Sustainability Through Green Manufacturing System: An Applied Approach

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Lecture - 15
Green Manufacturing Modelling: Metrics for Green Manufacturing

Good morning, welcome back to the sustainability manufacturing course in this course we are trying to learn what is a manufacturing system, what are various elements of a manufacturing system, what is sustainability green manufacturing and how we can turn a system towards eco efficient system or how a green system can be obtained. So, in this lecture I will cover modelling for green manufacturing, this model is actually a system model.

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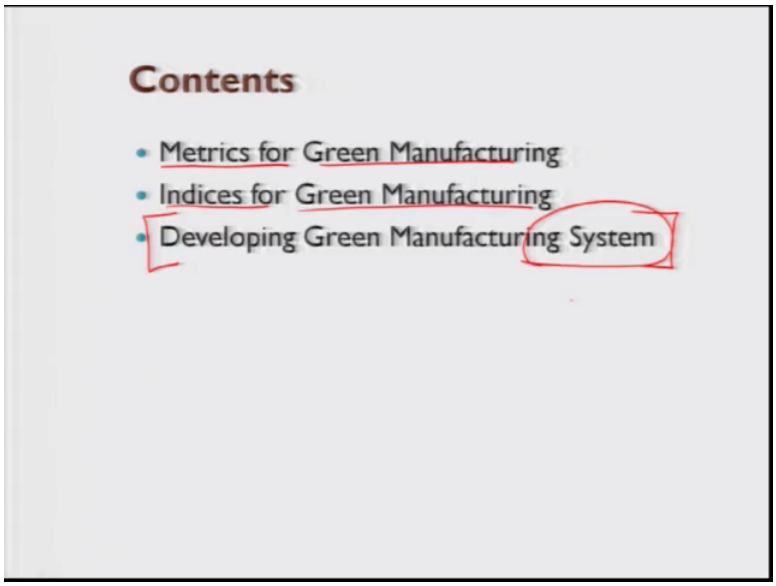

Now before discussing this model, I will go through what are metrics for green manufacturing and what are indices for green manufacturing, then we will see a model how a model could develop for a system at a system level. The system level could be further divided into facility level, process level, unit manufacturing level ok.

Now, what is metric actually? Metric is something that is used for measuring now metric is a system or standard of measurement.

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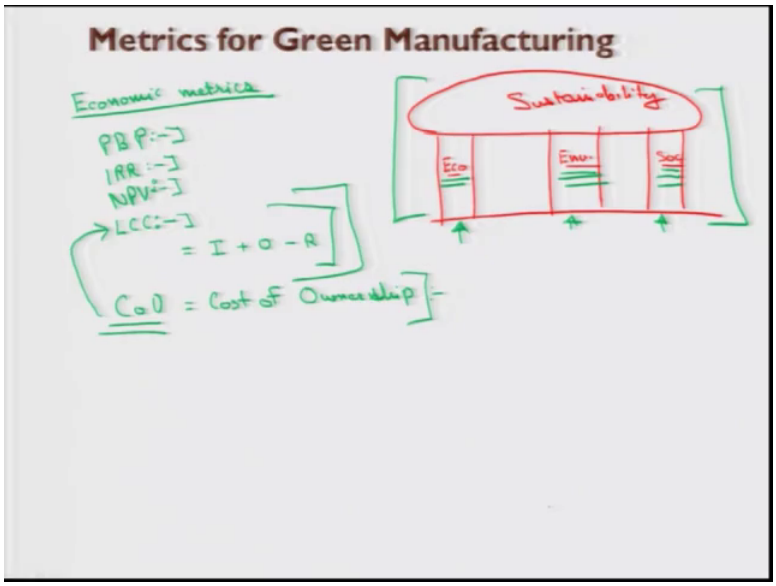

And when we say metric for green manufacturing, these metric can be broadly divided into the three pillars of sustainable manufacturing. If you remember what were these pillars here? Economic, environmental and societal these three pillars were there. Now these metric can also be divided into these three pillars. Now in this part of our course we will try to learn or we will try to provide a base line for understanding existing economic social and environmental metric systems.

So, first of all start with economic metrics; now economic metrics are more focused on investment decisions and on increasing profitability with time the common metrics here are this is payback period or may be internal rate of return or net present value. So, what is this payback period? Payback period is the actually the time after which the initial investment that is made is all recovered through the revenue, through revenue that is through the profits.

Next is internal rate of return; internal rate of return gives the annualized effective compounded rate of an investment. So, net present value is actually determining whether an investment in future cost savings is worthwhile and if it requires adjusting future cash flow into a current time frame. So, this is net present value. So, these are very general metrics here another metric may be life cycle costing that we have discussed that is the overall cost including investment, operational and replacement cost at the end. So, life cycle cost is equal to investment cost if I put I as investment plus, operational cost minus

disposal cost I put is R as replacement cost when we sell or product or equipment here. So, next metric here I like to discuss is cost of ownership, this is cost of ownership. So, what is actually cost of ownership? It is a similar metric to life cycle costing, but it is more used in manufacturing because it has general applications in may be in green manufacturing (Refer Time: 04:30). A complete economic analysis metric is implied for cost assessments and comparison among various alternative options in green manufacturing could be done using this metric.

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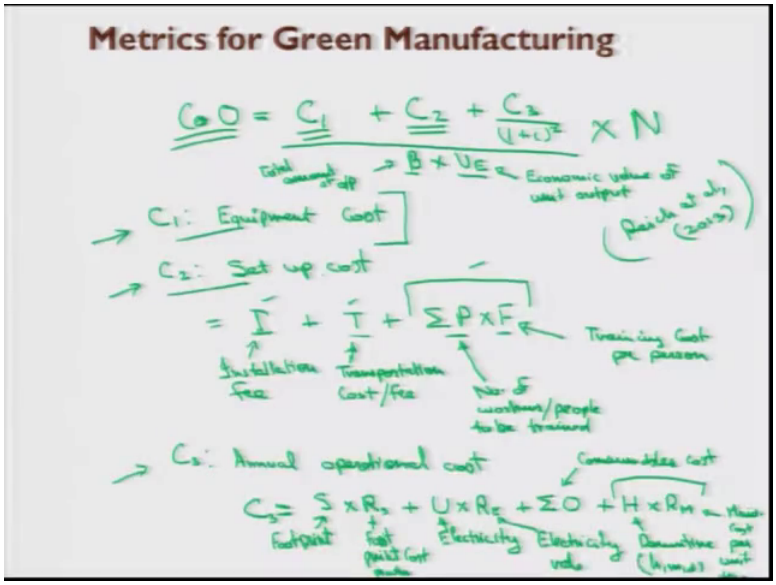

So, how is this cost of ownership evaluated? Cost of ownership is (Refer Time: 04:51) proportional to are cost of equipment and it is actually sum of the cost of equipment and the cost of setup of this equipment, I will put one more term here C 3 by 1 plus i power z and it is inversionally proportional to B and V E, I will explain these terms here into n what is C 1here.

C 1 is my equipment cost equipment cost is actually initial investment cost may be initial or may be in the first if I talk about the manufacturing concern the cost that is there in the initial face only. Now C 2 is my setup cost what is this C 2? This is equal to I plus T plus summation P times F what are these terms? This I is installation fee, T is transportation fee, P is number of people to be trained for this and F is the training cost. So, these all becomes my total training cost it is training cost per person. So, this is my transportation cost, I call it cost or fee it all depends then number of workers or people to be trained to

make this setup and this is training cost training cost per person. So, this total becomes my total training cost. So, this setup is my installation, transportation and training.

Now, what is this 3C3? This becomes equipment this is setup. So, what is C3? C3 here is my annual operational cost. So, this is working in the same fashion as we did in our life cycle costing. So, this is my annual. So, C 3 is also dependent on certain things here which are footprint for the equipment into my footprint cost, I am talking about green manufacturing here. So, this is my carbon footprint. So, plus the electricity that is consumed, I will put it U electricity consumed per year into electricity rate of electricity plus summation O, this O is actually sum of all the consumables also we have one more term here that is H into R m. Now what is H here? H is my down time hH is down time and R is maintenance cost and this becomes total maintenance cost here.

So, in this case this S is I would write here footprint then R s is my footprint cost for may be rate and U is my energy actually. So, in this in factory I will say electricity, then R e is my rate of electricity, O is consumables, H is down time that is in may be hours or minutes or seconds and R m is my maintenance cost per hour cost per unit time I would say. Now we are left with a few terms here that is B, now we have a few terms in denominator as well. So, what is B and V E cost of ownership is inversely proportional to my or total amount of output of the system I would say. Total amount of output and V E is economic value of unit output. So, this model represents a method to calculate my cost of ownership. Now this model was given by Reich and others in 2013.

Now, this cost of ownership has included everything the equipment cost are the purchasing cost of the equipment and assistive with components, setup cost include those for installation, then I have this one operational cost that is the cost of operating then it includes everything and (Refer Time: 12:38) training labour cost installation in the facility annual operational cost, electricity consumed, factory floor place that is occupied maintenance cost consumables. So, this model is a kind of comprehensive model in comparison to the previous model LCC model which we discussed. So, it is better to use this as a financial metric.

Now, other metrics are in these concerns environmental and societal.

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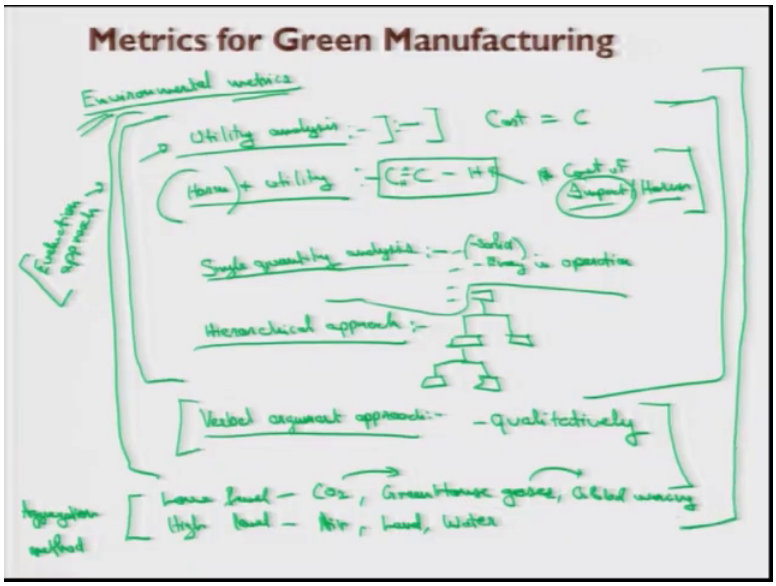

Now, environmental metrics; environmental metrics are generally based on their evaluation criteria, the approach this metrics are evaluated actually the evaluations approaches may be utility analysis utility analysis, which is the combination of qualitative or may be quantitative criteria to a quantitative results waitings of each criteria are subjective to the user the user who is using this one then we have may be with utility we can even have harm plus utility analysis, this is very close to cost utility analysis the general utility analysis here this is only cost here, in this case harm is also there.

The harm is actually what is the final output when we subtract the environmental harm from this cost, that is the cost that is this is actually cost here if I say this is cost C this would be cost C minus H right C H would be C minus H. So, this would be the cost the H is cost that is associated to recover the harm that is created, the impact that is created by this manufacturing concern. So, these terms are very broad we need to further quantify this which this is impact for energy, for waste or we talking about material waste or we talking about what kids of waste is there solid liquid gaseous what kind of pollution is there. So, this impact is to be further detailed.

Now, approach for critical quantities might be one of the thing the critical for example, only one quantity. So, I would rather say special or may be single quality. So, I would rather say here single quantity constrained right. So, single quantity analysis. So, this is

not a total energies this is about only one thing if I say only solid waste or may be only energy in operation. So, these are just examples. So, any single quantity can be taken here, then hierarchical approach analysis is also there in this case the criteria structure according to the hierarchy. So, at what level of hierarchy is it impacting it all depends upon this.

So, this is my hierarchical approach. So, one of the very subjective or qualitative criteria here is verbal argument approach. So, in this what happens when something is not very easy to be quantified? So, if thing is not quantifiable verbal arguments that we goals aims are defined qualitatively here and verbal argumentative approach is used for quantification if the any of the other criteria is not available. For example, the internal customers the workers or may be the users or the other stakeholders may be asked that what do you feel about the environmental impacts of specific product may be specific concern in or in a factory. So, this is a very subjective approach here. So, this was all the evaluation approach here, also the environmental metrics can be defined or can be classified according to their aggregation method that how these different (Refer Time: 18:27) are aggregated.

And these methods can be broadly divided into low level and high level what is low level here? Low level is just my own factory single factory or may be carbon dioxide emissions for a single factory may be greenhouse gases if I take it to further extension, then may be global warming its potential or its contribution global warming. Now at high level we think about the three basic utilities that human being need that is air, land and water now this is all broadly the environmental metrics.

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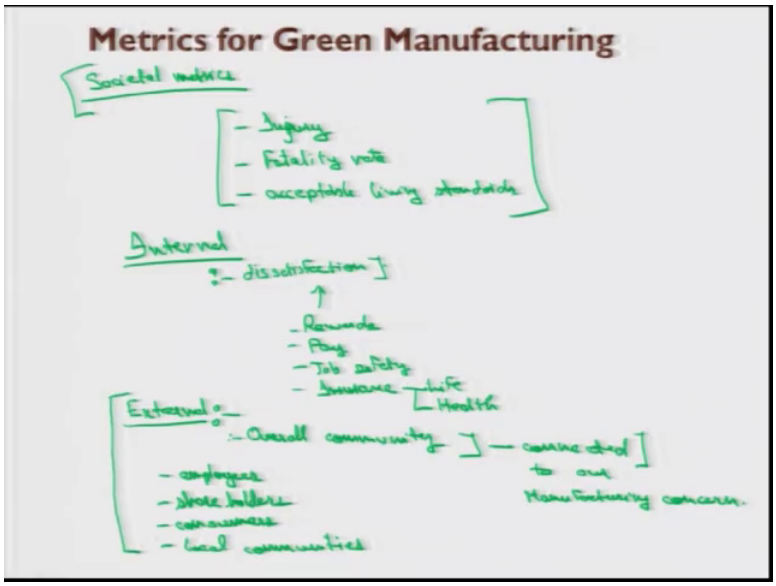

Next I will come to the societal metrics. The societal metrics cannot be directly defined and even the environmental metrics are not able to address everything that has effect on our society for example, the injury and fatality rate, I would put here injury in the factory or may be fatality rate or other subjective things like acceptable limit standards there or not. So, these are there is no direct metric or direct evaluation criteria to get our societal metric societal evaluation. Now for example, I took the example of lather manufacturing in Kanpur the water that is disposed to river Ganges here has chromium based impurities in that and that is effecting the society that is effecting the living standards or across the banks of river Ganges in Kanpur city.

Now, that had an effect on the society here now actually the lather industry relocated from this place. Now all these things the effects the skin rashes that would be developed the other effects that is what the health hazards (Refer Time: 21:26) that environmental metric is not able to evaluate. So, different studies are carried out to find out these effects. Broadly these can be divided into internal and external, internal effects and external effects and a metrics those are associated with these effects. The internal effects these can for example, the workers were working in a may be cotton manufacturing or some cloth manufacturing company, he is having some problem of breathing or may be the people who are working with where FRP fiber reinforced plastics. So, the sterile level there is very high. So, workers generally get the sterile went into their lungs. So, that also creates health hazards.

So, these kinds of internal like hazards would may create dissatisfaction within the company and it also depends on our total our overall sustainability framework. So, these things this dissatisfaction within the company needs to be addressed how this is addressed here? Now they can pay some rewards or may have give some extra pay, then job safety then insurance, then may be life insurance and health insurance life and health. So, I had a chance to visit Sutlej motors in recent past those company who manufactured the buses the Mercedes, buses and airport buses. So, they actually get their workers a through a process through a medical diagnostic and further they get their sterile from their lungs removed through certain medical processes. So, this was one of the thing they did to keep their worker satisfied or dissatisfaction level should not rise, they were concerned about that. So, these things are important here.

Now, external factors here are the factors that effects the overall community, that is everybody who is connected to my manufacturing concern. Now here examples may be the employees, shareholders, consumers, the end users or consumers then local communities similarly some definite social accountability as a total contribution that company makes the society has to be there. So, with this I will take a break here and we will continue this lecture in the second part where I will discuss the indicators. Now here I have discussed the metrics across these three different pillars. So, these are three pillars.

I have discussed what are metrics for this one next I will come with the indicators. So, what are indicators? Indicators is the thing that indicate something or that tells at what level or what state are system is. So, what are the indicators for green manufacturing and OECD has given certain indicators that input operational and output levels, OECD as a actually organization for economic operation and development, which is an international body which works towards the social wellbeing of people all around the world it has come up with certain indicators for green manufacturing. We will discuss those in detail and also we will discuss certain indicator, those are at system over all system and at product levels this will discuss in the coming lecture.

Thank you.