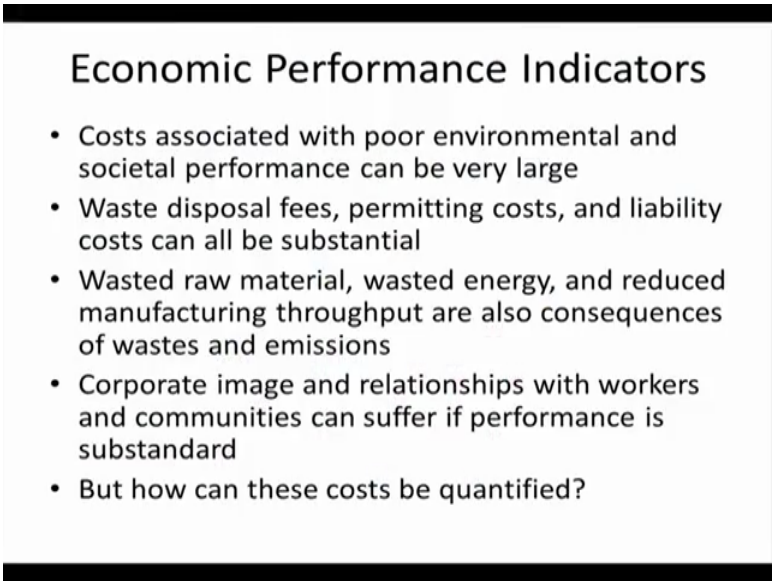
Life Cycle Assessment
Prof. Brajesh Kumar Dubey
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture – 35
Sustainable Engineering Design Principles (Contd.)

Welcome back. So, this will be the last module for the week 7.

(Refer Slide Time: 00:23)



And we have been looking at. So, as if you remember in the previous one, we looked at all those different engineering principles for sustainable design. And at the end I told you that we need to monetise all these factors as an as an engineer or as a designer we always look at the cost associated with any design or any process. So, there are some costs which you can easily quantify, but there are some costs which is very difficult to quantify there are some immediate cost and there are some long term cost. So, we will look at some of these economic performance indicated. So, that is where we will start in this particular module. So, in terms of economic performance indicator there are always costs associated with poor environmental and societal performance can be very large. So, what we do we mean by that.

In terms of the poor environmental say think about if you had a certain environmental disaster few years back in 2009 we had this environmental problem in terms of oil spill, in in Gulf of Mexico which was this bp oil spill. And there was a huge environmental

cost associated with that, because that oil spill has impacted the coastal in the coastal areas across several miles in like Florida Louisiana Mississippian and all those states. So, similarly right now I in as we speak just like few weeks back, we had an issue of oil leakage in Chennai. So, that also is that oil leakage in in Chennai is has we are getting lot of environmental impact associated with that and we do not know what would be the environmental cost associated with that.

The cost is not only the clean-up cost the cost is also. The impact that this oil spills have on acquainting a species the on the sea species which is present and all the impact on the soil the species present in the soils, the bacteria's present in the soil are we going to lose them. Because everything which is there in that is the beauty of our nature every each and every organism that is present in our nature has certain function. They help nature to be to actually to do their work, are they small worms or a small microbe to bigger microbes to fish to human beings to every everybody is doing something which is helping the nature mostly sometimes in a positive way and the most sometimes in a negative way, but that they do help.

So, they are there are cost associated with poor environmental and societal performance societal performance. Say if people get start getting sick during there are it is a during Iraq war after the war was over and although there is some people may argue that war is still going, it is never over, but say when war officially declared to be over and after that we had the issue of several babies being born with lots of deformities and palooza. And those are areas the reason for being that that all the warfare chemicals and other things that was used that was actually disposed in a very unscientific manner. And that impacted the soil the water in that particular area and people getting exposed to those chemicals and the pregnant woman getting exposed to those chemicals when the baby was born they were having certain deformities.

So, think about that it is only impacted the present generation, but impacted the future generation and it is now the baby which is born with deformities he or she has to live with the deformities throughout the life, can we really quantify the in a monetary term probably not, but that is that is a huge cost that the society has to bear. So, there are and then whatever the some of the other cost which you can try to quantify there is always a waste disposal fee there is a permitting cost for setting up a treatment plan there are

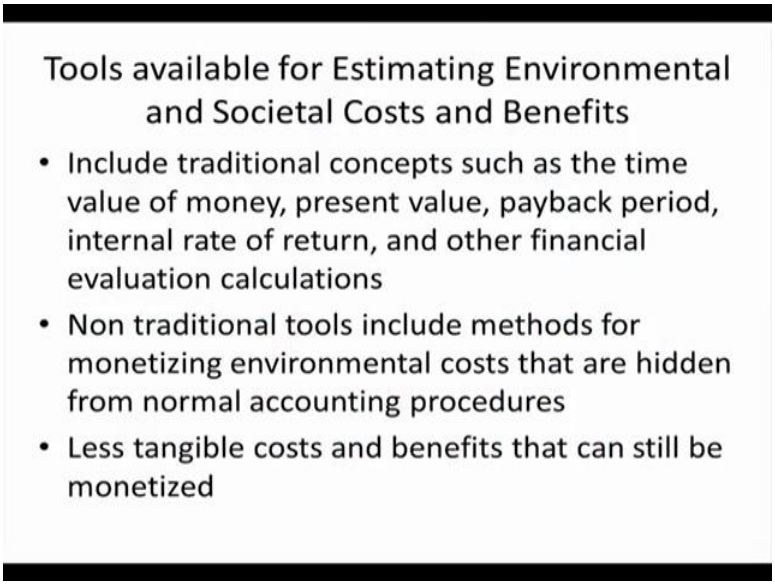
liability cost if things get there are like a lawsuit is. So, there is a cost associated with that.

There is we can probably put some cost associated with the wasted raw materials if we do a poor design wasted energy based on the energy pricing you can always come up with a cost associated with that reduce manufacturing throughput, so also consequence of waste and emissions. So, some as you can you can if you start thinking about it some cost probably you can have a direct number some cost you can come up with some number and for the certain cost especially societal and other cost it is very difficult to put really a number of value associated with that.

Then there are also costs associated with the corporate image. Think about the issues with the nestle Maggi that we had almost a year back. Now I think and that whole image of nestle which got a lot of dent because of that that episode. And then the then the money the money lost because of that image dent and at the same time money now invested to get that image back that is there is also a cost associated with that. So, that is and in terms of then the corporate workers and communities their performance all these things in terms of if they get sick the performance being substandard. So, there will be a cost associated because of the main power or main our loss.

So, all these cost needs to be quantified, but how to how to do that how this cost can be quantified.

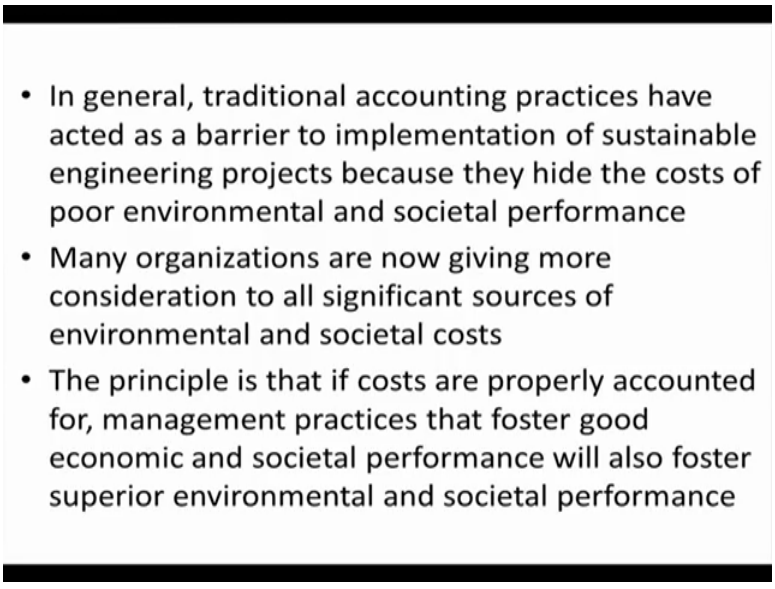
(Refer Slide Time: 05:50)



So, there are some tools available and there are some tools which used for estimating environmental and societal cost and benefits. So, we will try to talk about that a little bit in in this particular module there are some there are some like you can have a time value of money, let us say it is a traditional concept you can have a time value of money if you have taken any engineering economics or a economics course you have done that if you have not you can always pick up a engineering economics book and these. So, these basic concepts are explained. So, time value of money present value what is a present value how much would be the payback period, what is a rate of return other financial evaluation calculations all those things can be done in terms of (Refer Time: 06:31) with some number. And there are some in terms of how to include the methods for monetising environmental cost that are hidden from normal accounting procedures, because if you do it normal accounting procedures or the environmental cost does not show up. So, we have to kind of incorporate those environmental costs. So, there are less tangible cost and then, but and some benefit is which can still be monetized.

So, if you are coming with a better environmental control what are the benefit is how you can monetize them.

(Refer Slide Time: 07:07)



So, in traditional accounting practices what happens is we always we that traditional accounting practice is they hide the drawbacks or they or we can say that they hide the environmental and societal performance cost in their balancing. So, when you look at a

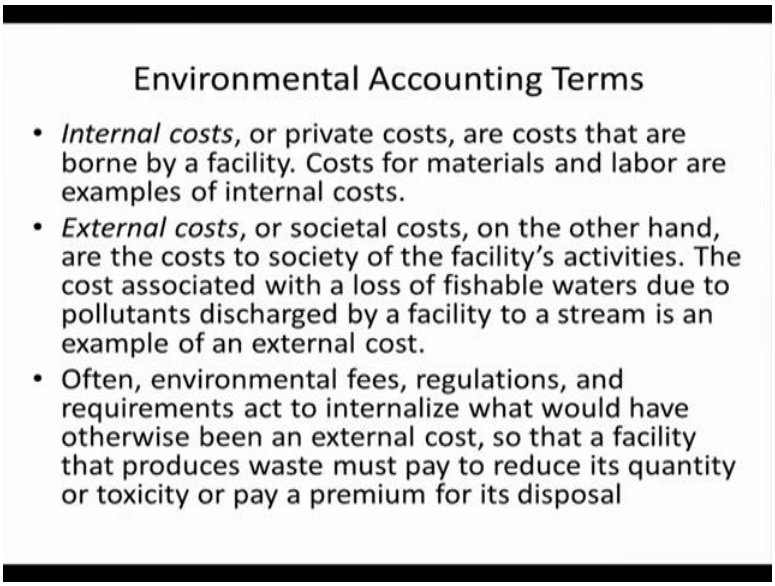
balance sheet of any particular company, now in the month of March. So, we are kind of we are in the month of march and then towards the end of march the financial year will be over, and then you will have this budget all those different companies will have their balance sheets coming out.

So, just pick up any of these balance sheets and look at the balance sheet they will they will have all the this is our raw this is the input cost this is output cost this is a labour cost, this is what we paid for a salary and all those kind of different aspects associated with that energy usage water usage, if they got in more detail. But never it will say that because of our activities. So, much of the environmental harm we have done and for that this is the cost associated with that, because it is very and that is, but we need to we need to incorporate those cost into our calculation just to be a same level plane field, otherwise what will happen is when you looked at all those different engineering principles in the previous module, if you try to incorporate all these engineering principles in your company, while your competitor does not do that.

And if you do not incorporate this environmental and societal cost your the product which are greener may come out to be expensive because we are looking at the holistic we are looking at things. But the other company which they are actually cheaper, but actually if you look at if you include all the environmental cost the cost may go up. So, again you are at benefit if you if you if you are kind of taking all these green engineering principles into account, but it may not it may just show up not that better in terms of if you just go by the traditional way of calculating the cost not incorporating the environmental cost as well as the societal cost.

So, we need to be really careful in terms of when we do the comparisons many companies. Many organisations are there which are now actually giving consideration to all significance sources of environmental and societal cost there are companies within India as one. The principle of that the costs are properly accounted. And we do the good management practices good economic and societal performance. They actually sought to be better in terms of superior environmental and societal performance and at the same time they do come up with lower environmental footprint and lower total cost associated with that.

(Refer Slide Time: 09:42)



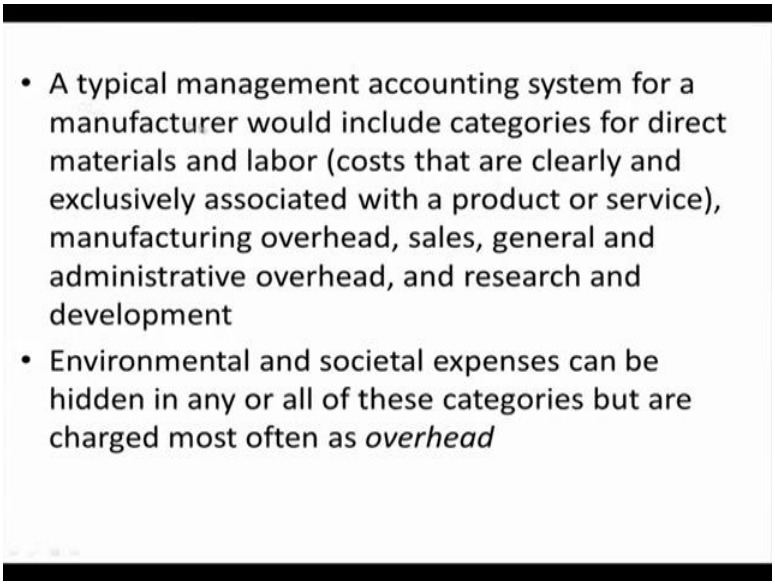
So, how we will go about this? So, there are some terminologies we will try to go about the environmental accounting terms. So, we have always talked about accounting from a just from the money point of view. So, here also we are trying to put environmental aspects in a monetary term. So, there are it like a internal cost or private cost. So, what is that those are the costs that are borne by a facility cost of material and labour are example of internal costs. So, it is costs that are borne by facility. So, they are paying for it and external cost or societal cost on the other hand is a cost that society or the cost to society of the facilities activity. So, for example, if there is an act of facility activity is leading to loss of fishable water, due to a pollutant discharge in the river in example of external cost.

Now, how will we quantify that do we probably have to come up with based on our previous cost numbers, how much fish was actually harvested from that particular area per year. And what is the market value of that fish and from that will we have to take a number of years into account, and then how much it was a total amount of money lost because of this activity. So, that is only the activity that is the money lost because that fisherman could not get the fish and sallet. So, that is one aspect of the cost the other aspect is the water is contaminated now. So, water needs to be cleaned up as well. So, there is a water clean-up cost associated with that.

So, that is again we can we can probably put a what is a cost of a typical waste water treatment plan, and for those kind of contaminants how much it will cost here we can do some literature, again we can come up with some number, but if you have to come up with a number that we fought next 3 years or 4 years when this river or this stream is non usable what is because of this stream and river was used for probably for religious purposes for some for some lie religious functions throughout the year or people taking bath in there people taking a dip or people just doing some recreation activity, but if because of this contamination if some of those cannot be done there is a cost associated with that, but then how to put that cost into account.

So, that is that that there is a way to do it as well, but it gets little bit tricky in terms of and different people will probably interpret in a different way. So that, that will be again an external cost associated with that often there are other type of cost environmental fee regulation requirement to act on into of internalize what would be otherwise been external cost. So, the facility that produces waste must pay to reduce it is quantity or toxicity or pay premium. So, those kinds of things are over there.

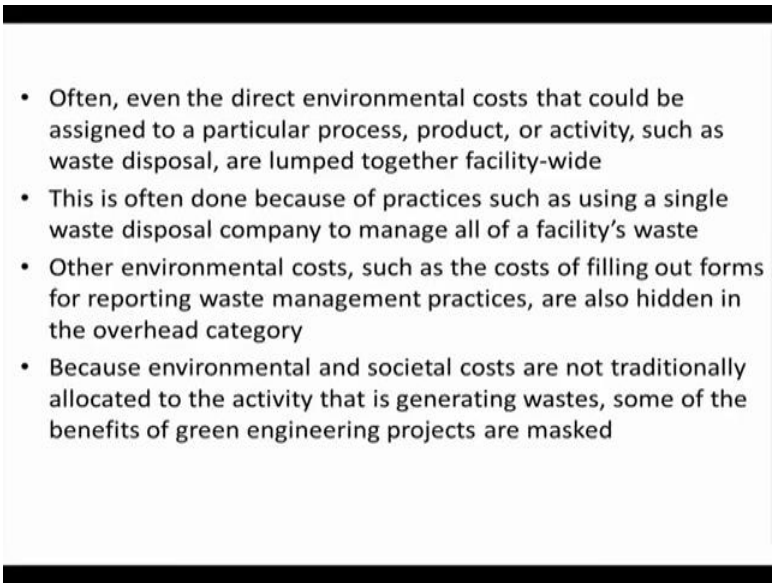
(Refer Slide Time: 12:42)



So, typical management accounting system which just will go direct material and labour that cost that are clearly and exclusively associated and including a manufacturing overheads sales and general administrative overhead and then some research and development.

Environmental and societal consideration can be hidden in any are another category, but are charged most often as overhead. So, we can put this money as overhead money if we can as a part of the cost that that goes in there.

(Refer Slide Time: 13:17)

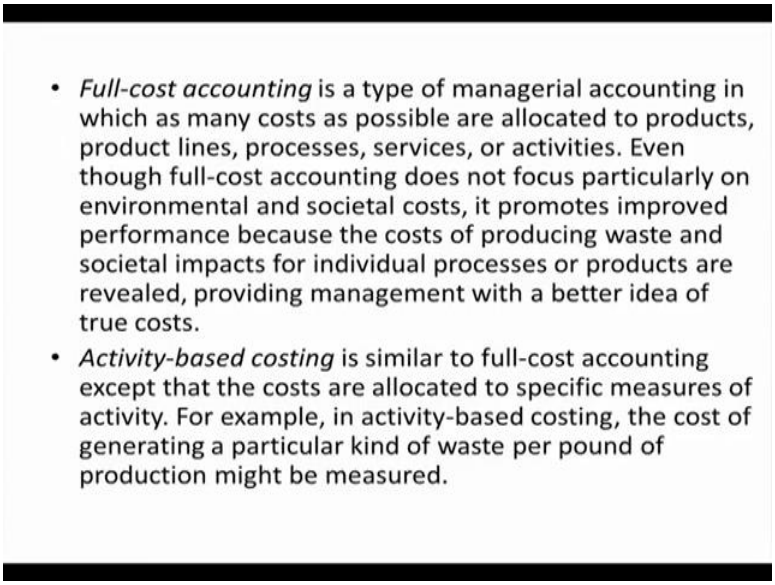


So, we are what we do even the direct environmental cost which could be assigned to a particular process or product or activity, such as waste disposal usually what they what is done they lumped together in a facility. So, we put all everything together as a one cost. And say if this often done because practice is that you will use a single waste disposal company to manage all of your waste. And then there are lots of you have to for fill up form. So, you have to fill up lots of forms for environmental compliances.

So, these forms will be certain man hours are required. So, there will be a cost associated with the man hour and then that is all usually hidden in the overhead category, because environmental and societal cost are not additionally allotted to a particular activity. So, the benefit is of win engineering projects are really it gets must you do not see the benefit directly. Because although you have applied certain win engineering principles you have improved part of the process that is since the cost associated with managing the waste managing the waste water and another stuff that goes as I would say that does not go say that does not get attached to that one particular process of which you have improved upon you are looking at the entire cost entire processes.

So, whatever the benefit you are getting in terms of improving that particular process that does not really show up very clearly, the benefit is not seen very clearly because you are not you are looking at the whole thing, we are looking at the total processes together in terms of it is cost. So, the benefit is of one particular process does not get reflected very well in terms of the benefit.

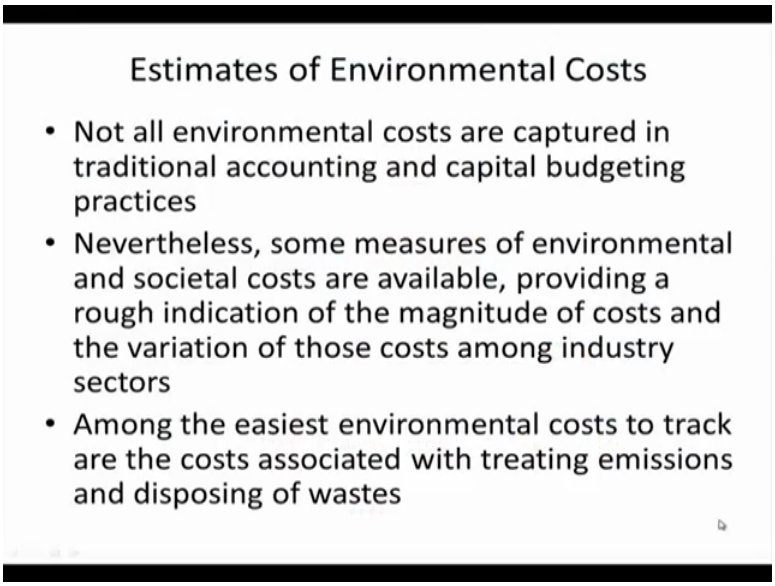
(Refer Slide Time: 15:03)



So, you go for what is known as the full cost accounting type of managerial accounting you can allot all the many cost as possible look at for product line process service activity. It does not focus particularly environmental and societal, but it looks at since it takes account all the different cost associated with that it does take. So, if you improve upon waste management if you will improve upon societal impacts, it does show up it does give a better idea of the true cost. So, you should go for the full cost accounting.

Then there are activity based costing which is like it is a similar too full cost accounting, but you are specific look at the specific measure for activity. For example, if you look at activity based costing the cost of general cost of generating a particular kind of waste per pound of production might be measured and then we can try to reduce the cost being produced and then we will say how much money we have saved accordingly.

(Refer Slide Time: 15:57)



So, that is like in terms of with different types of like an I would say parameters or different types of we talked about this different terminology used for these. Now we will try to look at how we try to estimate some of these environmental cost and which I kind of told you some of these examples already. So, not all of the environmental costs are captured in traditional accounting.

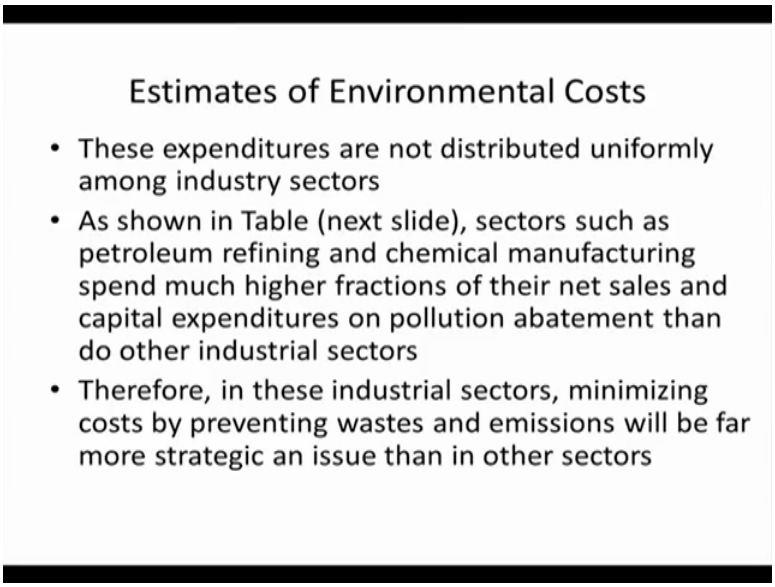
So, what happens is they are some measures of environmental and societal costs are available, but among industry sectors among the easiest environmental cost track are the cost associated with treating emission and disposal of waste because we can we can quantify that how much it money required to dispose the waste again disposal of waste. If you just think about the waste how much was the waste disposal fee that was charged that is one cost, but since you are producing this waste and the waste is being dumped into the land fill what will be the landfills leisure being produced from the land fill landfill gas is being produced.

Then then are some cost associated with the leisure treatment there are some cost associated with that landfill gas treatment and you are taking a land and you are making it a landfill which are you are reducing the cost of the near of the area nearby because nobody wants to have land filled in their backyard. So, the property prices near the land filled usually have a tendency to go down. So, there is a there is a drawback of having a land filled there, but there, but though there is a cost factor and then since say land filled

if something happens in future what would be the problem associated with that. So, all those things are there.

So, not all of these environmental costs are captured in traditional accounting and capital budgeting practice so, but some are available. So, that gives a rough indication of magnitude of the costs and the variation of those costs among industry sectors among the easiest environmental costs to track is what we talked about the cost associated with treating emission and disposing of the waste. These expenditures are not distributed uniformly among industry sectors. So, which was they are usually lumped together.

(Refer Slide Time: 18:14)



So, what the different sectors you will as we will we look at some of the examples in next slide the different sectors such as petroleum refining or chemical manufacturing they these this spend higher fractions of their net sales in pollution abatement then other than do the other industrial sectors. So, minimising costs or preventing waste will be far more strategic issue then, so in this particular type of sectors.

(Refer Slide Time: 18:33)

Table 5-1 Pollution Abatement Expenditures by U.S. Manufacturing Industries

Industry Sector	Pollution Control Expenditures (as % of Sales)	Pollution Control Expenditures (as % of Value Added)	Pollution Control Capital Expenditures (as % of Total Capital Expenditures)
Petroleum	2.25%	15.42%	25.7%
Primary metals	1.68%	4.79%	11.6%
Paper	1.87%	4.13%	13.8%
(pulp mills)	(5.70%)	(12.39%)	(17.2%)
Chemical manufacturing	1.88%	3.54%	13.4%
Stone products	0.93%	1.77%	7.2%
Lumber	0.63%	1.67%	11.1%
Leather products	0.65%	1.37%	16.2%
Fabricated materials	0.65%	1.34%	4.6%
Food	0.42%	1.11%	5.3%
Rubber	0.49%	0.98%	2.0%
Textile	0.38%	0.93%	3.3%
Electric products	0.49%	0.91%	2.9%
Transportation	0.33%	0.80%	3.0%
Furniture	0.38%	0.73%	3.4%
Machinery	0.25%	0.57%	1.9%

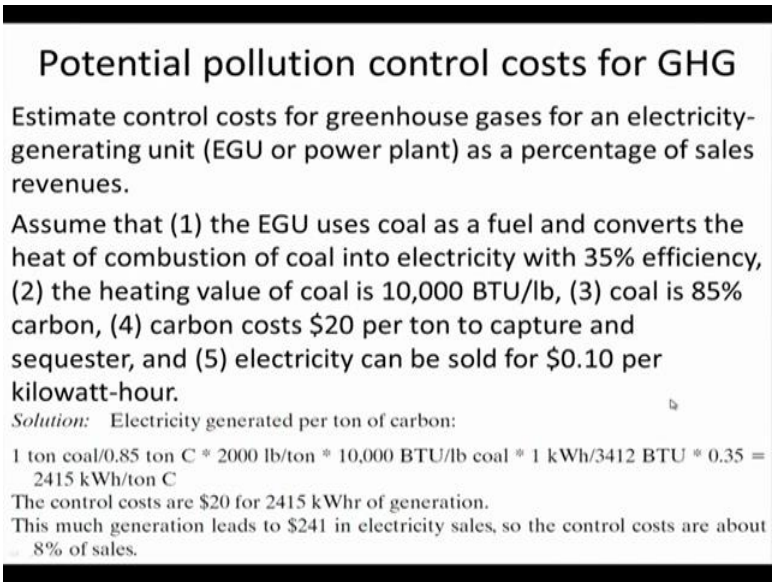
Source: Data reported by U.S. Congress, Office of Technology Assessment, 1994; original data collected by U.S. Census Bureau

As you can see this particular table you can on the let you look at this petroleum primary metals paper chemical manufacturing stone products lumber leather products fabricated materials. So, all these different types of industry sectors have been shown over here and then we have this is what is the pollution expenditure as percent of sales.

So, as you can see as we go down this has been arranged in the with more pollution control expenditure being on top while the numbers as you go down you see less and less numbers being there. So, petroleum industry primary metals paper mills chemical manufacturing they are kind of doing a all nearly they spend a higher chunk a percentage wise as percentage of the cell the pollution control expenditure and then the pollution as per at the percentage of the value addition you see that as well. So, value addition is then pollution control capital expenditure as percentage of total capital expenditure.

So, based on the total capital expenditure nearly 26 percentage goes in pollution control for petroleum industry 12 percent in primary metals 13.8 to 17.2 percent these are the 2 different sources makes nearly. So, that is we get chosen to into the pollution control capital say. If there are it is there are like good amount of money that is been invested on that.

(Refer Slide Time: 20:04)



So, then if you want to calculate what is the potential pollution control cost for the greenhouse gas, we can estimate the control cost for greenhouse gas as a percentage of the sales we can do that percentage of sales revenue. Say if you assume that for electricity generating unit which is which is shown as a EGU over here uses coal as a fuel and converts the heat of combustion of the coal into electricity. And as we have seen in the very first module or may be the second first or second module that these processes are very low efficiency. So, we are looking at a 35 percent efficiency the heating value of coal is given to us like 10,000 BTU per pounds.

Coal is 85 percent carbon costs dollar 20 per ton to capture and sequester electricity can be sold at 10 cents per kilowatt hour. So, if these are the values which is provided to us if you want to find out what is the like as a in terms of we can look at in terms of the different fraction like what is the percentage in in terms of the sales revenue and other stuff. So, electricity generated per ton of carbon based on the data that is available to us we can find out it is a 1 ton of carbon 85 percent coal is 85 percent. So, one coal means how much carbon. Then carbon this ton is British term which is used in US and other places such 2000 pounds per 1 ton, then we know BTU per pound for coal and we also know that one kilowatt hour is just conversion of BTU to kilowatt hour then 35 percent.

So, from 1 ton of per ton of carbon we get 2000 hour 115 kilowatt hour, now price is dollar 20 per ton to capture and sequester. So, control cost is dollar 20 per ton. So, for

this much kilowatt hour that is a control cost this much generation leads to 241 electricity sale we can multiply 10 cents multiplied by 241, 5 that gives you 241 dollars in electrical sale. So, if you look at the control cost as a percentage of the sale total sale will be 241-dollar control cost is 20 dollars. So, 20 divided by 241 that is around 8 percent.

(Refer Slide Time: 22:39)

Table 5-2 Summary of Environmental Costs at the Amoco Yorktown Refinery

Cost Category	Percentage of Annual Non-Crude Operating Costs
Waste treatment	4.9%
Maintenance	3.3%
Product requirements	2.7%
Depreciation	2.5%
Administration, compliance	2.4%
Sulfur recovery	1.1%
Waste disposal	0.7%
Fees, fines, penalties	0.2%
Total costs	21.9%

Source: Heller et al., 1995

So, that is kind of gives you. So, we can do this kind of calculation. So, and if you some of other example in terms of one particular refinery if you look at the different categories of cost then if you look at the or based on the annual non crude operating cost waste treatment nearly 5 percent and maintenance fall 3.3 percent product requirement 3 percent depreciation administration sulphur recovery total cost is around 22 percent. So, it is 22 percent kind of goes into the environmental cost at a particular refinery.

So, this is I gave you just an example to give you an idea. So, this is in terms of different type of cost how much it kind of ends up over there.

(Refer Slide Time: 23:19)

Table 5-3 Summary of Environmental Costs at the DuPont LaPorte Chemical Manufacturing Facility

Cost Category	Percentage of Manufacturing Costs
Taxes, fees, training, legal	4.0%
Depreciation	3.2%
Operations	2.6%
Contract waste disposal	2.4%
Utilities	2.3%
Salaries	1.8%
Maintenance	1.6%
Engineering services	1.1%
Total	19.1%

Source: Shields et al., 1995

Another example here total is 19.1 percent earlier if you look at the refinery was around 20 percent this DuPont chemical manufacturing facility nearly 20 percent. So, not there is not that difference around like a around 10 percent plus and minus. So, here again depreciation operation contract waste disposal utilities salaries maintenance engineering services. So, all those aspects have been included over there.

(Refer Slide Time: 23:45)

A Framework for Evaluating Environmental Costs

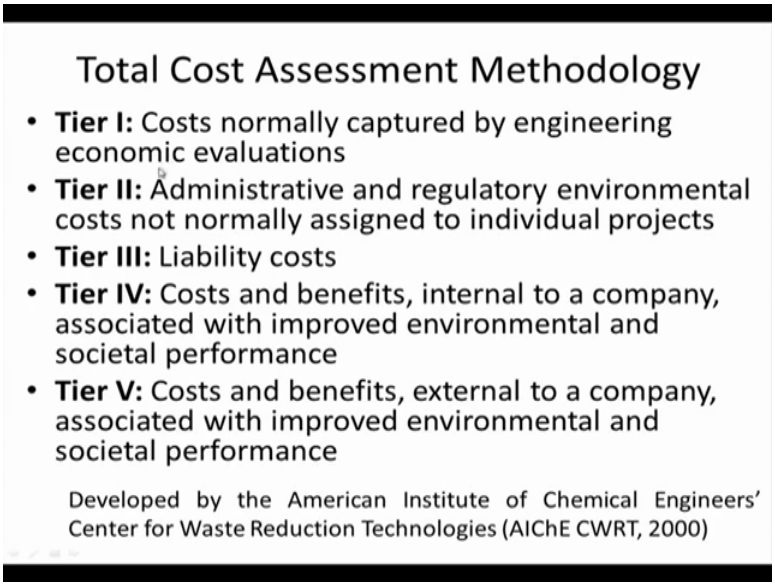
- Engineering projects are generally not undertaken unless they are financially justifiable, and projects designed to improve environmental and societal performance beyond regulatory requirements usually must compete financially with all other projects under consideration at a facility
- Fortunately, projects resulting in improved environmental and societal performance are frequently profitable
- However, the potential profitability of environmental and societal projects is difficult to assess, and it is common for many of the financial benefits of improved environmental and societal performance to be neglected when projects are analyzed
- That is why a better understanding of methods for estimating these costs and benefits serves to promote sustainable engineering

So, there was always a need for having a framework for evaluating environmental cost. So, as you can as you saw from the examples of the discussion. So, far there are waste to

do it, but there they are as you can say the things can get can go subjective. So, with the way I look at certain aspect and the way you look at certain aspect may be different, and then we will end up kind of giving a different kind of the different kind of cost numbers associated with that. So, it is engineering projects. So, we have this is generally with there we do not take any unless they are financially justifiable and project is designed to improve environmental and societal performance.

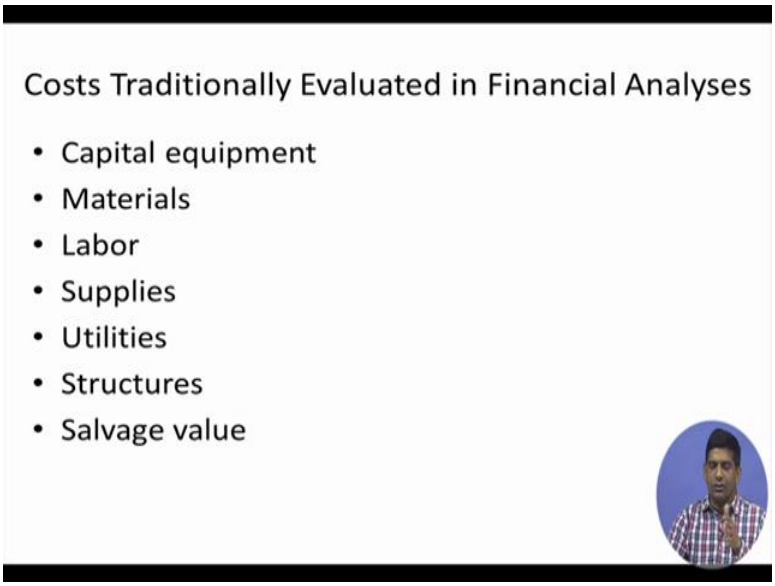
Projects resulting in improve environmental and societal performance are frequently profitable which we have been found that which results in; however, potential profitability of environmental and societal project is difficult to assess. So, like how they will be and it is common for many of the financial benefit is off to be neglected when project is analysed. So, that is why we have to have a better understanding of these costs and serve promote sustainable engineering.

(Refer Slide Time: 24:59)



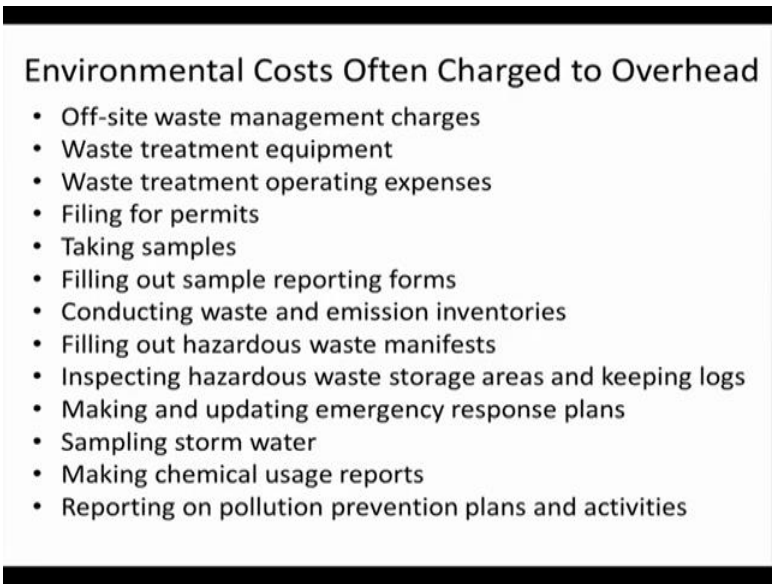
So, what we do and how we go about this total cost assessment methodology and we will we go for tier one. So, for the cost normally captured by engineering economic calculation then we go to the tier 2 cost which is the administrative and regulatory environmental cost not normally assigned then liability cost in tier 3 tier 4 takes into cost and benefit is internal to a company associated with improved environmental and societal performance, then tier 5 looks at cost and benefit external to the company.

(Refer Slide Time: 25:36)



So, all these different costs as much as possible is quantified and then you add them up to get the total cost associated with that. And they are usually what kind of cost we are looking at we are looking at the capital equipment material labour supplies utility structures salvage values and all that.

(Refer Slide Time: 25:46)



So, and as I said earlier many times the environmental cost is charged to the overhead which includes offsite waste management charges waste treatment, equipment operating, expense filling of the papers, permit is taking sample report forms conducting waste

emission inventory sampling. So, all these different aspects that you see over here inspecting hazardous waste sampling storm water making chemical usage report. So, any each and of the again these are like a long list very exhaustive list and, but there are still could be some of the other aspects which is not been included over here for each one of these.

So, when the environmental cost there has a cost associated with that, but usually we lump them all together and put it as part of that 25 percent or thirty percent overhead cost that we have.

(Refer Slide Time: 26:34)

In terms of the liability cost that include compliance obligation, if you have to do remediation that to obligation is there fines penalties and then if you do anything to the private parties for personal injuries property damage economic loss. So, there could be primitive damages natural resource damages all these things are liability cost associated with any activity.

(Refer Slide Time: 26:56)

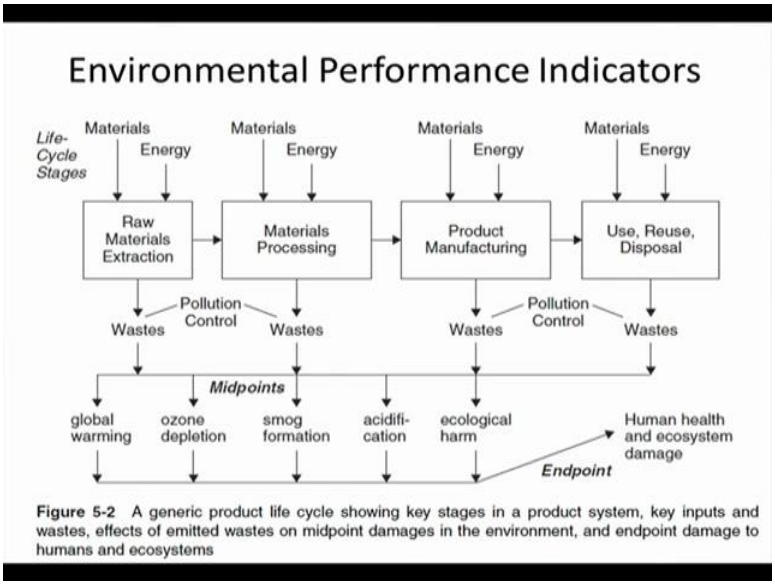
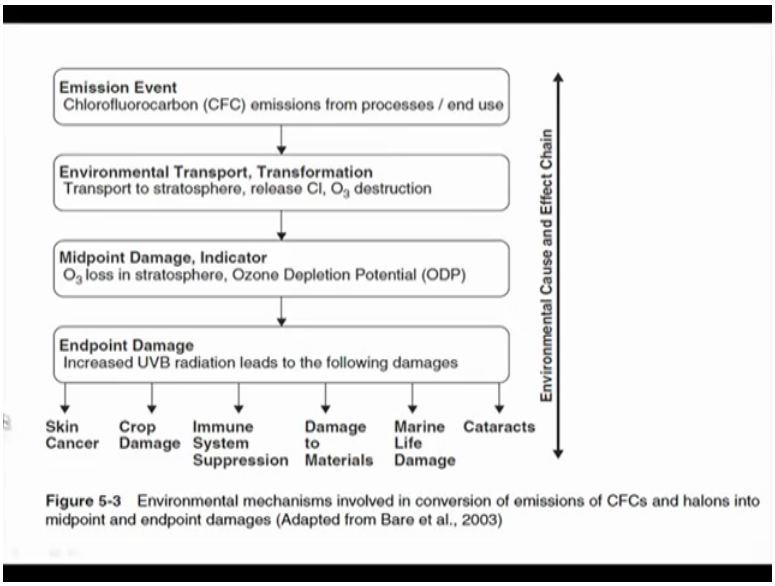


Figure 5-2 A generic product life cycle showing key stages in a product system, key inputs and wastes, effects of emitted wastes on midpoint damages in the environment, and endpoint damage to humans and ecosystems

So, let us look at this particular like a chart then we will kind end this particular module. So, in terms of the life cycle stages which we kind of saw earlier as well raw material extraction processing manufacturing use and disposal. For each one of these material and energy input is there, for each one of that we have some waste being produced and we can use pollution control to reduce the waste being produced. And then you have the impact that is coming from each one.

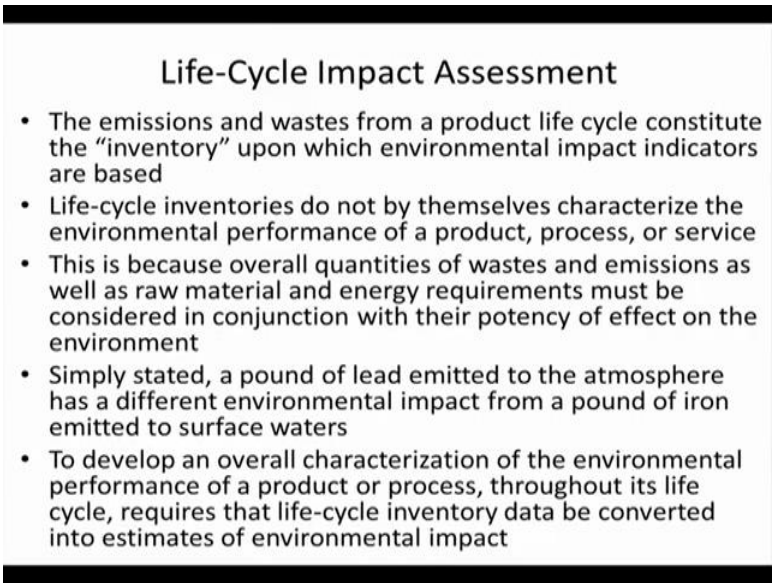
And then you have this is these are called midpoint and then you have like a endpoint which is a human health and ecosystem. So, this whole thing if you remember this is nothing else, but what we talked about as a step by step methodology for life cycle analysis. So, again all this stuff that we have been talking together how they relate to this life cycle stuff. So, that is we have these are the different life cycle stages. So, having this life cycle thinking helps us to come up with this better environmental performance indicator.

(Refer Slide Time: 27:57)



So, you can look at the emission, you can look at the environmental transport transformation midpoint damage, endpoint damage, and all the what is the environmental cause and effect and all that.

(Refer Slide Time: 28:06)



So, we will be being said all these things. So, far in the next module we will be kind of looking at this life cycle impact assessment if we have already done earlier, but again it is will be kind of a recap and then we will look at some of those calculation of how it is done. And then we will this from the next module we will get into week 8 which is the

last week of the course and. So, that will look at again kind of recap your life cycles the way we started it, and then we will have some case studies from different research projects that I have worked on some of the industrial projects as well.

So, with that let us close this particular module, and I will see you again in the next week module which would be a last week of this course I hope you are enjoying this course.

Thank you and see you again.