Aspects of Biochemical Engineering
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Lecture – 59
Economic Analysis of the Biochemical Processes

Welcome back to my course Aspects of Biochemical Engineering. So, we are almost coming to the end of our course. And this topic today I have I have chosen that is the economy analysis of the biochemical process, as we know that this is the major concerned about the about the industrial processes, because whatever thing we develop that we want to apply it that you know that should be economical. I know if it is not economical we cannot use for the benefit of the society.

So, question comes how we can do the economic analysis of the processes. And, it is something similar to the chemical process also, but let us see how we can do that?

Now, any industry whenever we operate we come across 2 type of expenditure; one is what you call fixed expenditure, another we have the operating expenditure. The fixed expenditure on the basis of the installation of the plant and other things that you know for you have some kind of installation cost and the, that money usually we take it from the bank as a loan.

So, we have principle amount we have interest, that we shall have to pay per month or or and then for operation of the industry we have different other operating cost; operating cost comprises of the may be raw material cost may be the other utility cost different type of utilities we have, we required electricity we require stream generation we required may be the soft water, I know that your compressor that you know different type of utility that we required and plus we have the man power that we have all this thing you have to consider, and then our output is our product. So, we if you know that how much product we are producing per day and we know that how much money we are spending per day.

So, if the cost of the product is more as compared to that money we spend in the industry we call net profitable industry. Now, if we if the if it is other way if the cost of the of product is less as compared to expenditure then we consider as the sick industry.

So, the let us see how we can do the analysis the do the economic analysis of the biochemical processes the where first thing that is important that what is called Economic Assessment.

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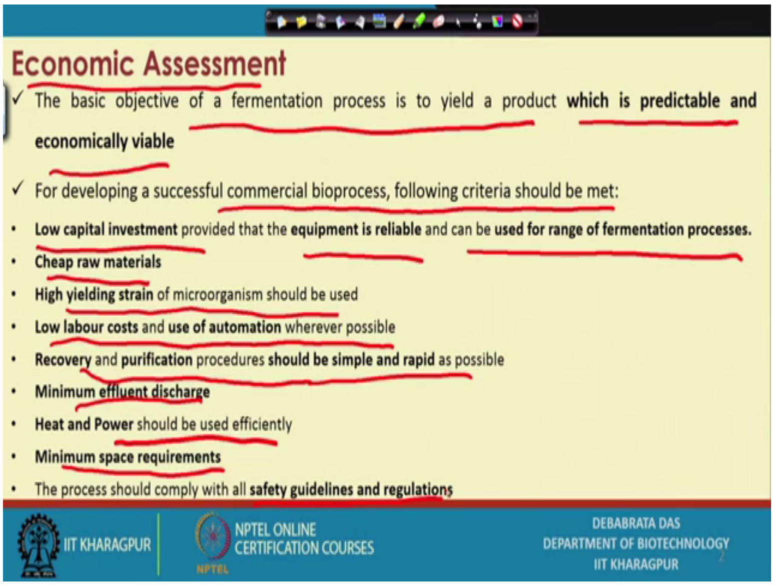

The basic object objective of a fermentation process is to yield a product, which is a predictable and economically viable.

So, this is very important, that you know our objective should be that it should be economical viable. For developing such successful commercial bioprocess following criteria should be made. What is low capital investment? Provided that the equipment is reliable and can be used range of permutation process. Let me tell you very simple, that suppose if you use the lot of lot of equipment that is already available in the industry that different fabricators.

So, if you use those equipment; obviously, it will very very it is a little bit cheaper. If you use the custom made system naturally it will be very costly. So, that you have to think of what that what a what a what should be the material of construction, what kind of reactor that we use that is very important, that is the low capital investment.

Now, cheap raw materials when you called cheap raw materials not only with respect to availability the availability also very important. Suppose, if I use the material is cheap and it is not available and it is no good. So, usually we found that, if you have multiple choice of sub straight then availability of the material will be very good.

The high yielding of strain of microorganism should be used and I told you that industry we use the industrial strain. What is the industrial strain? That can have the higher yield I told you that you know that if the concentration of product is more then our recovery cost will be less.

So, what is our desirable thing that our concentration of product should be as high as possible. And, that should be consistent it is not that one batch you have some product concentrations again, second batch you have less concentration, that is no good for our process.

So, that we shall have to look into low labor cost and use of automation whenever possible, I told you that you know if you the batch process is very easy to operate. And we do not require much of skill for the operation of the batch process, but what is the disadvantage of the batch process the yield the productivity is very less as compared to the continuous process.

So, we always look for continuous process. In the continuous process our productivity is very high and not our productivity very high, but also that the man power requirement is drastically reduced this reduced to almost 1 10th. So, that is that is one of the important factors. The recovery and purification procedure should be simple and rapid, that a that is also very important how simple we can separate it out the material that product.

And minimize the effluent discharge, because if your I can pick the example of bio steel process, but if you if you look at their lot of because if u India has more than 250 distillery and most of the distillery they are operated in the batch mode.

In the batch mode we usually we if the alcohol concentration is a is 7 to 8 percent, we have found that 13 liters of effluent is produced per liter of alcohol production, but you know that now if you increase the concentration of product ah; obviously, the effluent production also drastically reduce. And then we bio steel process is such a process is the it has they have a recirculation device and through which the they probe that this amount of effluent generation is reduced to one tenth.

So, this is very important and heat and power should be used efficiently that how efficiently we use the heat and power, minimum space requirement that is also very important and is complied with safety guideline at the regulation. These are the all things you shall have to take into consideration for the economic assessment.

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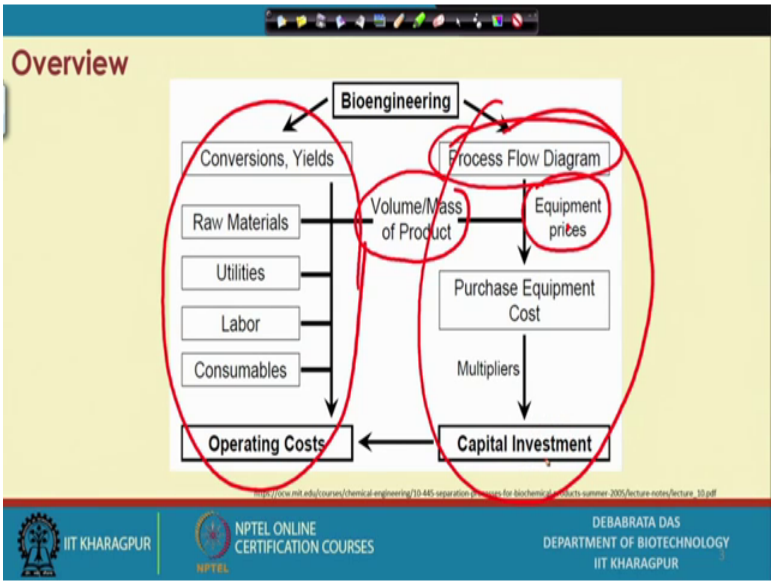

Now, if you look at the in the bioengineering processes, first we have the flow diagram and then we find out the what is the equipment price, and volume of mass of the product that we find out from the raw materials utility labor and consumables, this we find out what is the their operating cost the operating cost, we have all this factor capital cost will be this one this is equipment cost and that will mostly comes on the we have not only equipment in including the reactor, pump, bulb all these thing including all the downstream processing process that comes under the capital cost.

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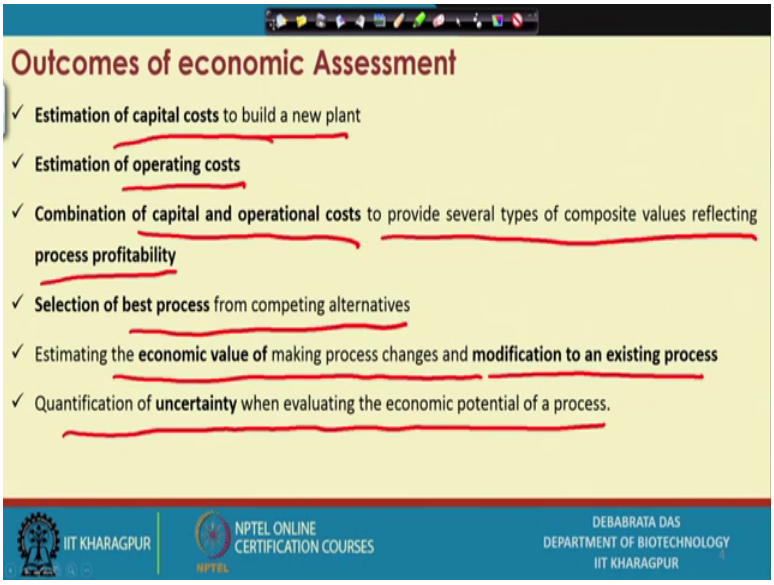

Now, outcome of the economic assessment if you look at the estimation of capital cost that we shall have to build a new plant, that we shall have to do the estimation of the operating cost combination of capital and operating cost to provide the several types of composite values, reflecting the process profitability.

I told you the capital cost and when you do a make the any capital cost we take the money from the bank and then we have 2 things we have principles certain interest both you have to pay per month, that you have to ad with the operating cost and then math with your cost of the product.

And selection of the best process by competing alternative estimation of economic value of making process changes and modification to an existing processor and quantification of uncertainty when the evaluating the economic potential of the process.

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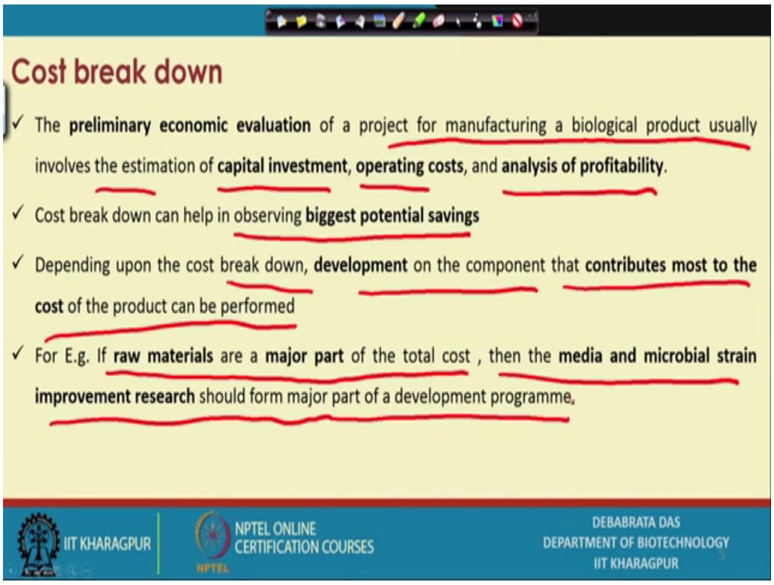

Now, cost break up as I pointed out the preliminary economic evaluation of a project, that a manufacturing of biological product usually involve, the capital investment operating cost and analysis of profitability. These are the 3 things we shall have to do it I have I have some example at the end I shall show you how we can do that? Cost break up can be can help in observing the biggest potential savings and depending upon the cost break up development of the component, and the that contributes most of the cost of the product can be performed.

As per example that if the raw materials are a major part of the total cost then the medium and microbial strain improvements research should form major part on a development program. So, this to you have to find out which place future role in the in the cost distribution process.

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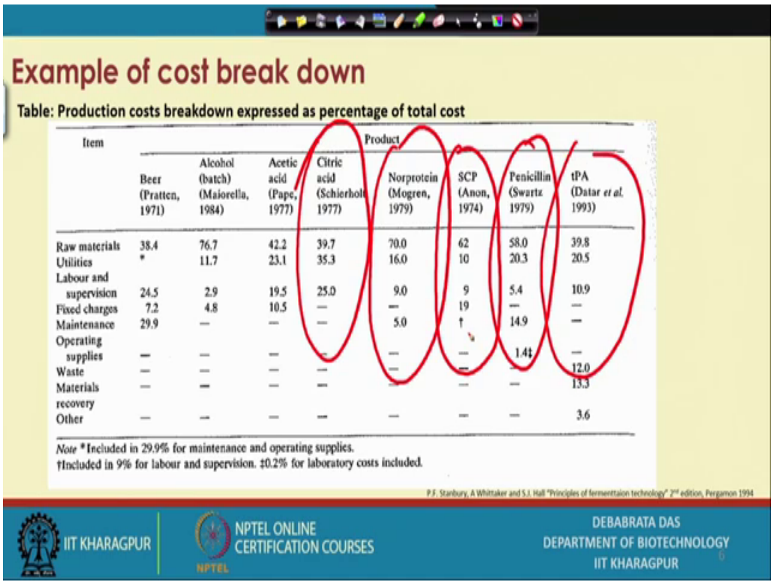

Item	Beer (Pratten, 1971)	Alcohol (batch) (Maiorella, 1984)	Acetic acid (Pape, 1977)	Citric acid (Schierholt 1977)	Norprotein (Mogren, 1979)	SCP (Anon, 1974)	Penicillin (Swartz 1979)	tPA (Datar et al. 1993)
Raw materials	38.4	76.7	42.2	39.7	70.0	62	58.0	39.8
Utilities	*	11.7	23.1	35.3	16.0	10	20.3	20.5
Labour and supervision	24.5	2.9	19.5	25.0	9.0	9	5.4	10.9
Fixed charges	7.2	4.8	10.5	—	—	19	—	—
Maintenance	29.9	—	—	—	5.0	†	14.9	—
Operating supplies	—	—	—	—	—	—	1.4‡	—
Waste	—	—	—	—	—	—	—	12.0
Materials recovery	—	—	—	—	—	—	—	13.3
Other	—	—	—	—	—	—	—	3.6

Note *Included in 29.9% for maintenance and operating supplies.
†Included in 9% for labour and supervision. ‡0.2% for laboratory costs included.

Now, here example of the cost break up we have this table gives you the some information, that in case of beer making industry what is the raw materials contribute and other labor and supervision fixed charge, maintenance as how is contributed. Then acetic acid industry how it is contributed this is the citric acid industry how it is contributed? The then nors nors protein this is single cell protein how it is penicillin how it is there TPA how it is there, that that distribution has been this is shown here.

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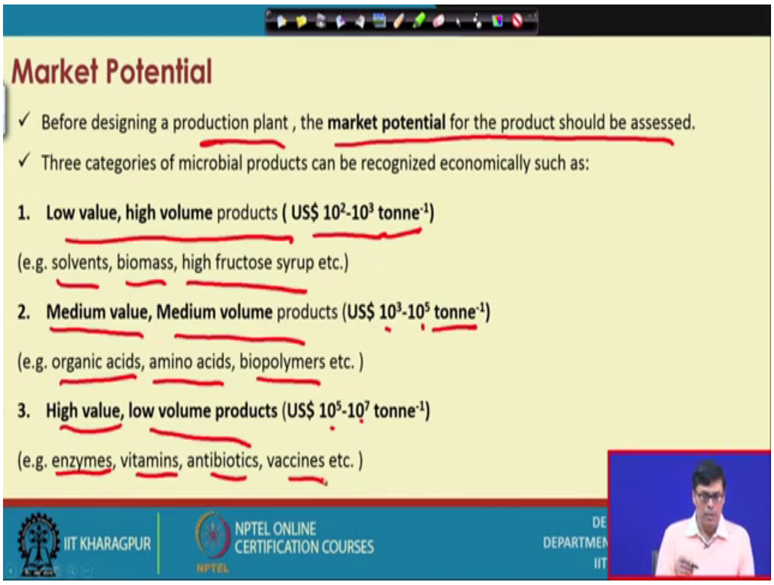

The market potential is very important the before designing the product production plant, the market potential of the product should be assessed, because this is very important. At the 3 category of products we discuss at the beginning the low value, high volume products, where that you know that cost of the product is 1000 to 10 000 per tones dollar us dollar, this solvent biomass and high fructose corn syrup.

Then, we have we have medium value medium volume products we have 10 000 10 to the power 3 10 to the power 5 dollar us dollar per ton, we have organic acid amino acid and bio polymer high value low volume products we are 10 to the 5 to 10 to the power 7 per tones, we have enzyme vitamins antibiotics and vaccine.

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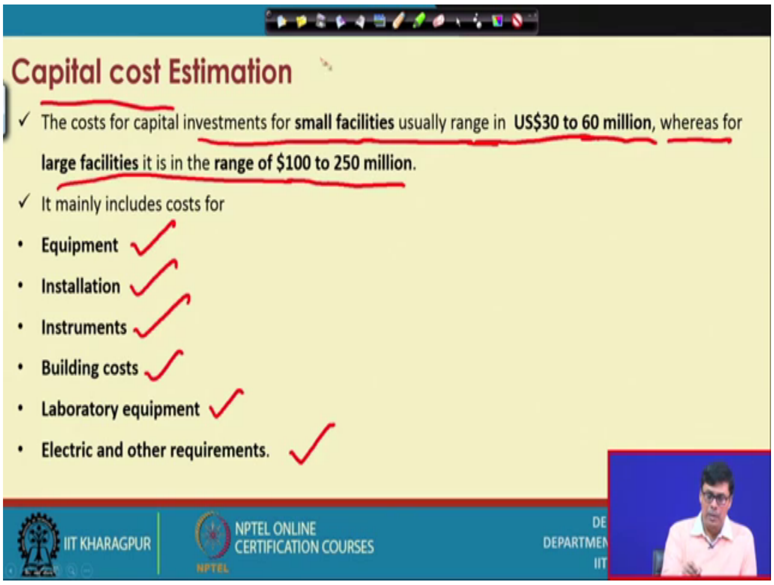

So, mark potential we shall to find out then, where for the capital cost how you do the analysis the cost of the capital is investment to small facility, using the range 30, 30 to 60 million dollar whereas, for the large facility we required 100 to 250 million us dollar.

The main includes the first is the your equipment, second is the installation, third instrumentation building cost labor equipment's, laboratory equipment and the electric and other requirement. So, these are the different things that we comes under the capital cost.

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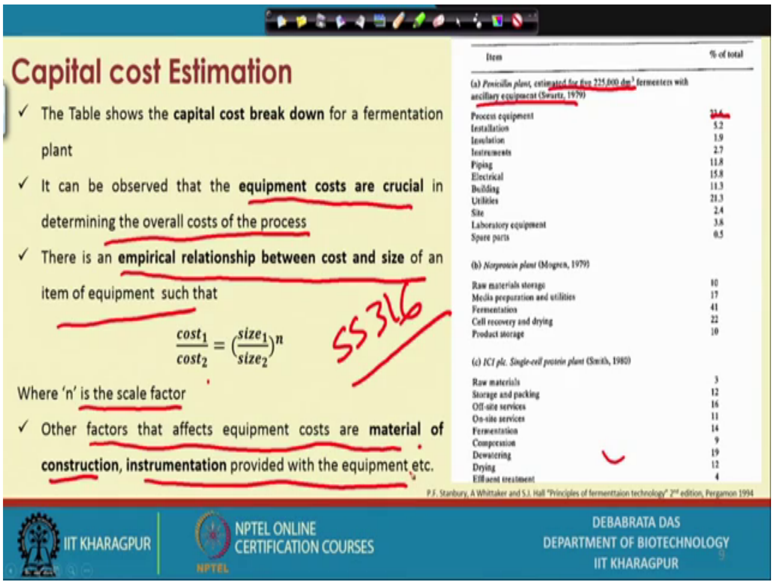

Now, capital cost estimation from the from the table you see that, this is the penicillin estimated of high 2 2 5 200 25,000 liter fermenter with auxiliary equipment, this is the this is the how this cost just percentage of the total is given, process equipment is 23.6 percent installation is 5.2, insulation is 1.9, in instrumentation instrument is 2.7, piping is 11.8, electrical is 15.8, building is 21 point. So, different cost distribution is given here.

It, can be observed that equipment cost are crucial, in determining the overall cost of the process, the empirical relationship between cost and size of the equipment is like this, cost one and by cost 2 equal to size 1 by size 2 to the power n 1 n is the scale factor, this is how this equation has been build up.

Other factor that effects the equipment cost is the material of construction, I told you that in the fermentation industry mostly we use S S 3 1 6 as a construction material, instrumentation provided with the equipment, that also more instrument we use more involvement will be the cost to involvement will be there.

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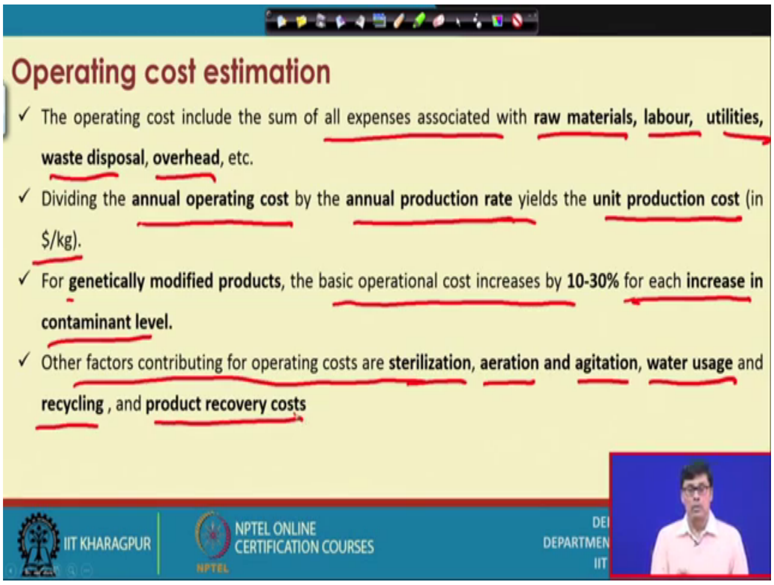

Then, operating cost depends on other several factors operating cost includes the sum of all expenses, like raw materials labor utilities waste disposal and overhead cost, dividing the annular operating cost by the annual production rate yield and unit production cost is the dollar per kg ah. For genetically modified product the basic operation cost 10 to 13 30 percent of the each increase in contaminant level.

The other factors contributing through the operating cost is the sterilization, aeration agitation, water usage, and recycling and product recovery cost. Particular I want to tell you that in case of low value high volume products, if you can recycle our effluent to the process that water requirement of the process will be reduced drastically the what the bio steel process will a the deals with.

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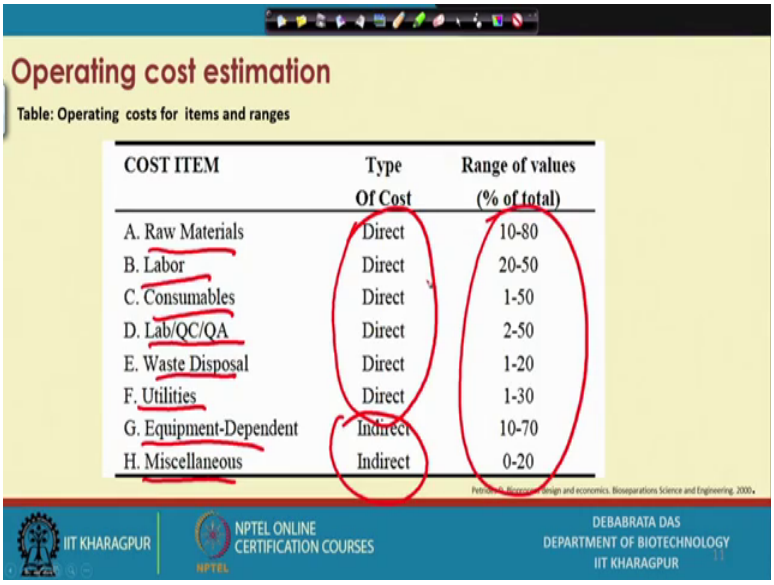

Now, operating cost this is the contribution this is raw materials, this is labor, consumables, laboratory quality control, and waste disposal, utilities, equipment dependent, and the miscellaneous. This is a most of the, this is the direct expenditure and this is the indirect expenditure.

This is the percentages contribution of this offering cost has been given here.

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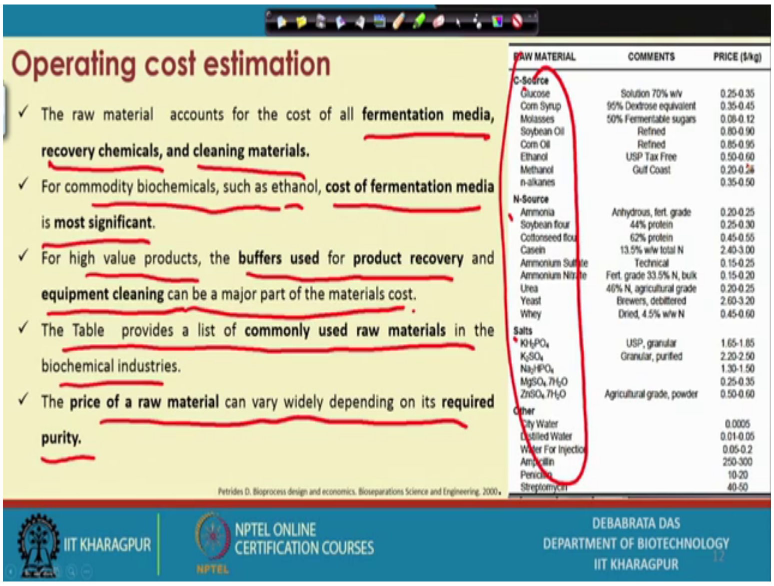

Now, the operating cost the raw materials accounts to the cost of all fermentation medium, this is this is important this is fermentation medium recovery of chemicals and cleaning medium, that then for community biochemical like this ethanol, the cost of the fermentation medium is more significant.

High value products the buffer used, for the product recovery equipment cleaning can be the major part of the material cost. The table provides the commonly used raw materials, in the biochemical industry the price of the raw materials can vary widely depending on the required purity.

So, the this is the raw materials that we have we have carbon source we have nitrogen source and other materials that we have and this is the this is the different concentration, that we use and this is a price how much price is contributed per kg of product formation, the per kg of this product formation that has been given here.

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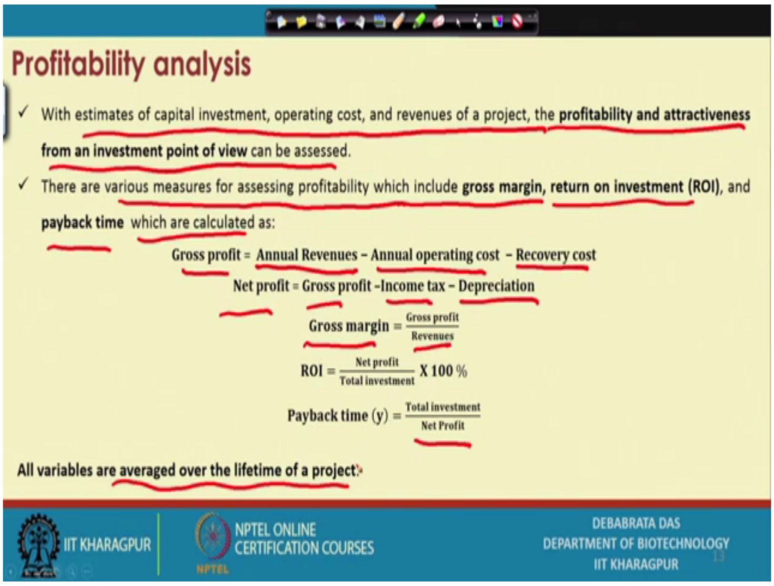

Now, profitability analysis that I was talking about the end of the day that we look for the profit, now with the estimates of capital investment operating cost and revenue of a project, the profitability and a attractiveness from a investment point of view can be assessed. There are various measured for assessing the profitability, which includes the gross merging return of a on investment and payback time, which are which are calculated.

Now, as for example, suppose when we go for any kind of that you know equipment, that particular reactor, we always find a find out the life of the fermenter, where suppose life of the fermenter is 10 years. So, what about money we have that money is spend for the fermenter, that is to be recovered within 10 years that is a that is very important that is the pay back pay time is there.

The gross profit will be net annual revenue annual revenue mostly comes by reselling the product, annual operating cost and the minus is the recovery cost.

The net profit is will be the gross profit minus income tax minus despeciation. So, gross margin is the gross profit by revenue and the that ROI equal to net profit by total investment to 100 ROI is the return of investment, and payback time is the total investment by net profitability. And all variables are average over the life time of the project.

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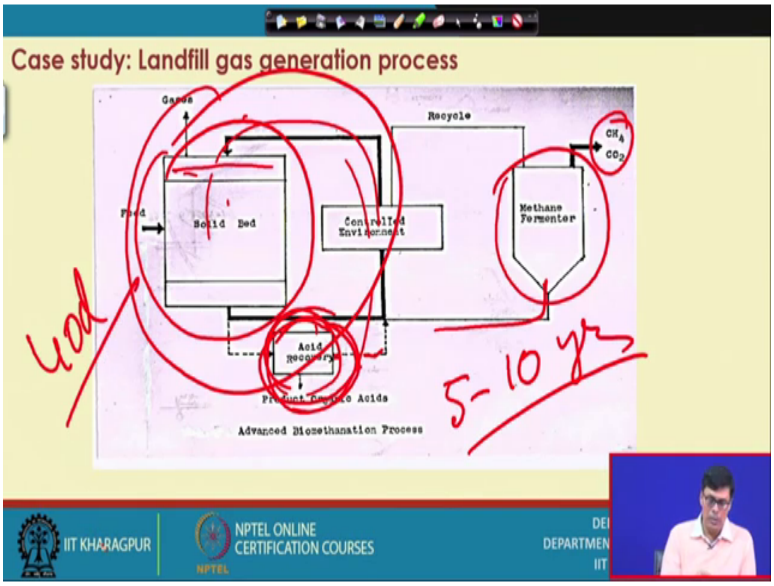

Now, let me give you a case study. So, that you know the things will be little bit clear to you all, I have I have taken the example of the landfill gas generation process. Now, landfill gas generation process is found to be very profitable business at the western countries concern. Now, what they do? They take the city garbage and dump it in the down land you know, that suppose this is the down land.

And then what they do that that you know this down land, they can they can they just stabilize and they produce methane. This and this is the kind of technique that I want to show you, how you can make the conventional groundner that landfill gas generation process very fast ah.

Now, this is the landfill area here we can sparge the acid raining organism here. So, that you know that that degradation of the solid material to organic acid will take place, this is acid recovery unit, you can recycle back again and again until and unless we that solid materials stabilize and then these liquid that that volatile fatty acid you pass through the methanogenic reactor to produce methane and carbon dioxide. And, this if you do this you can reduce the time of fermentation process drastically.

The age of any kind of landfill is about 5 to 10 years. And whereas, we have found that if you do like this, we can make the solid stabilization within 14 days 40 days. So, it is then it is very much the attractive.

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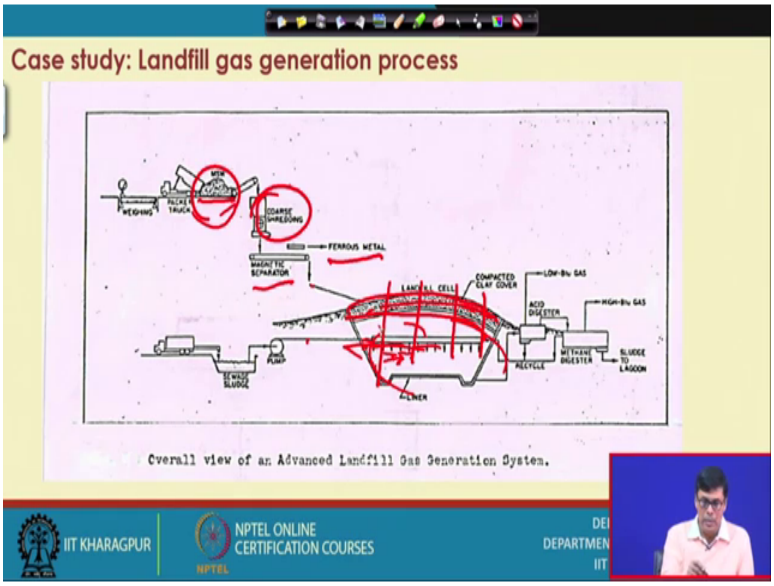

Now, this is the, this is how the landfill processes operated in the landfill, this is the down length of this process and here this truck comes in the weighing machine we take the weight. And it is unloaded here and then again come go truck goes there the difference will give you how much so, that waste material we the here they have downloaded.

And, then you do the shading machine, shading machine means degrade into the small pieces and then this is the magnetic separator, where we can separate the iron type of material, we get the ferrous type of material out and then we put it in the in the landfill.

Now, there is a international sanitary law, international sanitary law says that whenever you put any kind of organic waste in the land fill, this should be covered with 6 inch clay layer within 24 hours. Otherwise the gas I will be generated from the solid material followed the atmosphere that is the undesirable, that that they follow and when then what you do that when it is total filled up, then this is covered with about 18 inch thick this clay layer. So, just to ensure no gas will go out from the system.

Then, we make some kind of well here and we can we can we can what we can do? We can we spread the acidic raining culture here and here it has been shown, this acidic raining culture spread on here, and then it reacts with the all the acid raining culture use the organic material and convert to the acid it falls through the acidic digester. And then recycle back there and these acid finally, pass through the methanogenic reactor and produce methane and carbon dioxide.

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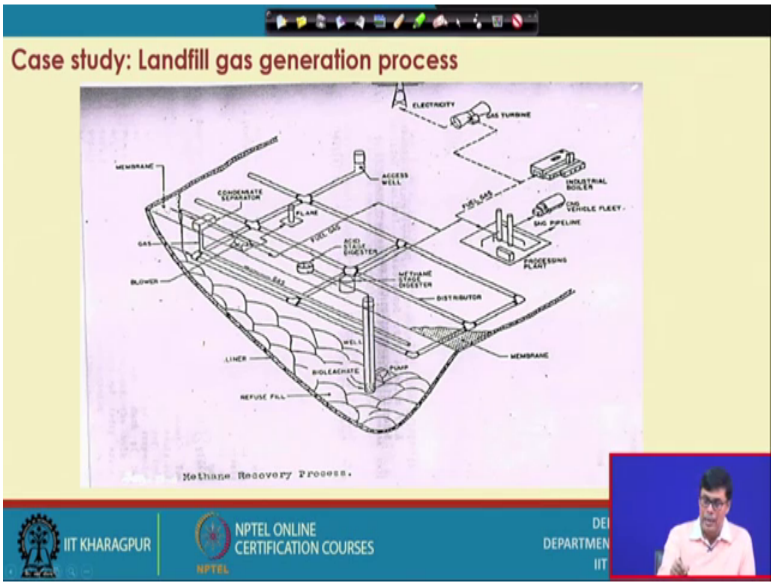

Now, this is this is in practice in the land field, this is the all the pipeline, this is the well I was talking about and this well we can we can apply it this methanogenic formation we can do in the well itself if you if I applied any kind of vacuum in this line, then all the gas present in the land fill that will come in the pipeline and then we have some gas purification unit here, we purify the gas and and send it to send in to for electricity generation this is the gas turbine and from that we can produced the electricity.

Now, this process that there is a there is a there is a analysis of the cost of this particular process.

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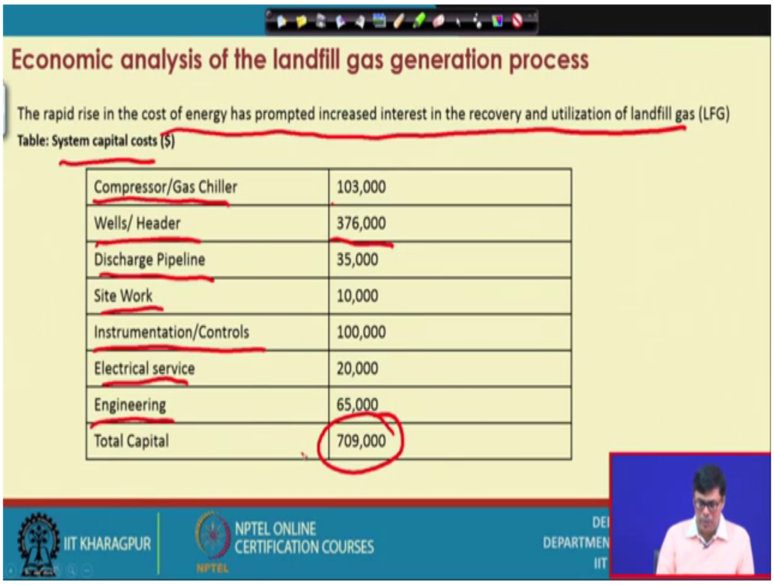

The this has been done and I want to give you some example, that how they have done that this is the rapid rise of the cost of the energy prompted the increased interest of recovery utilization of the landfill gas.

Now, for landfill, so what are the capital cost we have we shall have the compressor or gas chiller, that will cost you 1 0 3 100 and 103,000 dollar. Then, wells and header this is a 3,76,000 dollar, discharge pipeline 35,000, then site works is 10 thousand instrumentation and control 100,000 us dollar electrical service is 20 000 us dollar, engineering is 65 000; total is coming 7000 709, 000 us dollar.

This is the capital cost how they have calculated.

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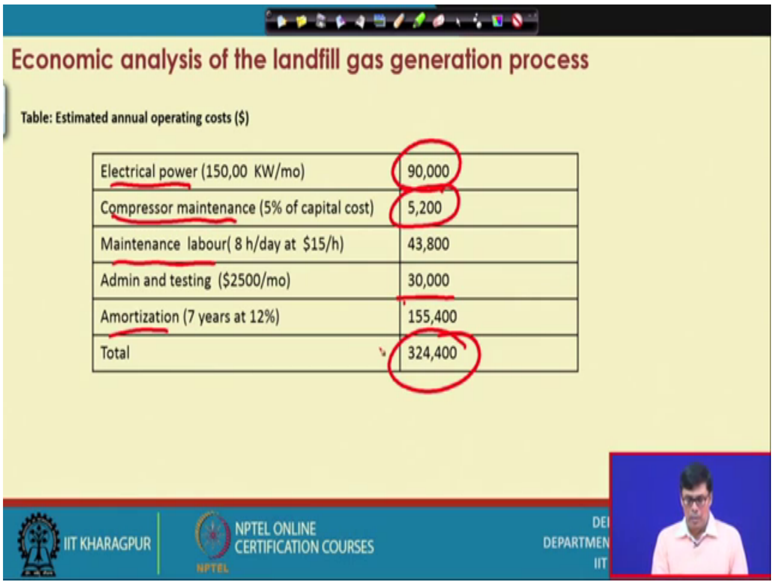

And, then the estimated annual operating cost what they have found the what is the electric power consumption, on the basis of they have found out this is 90, 000 US dollar, compression maintenance it is 5, 200 us dollar, 5 percent of the total cost, maintenance labor is a 8 hours per day at the rate of 15 dollar per per hour, it is coming about 43, 800 dollar.

Then, administration and testing on the basis of 2, 500 dollar per month is this coming about 30, 000 the amortization amortization is the 7 years at the 12 percent interest, that is the coming about this 155, 000 and 400 US dollar. The total operating cost is coming about 324,000 400 US dollar. So, this is the previous one is the capital cost this is the operating cost.

Now, when we mix together.

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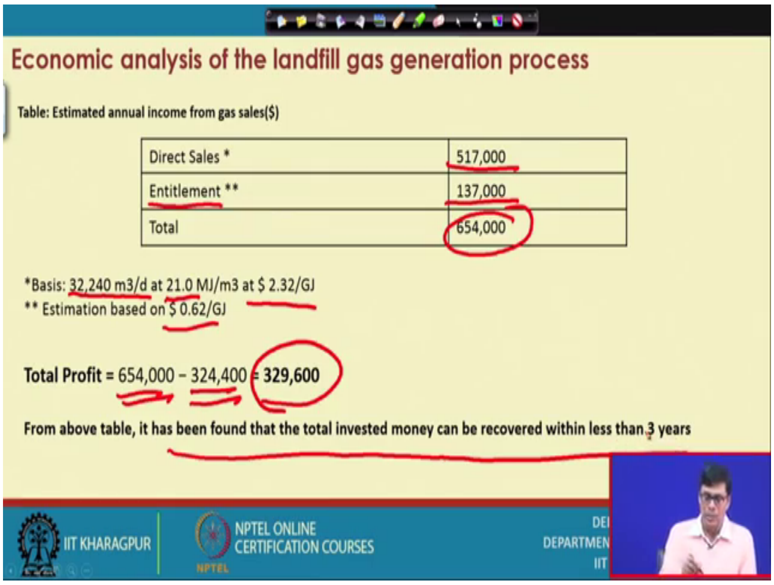

So, we have direct cell we we sell we by selling the gas, how much gas we produce? This is on the basis of 32, 240 cubic meter per day, and that calorie value is 21 mega joule per cubic meter, and and price is 2 2 2.3 2 us dollar per giga joule. And, estimated cost is based on this this point 6 2 dollar per giga joule, that we if we calculate and this is the direct cell we will get and there is the another cost another cost that is there, what you call entitlement cost entitlement cost based since, the this is use the waste material. So, municipality give some kind of revenue to some kind of money to the companies for a safe guarding the environment, this is what you call entitlement cost and total is coming like this.

So, this is this is the this is the total money we are we are getting and this is the money total money we are the spending and so, the net profit is coming about 329, 600, this is how we can do the calculation? The above table, it has been found that total invested money can be recovered within less than 3 years. So, I told you the age of the landfill usually 5 to 10 years ; that means, remaining 2 years to 2 years to 7 years they can earn with profit.

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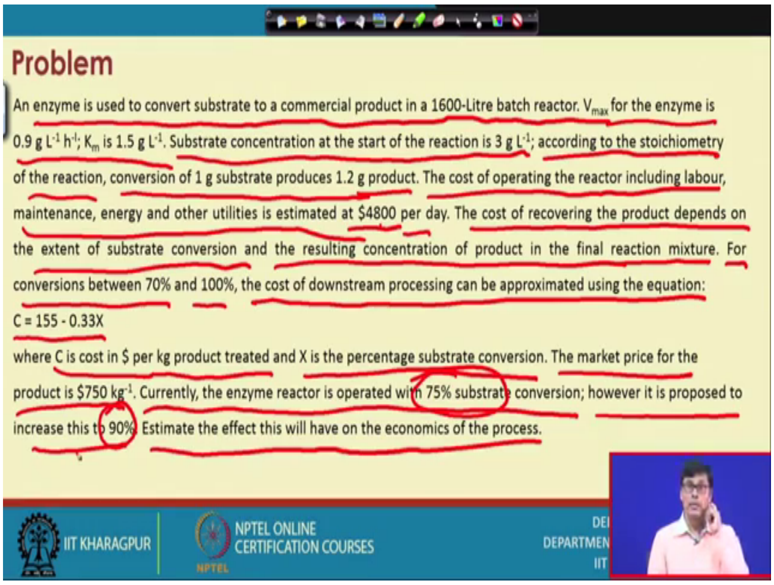

Now, there is the another another enzymatic that pure system that we walk out, that how you can find out the economy of the process? Let us see this is little bit different as compared to what we have done in the previous part.

The an enzyme is used to convert the substrate to a commercial product in a 1600 liter batch reactor, V max of the enzyme is given K m is given, K m is the Michaelis Menten constant substrate concentration at the start of the reaction is 3 gram per liter.

According to the stoichiometry of the reaction the conversion of one gram of product give one gram of substrate produces 1.2 gram of product.

The cost of operating of the reactor including labor, maintenance energy and other utility, estimate to be 4,800 dollar per day. The cost of recovering of the product depends on the extent of substrate conversion and the resulting concentration of the product, in the final reaction mixture.

For conversion between 70 to 100 percent, the cost of downstream processing can be approximate by this equation, this is the downstream processing cost. Where C is the cost of dollar per kg of product treated and X is the percentage of substrate conversion.

The market price of the product is 750 dollar per kg, currently the enzyme reactor is operated 75 percent conversion. However, it is proposed to increase this to 90 percent estimate the effect this will have on the economy of the process.

So, the problem is very simple that you know that we are operating the process as the 75 percent substrate conversion. And now we the industry wants to increase the conversion to 90 percent.

Now question comes, if we increase the ninety percent conversion is it possible to increase the economy of the process, because that we shall have to find out in this problem.

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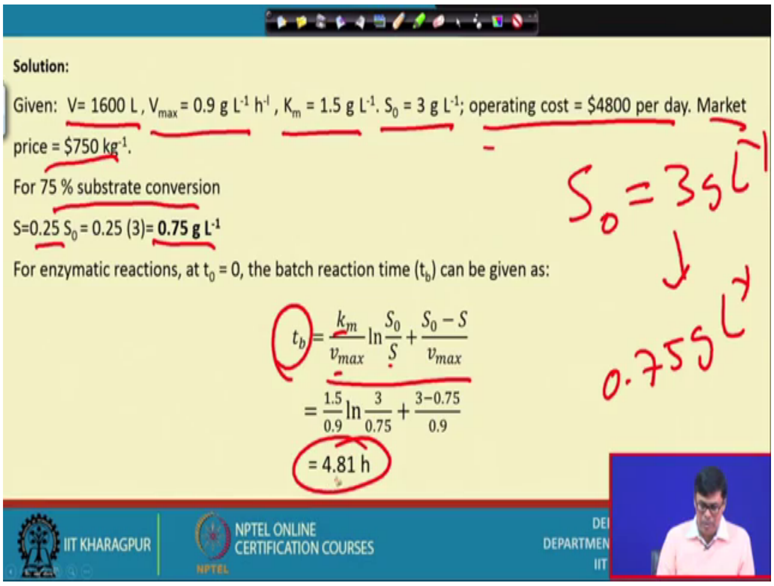

Then let us see how we can find out as I pointed out whenever you solve any kind of problem first you have to jot down that what are the data given, the volume is 1600 liters, the V max value is given K m value is 0 value is operating cost is given and market price of the product is given.

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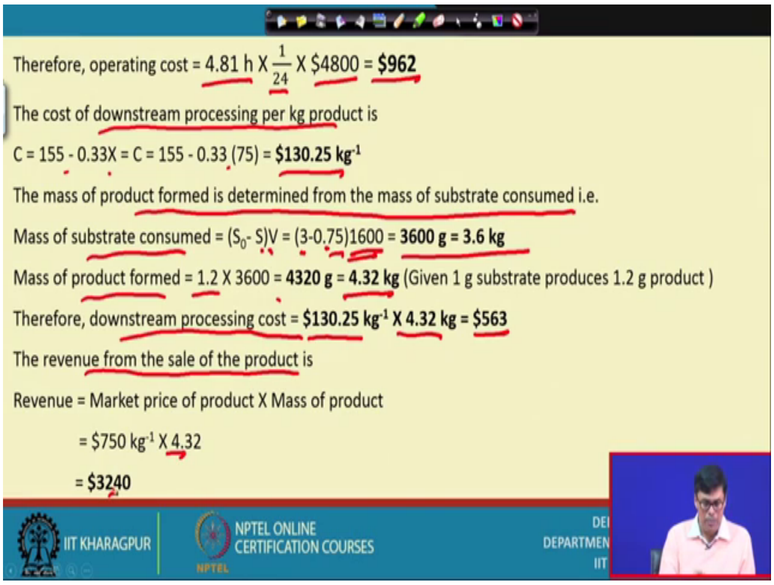

Now, 75 percent substrate conversion is there the; that means, 75 percent what is the s what is the s value that we have s S S S value will be power 75 percent; that means, 25 percent will be remaining 0.25 into S 0, S is a how much 3 gram per liter so, S will be 70.7 5 grams per liter.

So, what here for S 0 this is 3 gram per liter to to convert to 0.75 gram per liter question comes what is the batch time is required? This batch time we have this this correlation already we developed before, I do not like to solve it again. So, you can put the values k m v max is is 0 by S we can find out the batch time this is 4.81 hours.

Now, therefore, the operating cost will be what operating cost we can we can we easily find out that how you can find out that per day? That how how the then this is per day am I right. So, we this hour per day will be divided by 24 you can the so, you can find out the 962 is the operating that cost for the per batch.

Now, the cost of the downstream processing will be this this equation is given, if we put the value we can find out the the downstream processing cost. The mass of the product form is determining the mass of the substrate consume. That is the mass of substrate consume how you can calculate s 0 minus S into V S a S S 0 is 3 minus 0.75 and what is the volume 1600 so, 3.6 kg.

Mass of the product because we have already find that 1 gram of substrate produces 1.2 gram of products. So, this is the amount of product we will get therefore, downstream processing cost will be what this is per kg we have 130.25 dollar per kg. So, you multiplied that you find this.

So, the revenue from selling the product will be what this into this am I right, because per kg product was the cost is 75 dollars. So, you can find out 3240 dollars we can recovered.

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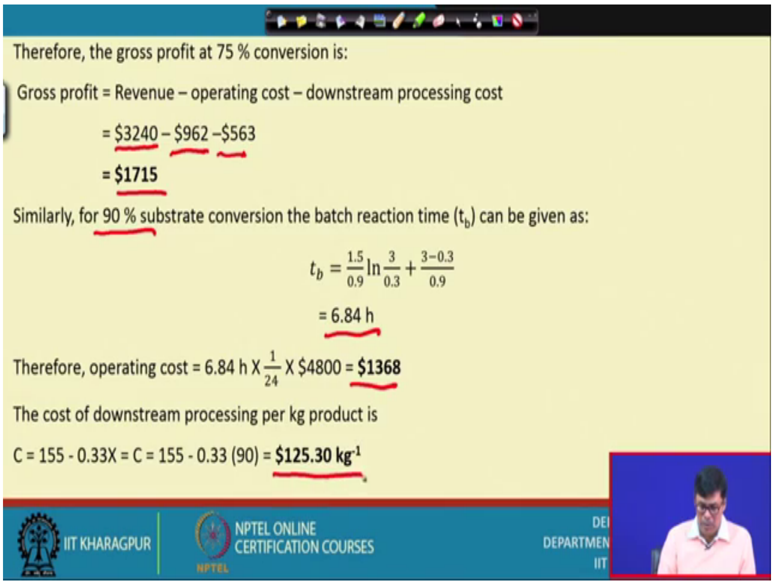

Now, therefore, the gross profit 75 percent is is revenue is that the 3240 minus operating cost this minus downstream processing. So, it is coming like this.

Now, similar type of cost analysis we try to perform, when we have ninety percent substrate conversion. And then we find the batch time requirement will be 6.84 and these were 6.84, then operating cost increases to this and then we can find out the downstream processing cost is this and then we find out that, what is the substrate consume we find this that increased to this and the product value also increase.

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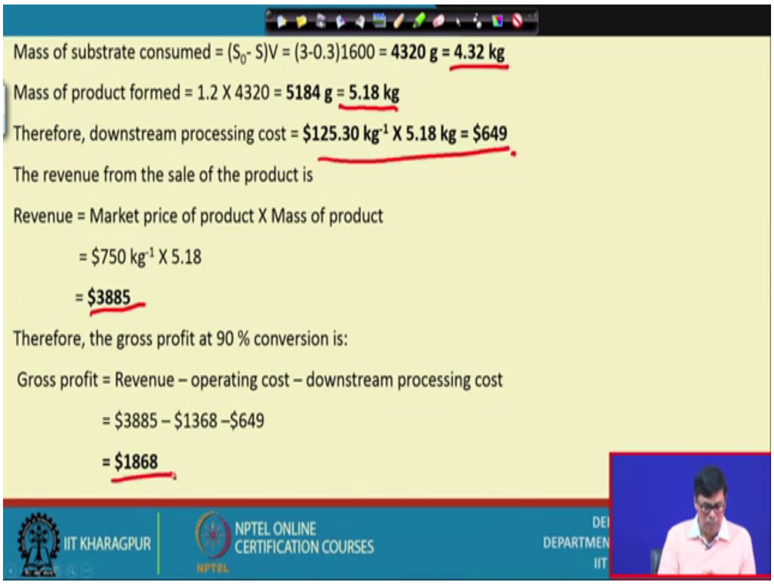

Now, after the product cost is downstream processing cost is this and product value is this.

So, revenue will be how much we are getting 1868.

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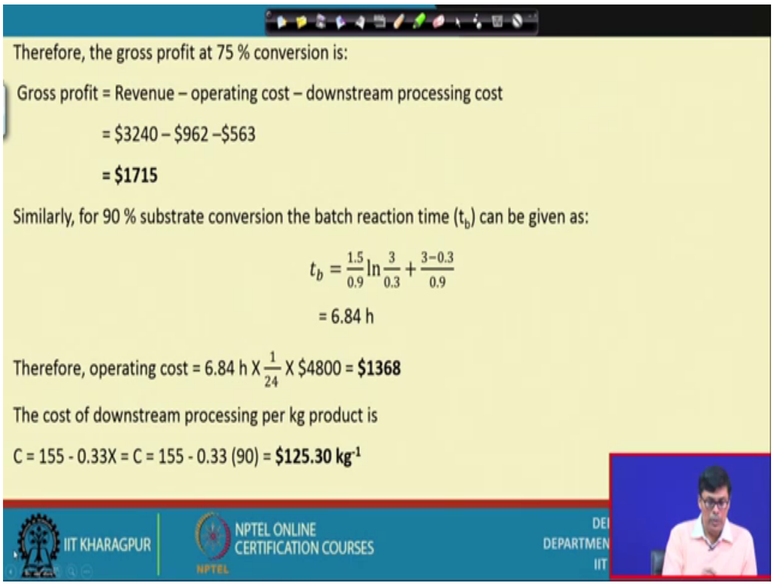

Now, if you if you look at look at before we how much we got 1715. Now, what we are getting 1 1868. So, thus the gain of the per batch by increasing the substrate conversion is is and dollar 153.

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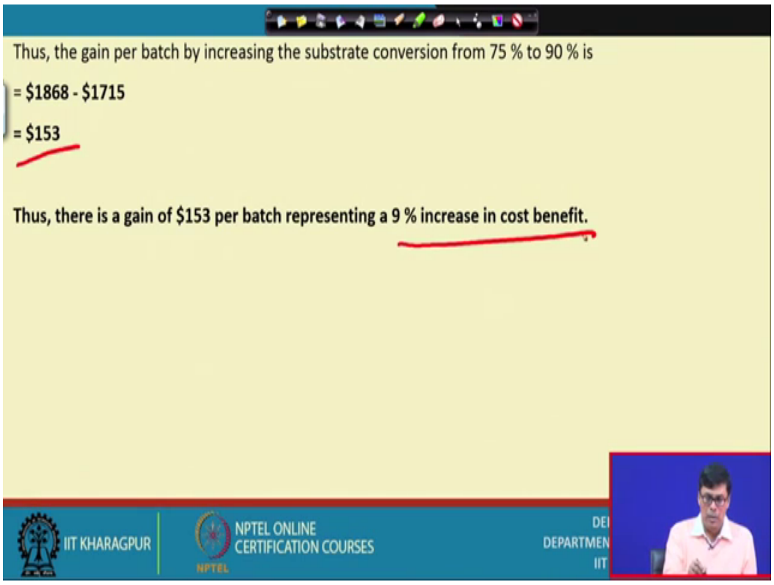

So, then the gain of once the 9 percent increase in the gross benefit that we that we observe, because you know that that this is how we can analyze the process, that find out the economy that you know viability of the process. So, this is a very interesting problem and through which we can find out by increasing the conversion efficiency how much profit we are going to get in the, some cases not necessarily all the cases your profit will be increases some cases the profit will may decrease also. So, in that case we we prefer to maintain our that conversion efficiency little bit less.

So, in this particular lecture I try to do the economic analysis which is the appears to be the most important and as per as per biochemical industry is cornered. So, I told you the 2 type of expenditure we have we have we have capital expenditure we have operating expenditure and and from that we can find out, that what is the what is the cost involvement of this process and from selling of product we can find out how much that the money will gain out of that, and there is some other factors we shall have to consider as per income tax and other things revenue is concerned.

So, you when you do the calculation of the profitability of the industry, we have to take into consideration of the all the factors and then in then in we can we can find out how much profit we can have in a particular industrial operation.

I try to discuss one case that landfill gas generation process if you operate for 3 years we find, that whatever money we spent for this process can be recovered, but age of the landfill is more than 3 years. So, we can run the remaining years with full of profit.

So, and one one one one enzyme conversion process enzymatic conversion process I try to discuss, and the there we find as we increase the conversion efficiency the profitability of the industry will increase.

Thank you very much.