating a product, we may actually build in some materials which come in, raw materials and then there will be flows in to that system. These raw materials will be converted and there is production phase.

There is a use phase, there is the recycling and reused and then the waste and the waste treatment, there is some energy supply and transport and finally there is this product flow which we are taking of. So, this could be an example of a product system based on which we can do the life cycle analysis.

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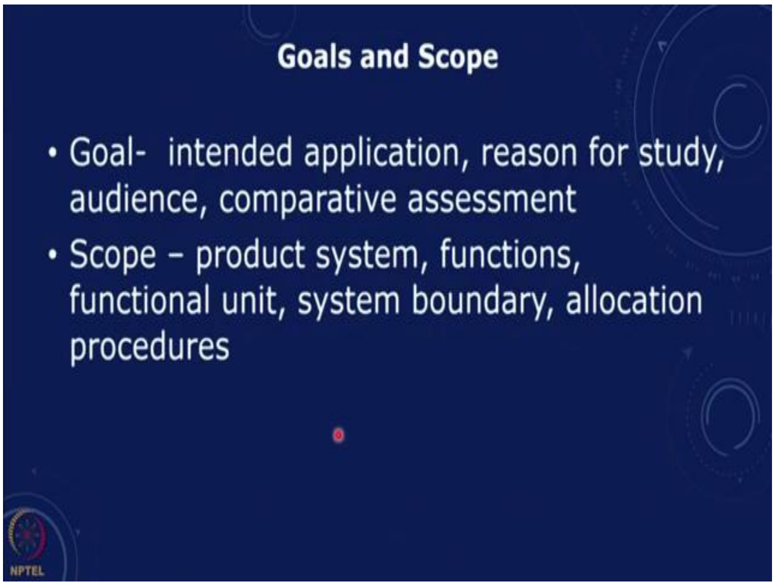

The, when we talk about the goal, it is important for us to understand who, what is going to be application of the LCA. And depending on the application you may modify the mythology, decide the system boundary. So, what is the intended application what is the reason for the study.

Who is the audience who is the person, who are the people who are going to use this LCA? May be it is being used for some comparative assessment so this goal and then based on the goal identify the scope what is the product system, what is the functions.

What kind of we may want define a functional unit. This is very important in most the LCA that we carry out that we define clearly a functional unit. Use it as a basis for comparing between different things, identify the system boundary also in the many of these cases allocation procedures because in your process we may have multiple products and to allocate the energy flows or the material flows to one of the products. We will have to have a basis by which we make this allocation.

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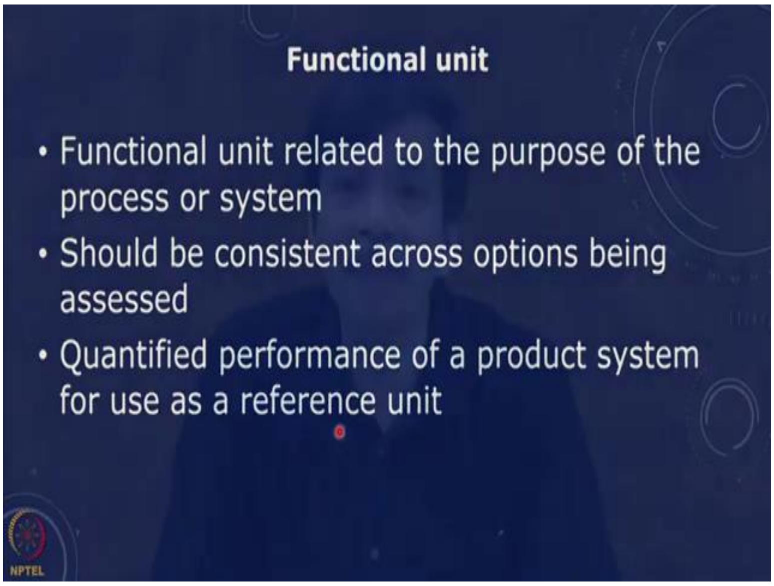

There are large number of different life cycle analysis, which have been done. Which are available in the public domain, in the papers and in reports and in books. And depending on your application, you can always find something which is similar, which have been done but then you want you do that for your own local context.

Because globally or nationally or locally the, there are differences in the way, in the electricity mixes, in the kind of procurement of the raw materials, in the environmental impacts and so the LCA, an LCA which has done for Europe may throw up different results from the LCA which has been done for an Indian context.

So, as I told you with the functional unit is a very important point in your starting point for the LCA. We must define a functional unit, which is related to the purpose of the process or system. So, and it should be consistent across the options being assessed.

So, for instance if you are looking at a power plant we may say you want to generated 1 megawatt hour of electricity, per megawatt hour of electricity. How much is the energy input? How much are the emissions? And then we can compare coal-based plants, photovoltaic based plants or wind-based plants or biomass-based gasification.

And then the quantified performance of a product system which is for use as the definition of a functional unit is the quantified performance of a product system for use as a reference unit. So, initially once we start the study and we identify what is the use we can then define a functional unit then compare all the options based on that functional unit.

So, let us take one of the interesting studies, which is there in literature. Number of papers on it is when we look at the, we know when you have tea or coffee there as many different options by which you can have your tea coffee in. So, you can look at a paper cup, you can look at a cup which is a polystyrene cup which is made, which is basically plastic and one can also think in terms of ceramic cup which can be washed and reused.

One can think in terms a glass cup. Which made of glass again can be washed and reused. And you can also think in term of in rural India and even in some of our towns we still have those coolers. Which are fired clay and the you can have tea in that and it is disposal cup but it gets, it can the broken cups are again fired and reused.

So, one can think in terms of. How do this, when we think in terms of a unit which we are comparing for having hot beverage like tea or coffee. How do this compare? So, there is this paper, the two papers by hawking, the first paper is a comparison of the paper cup with a polystyrene foam cup.

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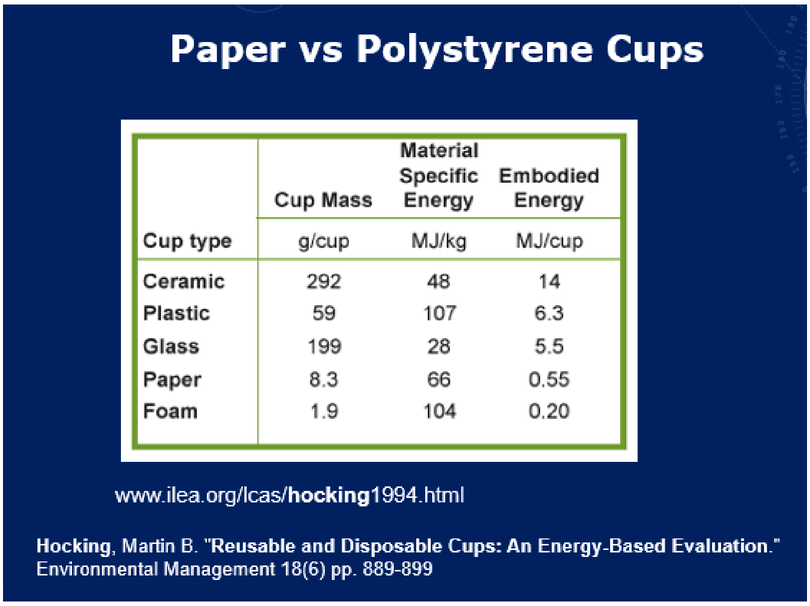

Cup type	Cup Mass g/cup	Material Specific Energy MJ/kg	Embodied Energy MJ/cup
Ceramic	292	48	14
Plastic	59	107	6.3
Glass	199	28	5.5
Paper	8.3	66	0.55
Foam	1.9	104	0.20

And there is another, so there is paper versus polystyrene cup and you can look at and there are we can also so for each of this, for a given amount of liquid to be the given capacity of the cup. So, in this case this is an A towns cup and the entire life cycle analysis has been done.

In the case of paper, it start with the wood which is the wooden waste and in the case of the polystyrene it is using, it start from petroleum as a feed stock in each of this the paper making process is energy intensive also requires water and other resources, has environmental impacts.

So, based on a certain amount of cup, certain quantity. The entire chain has been drawn up and based on that the amount of energy and materials which are embodied or required in this is calculated. So, just to give you an idea now we look at ceramic, plastic, glass, paper and foam. We can, the weight of the material per cup, is given here and you can see the difference in this.

The polystyrene cup is about one fourth this mass of the paper cup. However, the specific energy per kg is much higher for the polystyrene cup and the so the, but still the total and bodied energy lower than that of the paper cup. So, the hawking in his first paper mix an argument that one thinks that the paper cup is likely to be environmentally better but he says that the plastic, the polystyrene cup turn out to be better than the paper cup.

Of course, this is dependent on the kind of assumptions and the, so this is, and this comes out to be so you get point 2. If you look at `this the functional unit is one cup and each of this cups are of the same capacity and you can see this is 0.20 this is 0.55. When we look at re-useable cups ceramic, plastic and glass, and you can see the difference in the, you can look at the original papers so that you can see more of the details I am just giving you the final results, which will give you an idea of how this can be use.

So, look at the cup mass the material specific energy and then based on this when you multiply this, this gives you embodied energy or the energy per cup. Now, in the case of reusable cups, what would happen is that the number of reuses as well as we want to you know we want to sure this is done hygienically. So, this will mean that we will need energy to wash and this the calculation which has been done by hawking is for using the cups in a dishwasher. And the energy used in a in per wash is computed and that is added.

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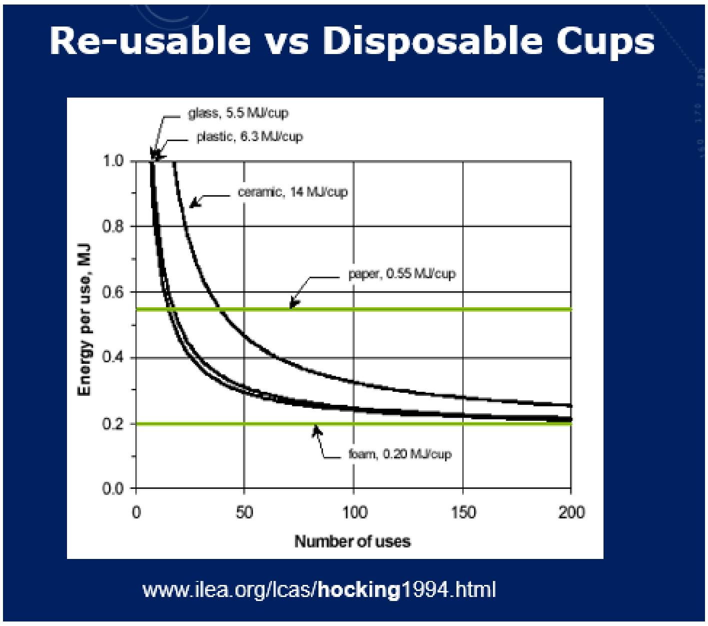

And based on this we get, a situation like this depending on the number of uses you can see that. There is trade-off between the foam cup and the paper cup and the reusable. So, if you look at the glass beyond a certain number which comes out here this is the breakeven number of if we going to use it for, let say 40 or 50 times then you can see that it is going to have a smaller energy per use will be much lower.

However, if you are using less than 10 you can see that this is, this is lower than this. So, the paper cup turns out to be and for the foam cup you can see that it is it actually seem to be quite the energy use is lower than the requirement for the reusable until you go to a very large number.

So, this is an interesting. Of course, if we change the assumptions and the ways in which we process the results may change. So, if you look at this paper by Hawking in science, there was a cretic and then were was the discussion so the assumptions depending on the assumptions one makes about the process the things can change.

Also, both in terms of polystyrene and paper the process and glass and ceramics actually there have been process efficiency improvements, so this are relatively all this are in the 1990s if you did the numbers today you would get slightly different numbers little more efficient as compared to the earlier.

So, I would suggest that you look at both these papers and this will give you an idea of one of the earliest ways in which one has done the life cycle analysis and in energy, energy and environment impact analysis for something that we always look at the different kind of choices of disposable versus reusable.

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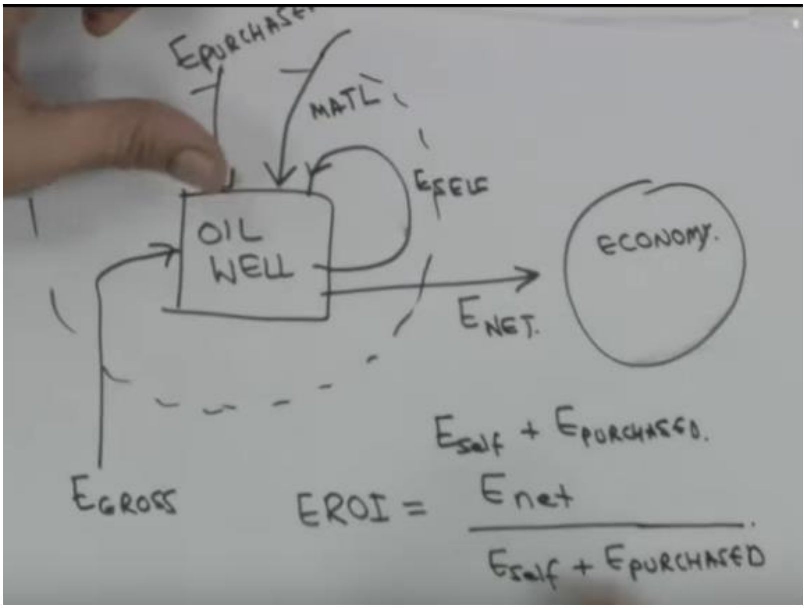

Now, when we think in terms different energy sources. If you look at. Let us say extracting coal or extracting oil in a period of time what happen is that if we look at an oil well. We have an oil well, we need to input different kinds of material will come in into extraction process. There is a certain about energy which is used, there is the axillary Eself.

There is gross energy input which is coming from the oil and then there is a net energy output. This is going to your economy. So, we would like to see now here if you we look at it there will be some materials and then there will be energy which is purchase. So, typically it might using electricity and we want to look at this boundary.

So, see all that we are using, which we have all that we are putting in is E self plus E purchase. And the energy return on investment is defined EROI as E net, E self plus E purchase. Now, there are many different energy sources. We do not take the content of the oil or the coal which is there in the ground whatever we are using in the process.

And this can be done either primary or it can be done up to the final use. In final use, if we are looking at it up to the final use. It means whatever energy is being use in all the processing finally when we are suppling that energy and over the life time of this process what is the energy return on investments.

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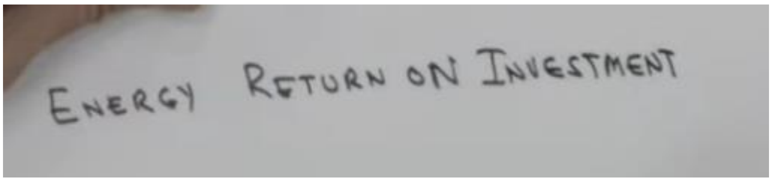

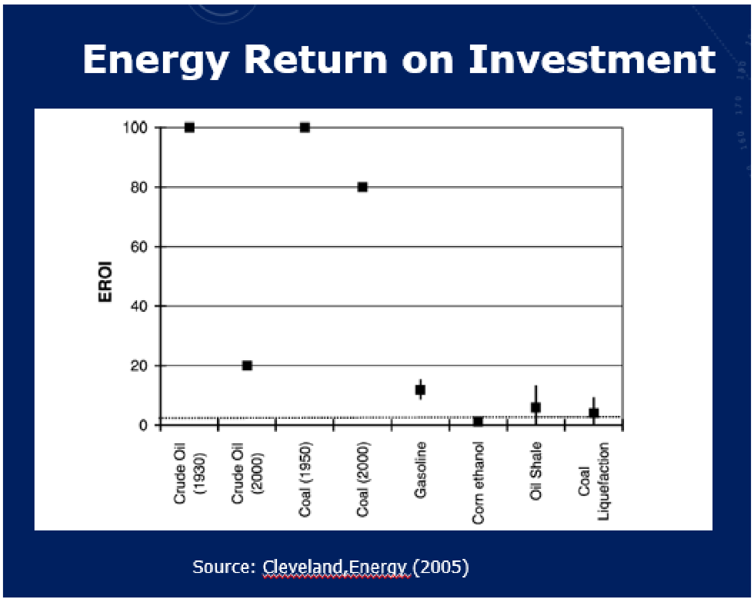

So, this is called energy return on investment. Just like we did the return on investment for the financial terms this means how much energy am I investing and how much energy I am getting out of it. So, typically what happens is in the case of in the early years when we had the oil well this energy return of investment was high.

This has now been coming down, and if you look at this we can see there is paper by Cleveland in the journal of energy, in the energy journal in 2005. And it shows the energy return of investment starting from the early 1900s and then going down, and so you see there is energy return on investment for oil has gone down, for coal and so on. So, this is of the order of 100 and it has is come down recent.

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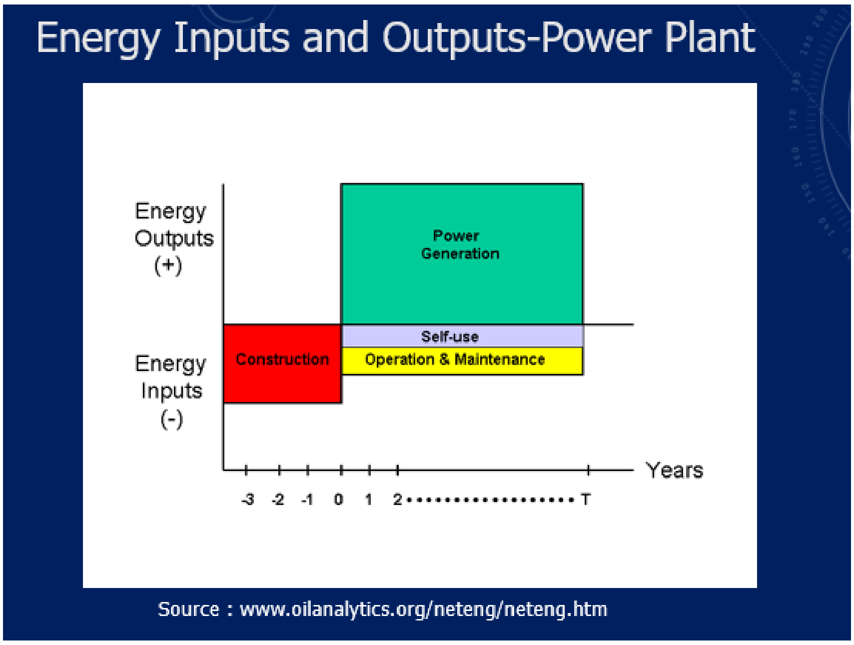

If you look at a coal-based power plant. There would be the energy inputs are all provided in the initial year. When it is start operating there is whole set of embodied energy because you have the steels, you have all the material which are coming in to the construct the power plant.

And then so this is all the energy which is invested during the operation there is an axillary use which is the self-use and then there are material and other embodied energy which is the O&M. So, the net which we are generating is this and when you subtract this, this will be net output we can see how many years it takes to pay back for the energy which is invested in the life of the power plant.

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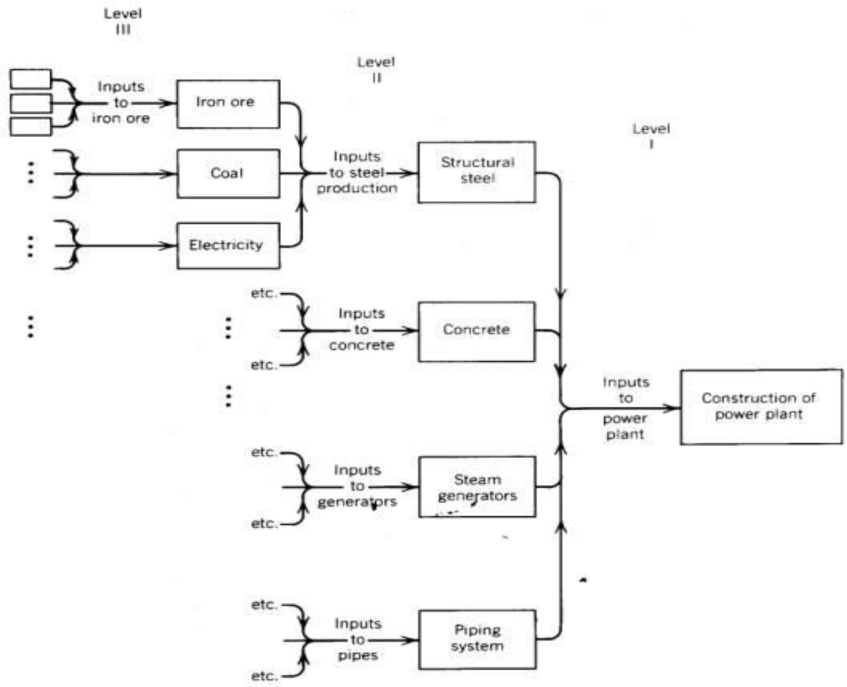
Levels of Net Energy analysis



Source: www.oilanalytics.org/neteng/neteng.htm

And in all this when we do the levels of analysis we can look at different sets of level. So, at the first level is we can just see in making the power plant what is the amount of embodied energy. That means we see how much of steel, concrete, steam generators, piping systems, the assembly energy so this is the, this is one level of calculation.

Then we can go to the aspect where we look at what is the amount of how much, how much energy is going in to production of the steel and then the iron ore which is coming in to making that steel. So, we can go to that level we can also than look at what is the energy which is taken in making the equipment which makes all of this.

So, one can go to different levels now when we go to next level the, you have to stop someone. So, you have to see if I go to the next level how much additional amount what percentage does it add to my overall numbers. So, at some points we make that closure and then go ahead. So, one of the calculation is in all this we calculate not just the energy but we also look at what are the amount of emissions which is coming in.

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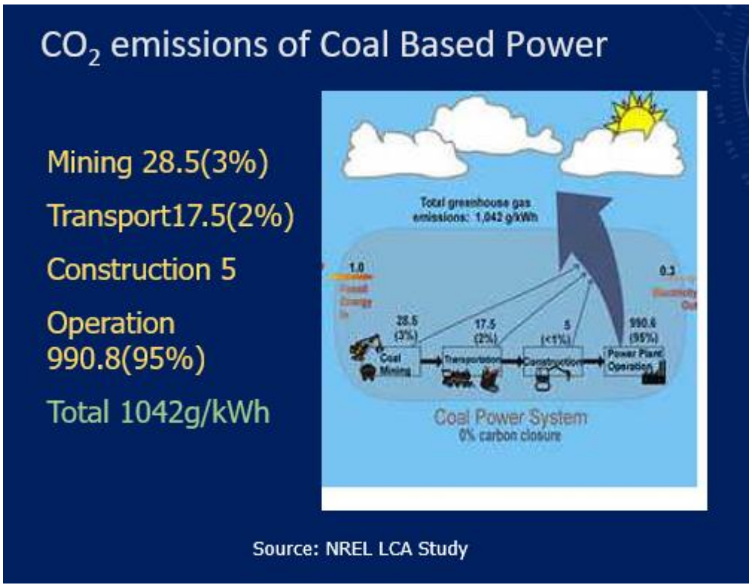

So, local and global just to show you an idea of the CO_2 emissions of coal-based power you can see that it start with the mining, the transportation, the construction and power plant operation. And the this for, this is the study done by Mann and Spath NREL and this showed that most of it, the largest chunk of it is been is in the actual operation of the plants. Some of it 3% is for mining, 2% transport and so on. But predominately it comes to about kg of CO_2 equivalent per kilowatt hour.

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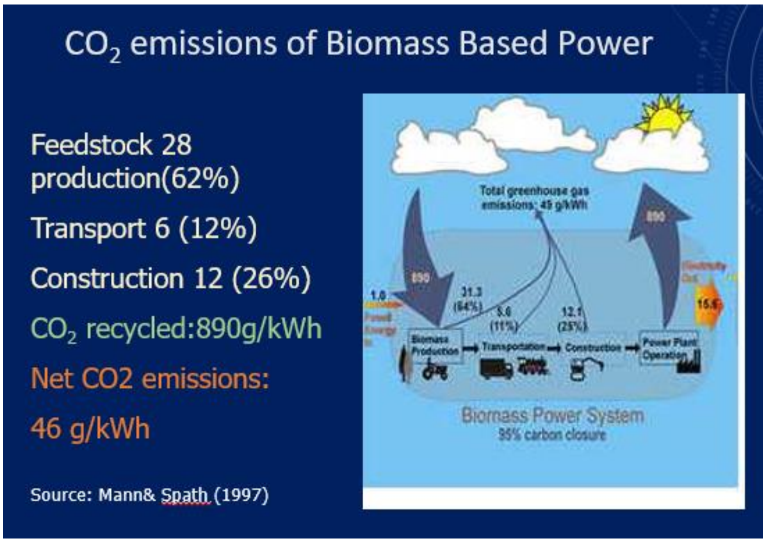

Similar comparison has been done for biomass and the net energy is biomass is consider to be almost carbon dioxide neutral. Because what happens is that the biomass during its entire growth cycle actually acts has a carbon sink. So, if the CO_2 which is recycled in this case is of order of 890 grams per kilowatt hour and the net CO_2 emissions again depending on how we do the numbers is just 46 gram per kilowatt hour as compare to that 1 kg per kilowatt hour.

And this feedstock production, the transport, the construction and the CO_2 emissions here which gets absorb at that. And so overall there is 98% CO_2 closure in IPCC considers biomass if it is done sustainably to be carbon neutral options. So, it is actually taken at as zero CO_2.