Non-ferrous Extractive Metallurgy

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Lecture No. # 37

Energy and Environment Related Issues in Nonferrous Metals Production (Contd.)

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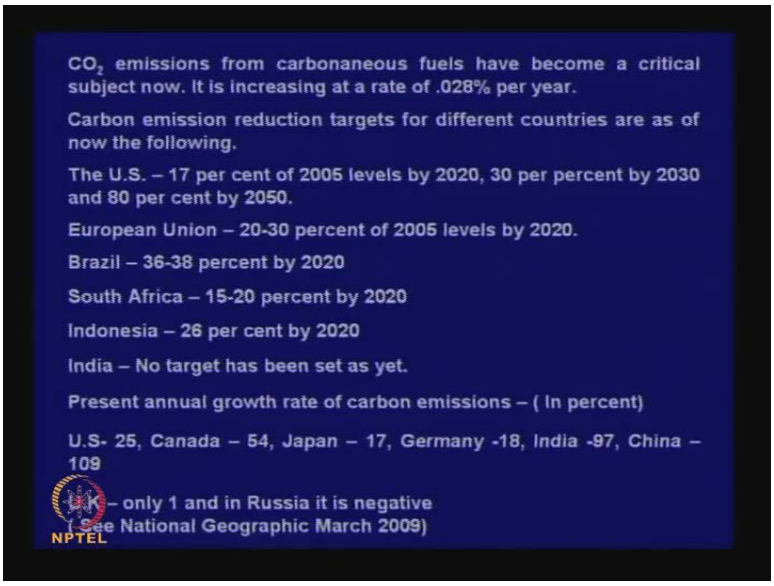

Friends, in the previous lecture we have discussed what all pollution problems are there in the aluminum industry, from the mining to the leaching, smelting, in every step. All kinds of contaminants come out of the system; there are solids, liquids, and gases. Only the tiny fraction of which finds use or will find ways and means of recirculation, the rest remain with question unanswered.

As regards gases, we saw, apart from CO 2, the smelters release many other gases, which certainly, has local effect can have regional effect, they also have global impact and the one that contributes to global impact, of course, is CO 2 as everybody knows.

Let me take that subject now and say 1 or 2 things about CO 2 emissions. Now, we all know the CO 2 emissions from carbonaceous fuels have become a critical subject now. It is increasing at a rate of 0.028 percent per year. And remember I mentioned, that 400 years ago when Taj Mahal was built, it was around 280 parts per million, which is now come to 380 parts per million. People say, if it goes to somewhere near 450 or so, I think the, there will be catastrophe in this world, there will be too much of global warming, as it is now temperatures, average temperature of the globe is rising.

And in recent conference in Copenhagen, everybody has agreed on one point that we cannot settle for anything beyond 2 degrees temperature rise. So, all the attempts have been made for fixing, the maximum allowable increase to 2 percent, 2 degrees.

Now, I am going to give you some figures from National Geographic March 2009 issue. Some of the figures need some revision, because in Copenhagen, the whole thing has been re-discussed, but the changes cannot be too drastic.

People cannot say, that we promise so much in the past, now we do not want to keep that promise. There has been some confusion of course, because the Kyoto protocol 5 years ago was based on certain principles, I mentioned that before, and the principles were, that the advanced countries will cut down there CO 2 emission, whereas developing countries would be allowed to increase their CO 2 emission, but at a reduced rate, so that they come to certain, develop, development and eventually all countries should have the same per capita emission.

People are not agreeing to this per capita basis any more. Advanced countries are saying no, it should be country-wise quota, but then India, China, Brazil, South Africa, they have resisted this. Let; let us discuss it little bit now.

Now, the carbon emission target, reduction targets for different countries as of now are the following, this is as per National Geographic 2009, not legally binding, but commitments from the government.

The U.S. says, it will cut down by 17 percent of 2005 levels by 2020, means, by 2020, they will come to a figure less than which will be, which will, which will cut 2005 figures by 17 percent, but actually when they promised this some time ago, they have gone back on their promise. They, they, they are not cutting down, they are increasing, but they promise to cut it by 30 percent by 2030 and by 80 percent by 2050; all reference to 2005 is the reference point.

European Union says, that it will bring down the CO 2 level to 20, 20 to 30 percent of, 2005 levels were 2020. Brazil says 36 to 38 percent by 2020, South Africa 15 to 20 percent, Indonesia 26 percent, India did not have a set target early in this year, but they are also saying 20 to 22 percent cut by with, with reference to 2005 level by 2020.

But now, this is a Herculean task because see, the present annual growth rate of carbon emissions in percentage is 25 percent, for U.S is growing per year by 25 percent and they are talking about cutting it down to their level less than the level at 2005, Canada 54, Japan 17, Germany 18, India 97 and China 109.

Now, India and China, the fastest growing economics in the world are under attack by the developing countries because of these very large figures of 96 or 109, which is the annual growth rate of carbon emission, every year it is doubling.

But what we need to see is, if we do it by per capita basis, it is far smaller compared to U.S, Canada, Japan, Germany, etcetera. Our population is large and they have to be brought to certain level, so we have to consume more energy. Unfortunately, power is coming from thermal power plants, so we are emitting more CO 2.

In U.K., somehow the rise is only 1 percent annual growth, and Russia, it is negative because it has very high. At one time it is negative, now these are not my figures; I am taking it from National Geographic 2009.

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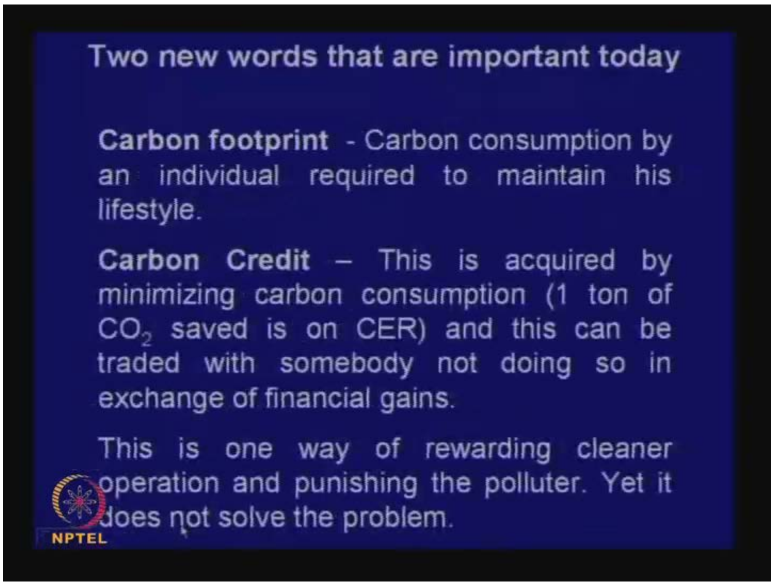

Now, there 2 new words have become very important today and you must know these words, one is carbon footprint. This is carbon consumption by an individual required to maintain his lifestyle, how much carbon are you consuming, of course not just in terms of food, mostly it is coming from transportation, how much fuel you are consuming for your, your transportation. If we are going by air, imagine how much fuel you are consuming.

Whatever energy you are using in the air-conditioning, in lighting, for your personal lifestyle, that all goes to give you a carbon footprint. So, I know of a manager, he was the chief executive of Manganese Ore India Limited, that company is very sensitive about this emission problem and I would tell you what they have done about it, but he calculates his carbon footprint, and every time he takes, and travels by air, he feels very guilty, he says I know my carbon footprint is increasing.

See, carbon footprint of a villager in a village is almost nothing, he does not consume carbon, the, his lifestyle is not at all injurious to global warming. But those who are fast, who are enjoying a different kind of lifestyle, we have carbon footprints and the, those who are more prosperous in, in power, carbon footprint is enormous.

Then, there is another term called carbon credit. Carbon credit is acquired by minimizing carbon consumption. If you are running an industry using a traditional source of power, if you can go for an alternative source of power and save on carbon consumption, you get carbon credit.

One ton of CO 2 saved is one CER, Certified Emission something, and this can be traded with somebody not doing so in exchange of financial gains. If one company is not able to reduce and he is being pressurized to reduce, he can buy; he can pay money to those who have saved. So, there is an exchange of the carbon balance.

As I said, it does not overall bring down the Carbon Credit, carbon, CO 2 emission, but the polluted is being financially punished and one who is doing better is financially rewarded, that is the system based on which Carbon Credit works. So, this is one way of rewarding cleaner operation and punishing the polluter, but it does not solve the problem. Please remember, it does not solve the problem, it certainly helps.

Now, I refer to this company called Manganese Ore India Limited. They are ferro-manganese producers and you know, ferro-manganese is produced, I have talked about that, in electric furnace smelting, which needs power. They have gone for substituting in a big way. Their energy supply using wind energy in Madhya Pradesh in certain regions, not very far from their plant operation, they are putting wind wheels, which are supplying energy to the grid from which they are drawing power and there are all kinds of calculations, I am forgetting how many megawatts they are doing.

They spend some 20 cores or 25 cores to set up those wind, wind power generation devices, most of them have to be imported because we are country, we are still not producing windmills. But they got Carbon Credit in that process; they had financial gain, so much so, that in a matter of a year and a half or so, they recouped that money. So, what they spent in setting up the power, wind power generation, they got it back and now, say, they are going for, they are extending that activity.

People talk so much about nuclear power, but people have forgotten, that India is a leader in Asia in wind power. We have some about 8 or 9 percent of our energy demand is being met by wind wings. They have certain disadvantages of course, because you know, it does not ensure a steady power supply to the grid. The power generation changes with seasons, it cannot be done everywhere, it is best where there are high winds in sea shores, on higher altitudes, the, there are disadvantage. But if we can do it, we not only conserve our coal reserves, we have an alternate source of energy, we get Carbon Credit.

In Denmark, as I mentioned, 50 percent of our energy supply is coming from wind energy, they are the leaders, but then, there energy consumption, total energy consumption is low. So, perhaps India is producing more even though it is only 8 percent of the total needs. But there is good case for going for such alternate energy sources and international agreements are pushing for it and giving incentives through Carbon Credit.

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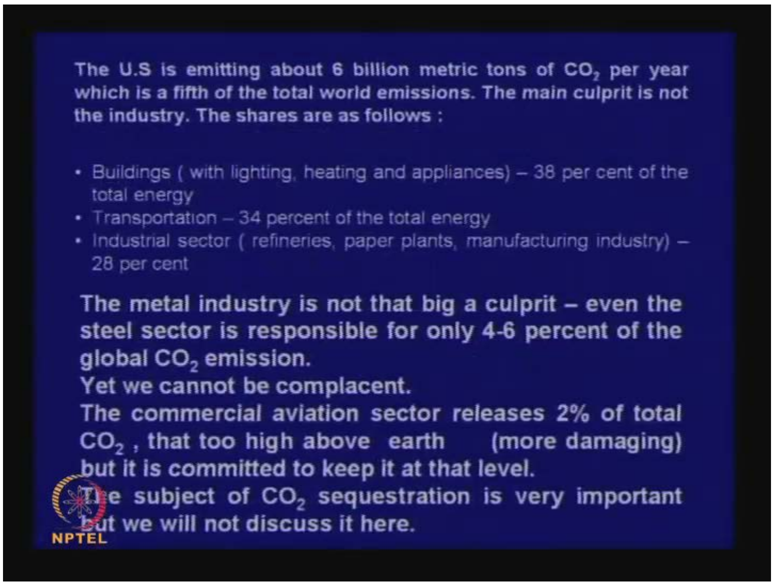

Now, I would like to give you some figures for U.S, not because I am overly fond of U.S or I wanted to critical, but the Americans have lot of data, reliable data, they analyze their situation time to time, we do not get such, so much of data, reliably for other countries, least of all for India.

U.S. is emitting about 6 billion metric tons of CO 2 per year, which is a 5th of the total world emission and their population is far less than one-fifth of the world population, they are only 200-250 million.

The main culprit is not the industry mind you, there, there the difference is, the distribution is buildings with lighting and appliances, 38 percent of the total energy; transportation, so many cars and vehicles on the road, 34 percent; industrial sector, refineries, paper plants, manufacturing industry, etcetera, 28 percent. It does not show agriculture, which is a big consumer electricity in our country because they run the pumps, pump in water, I do not know how much it is, but it is not shown here.

So, again, the main, metal industries, not that big a culprit. See, globally, even the steel sector is responsible for only about 4 to 6 percent of global CO 2 emission and non-ferrous metal industries would be even less, but that does not mean we can be complacent, everybody has to try his or her best. And please remember, suppose an industry takes up these issues seriously and come up with some, some technologies, those technologies may find universal application.

For example, this ferro-manganese industry in Madhya Pradesh, it has gone for alternate source of energy, at least partly, they are getting their energy requiring from wind energy. They set a very good example for everybody, other industries, they set a good example even for the building sector in our country, which is consuming so much of energy, just can think of wind, wind mills and that can have a cascading effect, or a multiplier effect. Suppose, there is a demand for wind energy and then, there will be in our country more and more people trying to make those devices, that will, wind (( )). Mostly, these are you know, huge fans, the, that are fixed to very high poles, you can see them on the Puri beaches.

In India the lot of research has been done, but commercially, it is still not available, we have to go abroad, import from abroad these wind wings.

Now, see, see, another, there is an important commercial sector, the commercial aviation. It consumes 2 percent of total CO 2 and that is more dangerous because the CO 2, that an aeroplane releases is at a higher level, it is, it is in upper atmosphere, where it is more dangerous. But they, the aviation sector with now honor bound to keep it at 2 percent. Even though, there can be expansion of the aviation sector, they have said, they will find ways and means of operating far more efficiently, so that it does not go beyond 2 percent.

There are many ways of doing it, you know, many aeroplanes take far too much of fuel because they want to cover long distances and when they take far too much fuel, huge planes, they become heavier, so they consume fuel less efficiently. So, there are answers to that, perhaps we have to have smaller planes, smaller distances to fly. There has to be an optimization to that effect, that he was simply not wasting fuel in carrying fuel, in your bowels. So, they have said they will keep it up to 2 percent.

We have no figures for the military. You know, in a military, sectors, sector, the amount of fuels, fuel, that we consume the enormous, especially when there are wars or battles, but mankind does not have the wisdom, they are not thinking far enough. If they go on fighting and killing each other and not only they are, they are causing lot of misery to everybody, they are causing lot of global thing also, because weather you are going in a tank or you are going in a military vehicle or you have a plane flying, we are all adding to global warming.

Now, what you do with the CO 2 that comes out? Nothing can be done about the CO 2 emitted by vehicles, you know, it is going all over the place, you cannot collect. But the subject of sequestration, means collecting CO 2 has become in terms of thermal power plants, where there is a stream of CO 2 coming out from one place.

So, there are now many projects working on how to use that CO 2. One idea is to take that CO 2, dump it for storage underground. There is, there are plants already operating 1 or 2 like that on an experimental basis. The whole idea is to take it about 2 kilometer below the surface, where there is a layer of brine and at that pressure, CO 2 becomes super critical, it will dissolve there as a liquid in that brine solution, it will stay there. In future, we might do something about it.

There are other ideas, I mentioned is, that maybe, you can convert CO 2 some kind of a building blocks, artificial corals. The best solution people are saying is you can think of growing bacteria, which will convert the CO 2 injected into water bodies into food, that algae will grow, that algae can give food and sometimes they have also grown a kind of algae, which secrete oil, which can be petroleum substitute, which means that carbon in CO 2 will make a carbon compound, which is oil like, so it will be recirculated. You burn oil, produce CO 2, this C O 2 will go through bacterial reaction, will produce oil again.

All such things are in the pipe line and I am sure 10 or 15 years from now, there will, methods would be found to use, do something over the CO 2 that is causing global warming, but we will not discuss this subject now.

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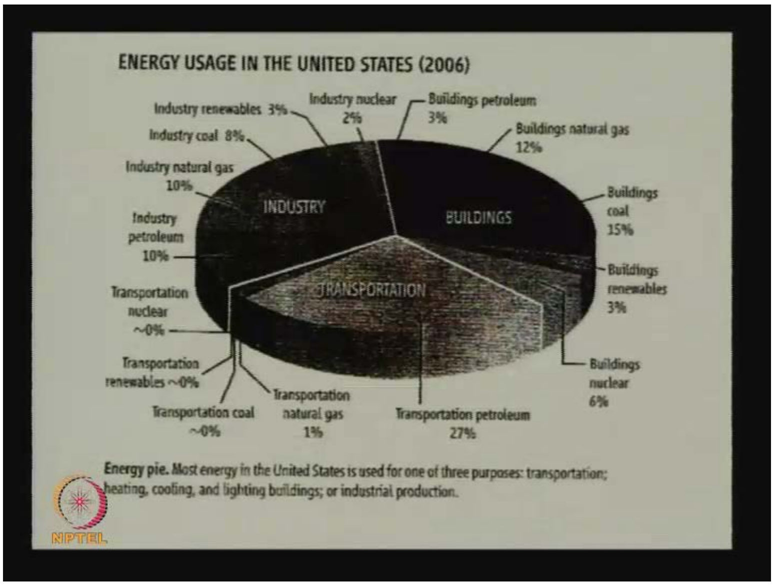

Now, here some data I want to show you, very important, but because, before that let me go to this. I mentioned about the distribution of energy consumption in the United States. Essentially, there are 3 sectors: industry, buildings and transportation. Obviously, in our country, this transportation sector will be less; we do not have so many vehicles. Our buildings, I think, will be also less because the most of the energy requirements in their buildings is in heating in cold climate. They have heating devices and buildings are becoming larger, heating requirements are more. Buildings also have many gadgets and appliances, they are consuming electricity.

Where are they coming from? See, if you look at the buildings, petroleum giving 3 percent; natural gas 12 percent; coal, thermal power plant 15 percent, all and building renewable, I do not know what exactly it means, but some nuclear sector is also giving some power to the grid from which the buildings are drawing electricity.

Transportation depends mostly on petroleum, 27 percent, 27 percent of energy need is by transportation petroleum; 1 percent natural gas; some coal, some locomotives and other things.

Now, if you go to the industry, industry, renewable industry, coal is giving so much; natural gas is giving 10 percent; petroleum is giving 10 percent in the industry; nuclear power is still not going in, but it is about one-third, one-third, one-third, they can think of

CO_2 sequestration in the industry. But in transportation, the CO_2 that comes out of the vehicles is so, so distributed, so much over a wide area because every vehicle is doing something, CO_2. People are nothing can be done about it unless you make the engines more efficient or instead of petroleum guzzling cars, go for electric batteries.

Batteries can be of 2 kinds, not electric batteries would need recharging because in that case, again you are consuming electricity. Now, there are hybrid cars where a nickel battery, self-contained, gets charged when the car is running and cruising and the battery takes over only during start up and acceleration, that is when the pollution is maximum, that is when the battery takes on and then the ordinary engine runs the car, but then during that process, the battery gets recharged. Now, in that process they have seen, that pollution is cut down by 90 percent and energy efficiency improved by 200 percent, means the car can go twice as much distance, pollution would be far less.

So, electric hybrid cars in the picture, but in our country some companies have considered option, they are not going for this, they are going for what is known as the devices, which will conserve momentum. Suppose, a car is going and there is a fly wheel, which is also begins to move. When the car breaks or stops, all the energy goes into the friction of the breaks or the tyre surface. Now, if there is a fly wheel and divide that, when you are breaking, that energy is transported to the fly-wheel; you know, when the car stops, the fly wheel starts, keeps running.

When the car wants to start again, takes the energy from the fly-wheel, accelerates and moves up. This technology has been demonstrating in our country, but some companies are thinking or going for this device rather than the hybrid cars, anyway. This is the kind of distribution we have.

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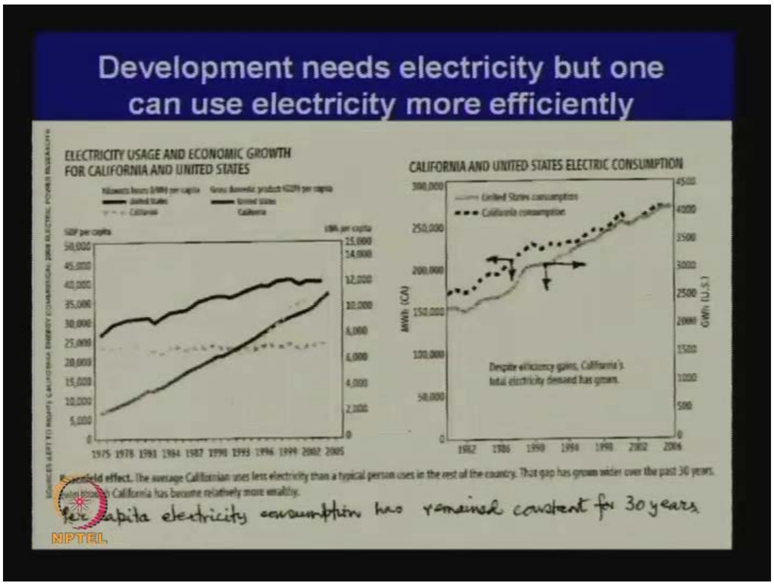

Now, look at, something I wanted to say about America. There are, here are some data for California, which is the most advanced state in United States and the entire country. This side is for here, you see, the U.S.A, no, California consumption and that side is for United State consumption. We are plotting electric consumption, now it is going up in United States, it is going up in California also and the units are given here. Because 2 things, 1st of all population are growing or more that, more than that, they are going to an advanced level of living; the GDP is growing, so the total electricity consumption is growing.

Now, something very interesting is shown here, look at these 2 sub-plots. We are plotting figures for United States and California, gross domestic product per capita and kilowatt hours per capita; kilowatt hours per capita, gross domestic product. This shows that if the GDP has to grow, per capita electricity consumption also has to grow. So, in the United States, you see, the GDP is growing, per capita electricity consumption is also growing. But something very interesting is shown in the case of California, the GDP is growing, but per capita energy consumption is not growing. In fact, per capita electricity consumption has remained constant for 30 years in California, although their per capita, the GDP per capita is growing.

This only means that state has learnt to use electricity more effectively, whereas the rest of United States has not learnt that, as well. So, there the GDP is growing, but per capita electricity consumption is not growing because they are going for more and more efficient technologies. This actually they call it the Rosenfeld effect.

That the average Californian uses less electricity than a typical person uses in the rest of the country, the gap has grown wider with the past 30 years, even though California has become relatively more wealthy.

Now, the message I want to give is, that if you have in an industry, the industry can grow, not necessarily consume more energy, it can grow consuming perhaps the same, at the same energy level consumption, provided it takes care to introduce more energy intensive devices or cuts down on energy wastages or has provisions to recoup the energy from the waste energy, either from the hot discharges or gases, or from the exothermic heat of reactions. So, there is tremendous scope of energy saving in industries.

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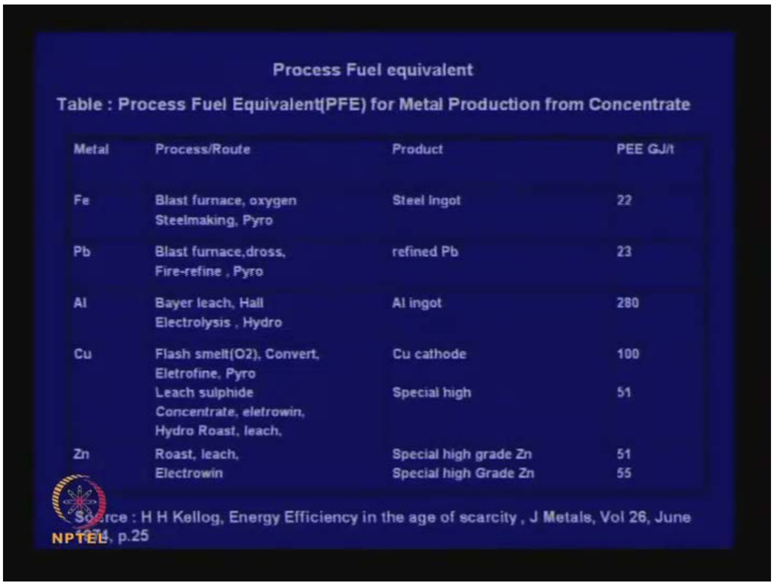

Process Fuel equivalent

Table : Process Fuel Equivalent(PFE) for Metal Production from Concentrate

Metal	Process/Route	Product	PEE GJ/t
Fe	Blast furnace, oxygen Steelmaking, Pyro	Steel Ingot	22
Pb	Blast furnace,dross, Fire-refine , Pyro	refined Pb	23
Al	Bayer leach, Hall Electrolysis , Hydro	Al ingot	280
Cu	Flash smelt(O2), Convert, Eletrofine, Pyro	Cu cathode	100
	Leach sulphide Concentrate, eletrowin, Hydro Roast, leach,	Special high	51
Zn	Roast, leach, Electrowin	Special high grade Zn Special high Grade Zn	51 55

Source : H H Kellog, Energy Efficiency in the age of scarcity , J Metals, Vol 26, June , p.25

I will come back to non-ferrous metallurgy, now again. Now, before you want to talk about energy saving in a non-ferrous metal industry, 1st thing we have to do is to analyze, do an audit, find the method of knowing, what really is the energy consumption in an extraction process.

I have started my lectures right in the beginning by giving an example of aluminothermic reduction, there you can take an oxide and if you reduced by aluminum, it is an exothermic reaction. So, one is make me tempted to think, it really needs no energy because if there is sufficient heat coming out, it goes on its own, you do not have to supply external energy, it is what we can call an autogenous process.

And when we are students we were actually told, that aluminum reduction is very good from energy point of view because you do not need energy supply. It is only later I learnt, it is wrong. If you really look at the thing holistically, we would know it is not, that you are not using energy because after all, the aluminum that you are using has consumed a lot of electricity when it was produced. That is what leads us to the concept of process fuel equivalent or PFE, which is calculated by taking into account the raw, the energy equivalent of raw materials, that have gone in; the energy required for the process to happen minus whatever energy that is generated in the process minus whatever energy you can recover from hot gases and hot liquid discharge or gases, whatever. So, there are ways and means of finding energy during the process or after the process.

But take into account not only the energy you have to supply either as a fuel or as electricity for the process to happen, but also the energy that was consumed in making raw materials, taking all these we calculate process fuel equivalent.

This concept was first emphasized by Kellogg and I have given a reference; it is as old as 1974, but the concept continues. Now, here are process fuel equivalent for different metals and some figures are quite interesting.

In the iron production where we have blast furnace, oxygen Steelmaking, that is a pyrometallurgical route, products Steel ingot, process fuel equivalent is 22 gigajoule per ton.

So, from the starting, from the raw materials up to the product per ton, this is the fuel requirement. You have taken out whatever energy we could get from the system, from whatever energy was required in production of raw materials as well as in carrying out the process. Lead blast furnace, dross furnace, dross, fire-refine, all that, pyro process, refined lead, up to 23. So, iron and lead, from energy point of view are almost equal.

The worst culprit is aluminum. If you consider Bayer leach process, Hall, Heroult's process, hydro or the hydro-metallic safe to give you aluminum ingots, it is 280; more than 10 times iron and lead.

Copper, now copper is very interesting. You know, copper, everything is exothermic, sulphites are, you are roasting, generating heat this and that, but you are consuming energy in the floatation cells, there is lot of energy lost from the pyro-metallurgical steps. So, energy supply is required. So, if you take all that into account to produce copper cathode, it comes to 100, especially because there is an electrolyte. I still have not brought in (( )), mind you copper cathode. Yes, electrolytic process is included, that is why it is high. If you go for special high, this I do not understand, that what is there.

In the case of zinc, roast, leach, electrowinning is around 56. So, the worst culprit from the energy point of view is aluminum, then comes Copper.

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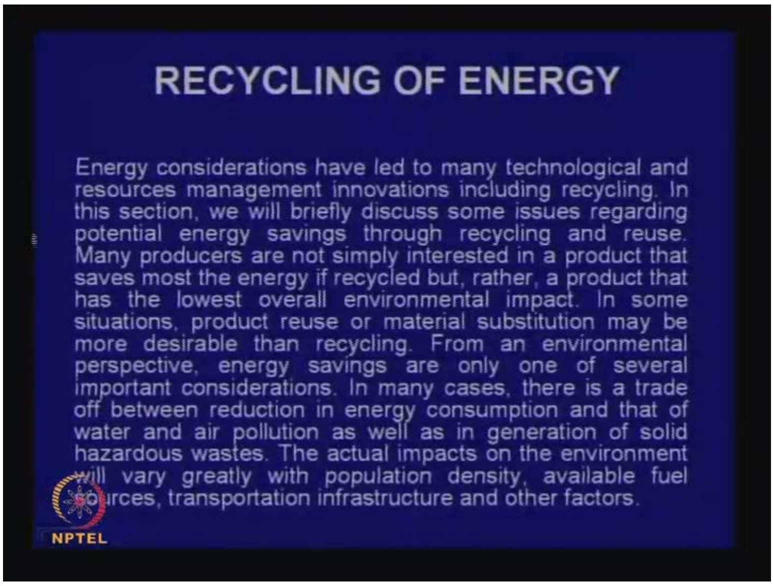

How do we recycle energy? That is a question of vital importance in industries because if you recycle energy, your net energy consumption would be low and if that is low, you will save in the energy cost, you will also release less CO 2 to the air, atmosphere will be cleaner. And from the point of view of industrial metabolism, where the idea is to dematerialize, means use less input and less output, everything is favorable.

Now, energy considerations have led many technological and resources management innovations, including recycling. In this section, we will briefly discuss some issues regarding potential energy saving through recycle and the use. I am going to give you some examples.

Many producers are not simply interested in a product, that saves most energy if recycled, but rather in a product, that has the lowest overall impact. I mean, we need to look at from environmental point of view also.

In some situations, product reused or material substitution may be more desirable than recycling. From an environmental perspective, energy savings are only one of several considerations; in many cases, there is a tradeoff between reduction in energy consumption and that of water and air pollution, as well as in generation of solid hazardous wastes; we have to optimize. The actual impacts on the environment will vary with population density, available fuel sources, transportation, infrastructure and other factors. So, it is a very complicated thing.

We cannot only say that we must use less energy. If you try to do that, there may be some other adverse effect, so, we have to have a holistic view.

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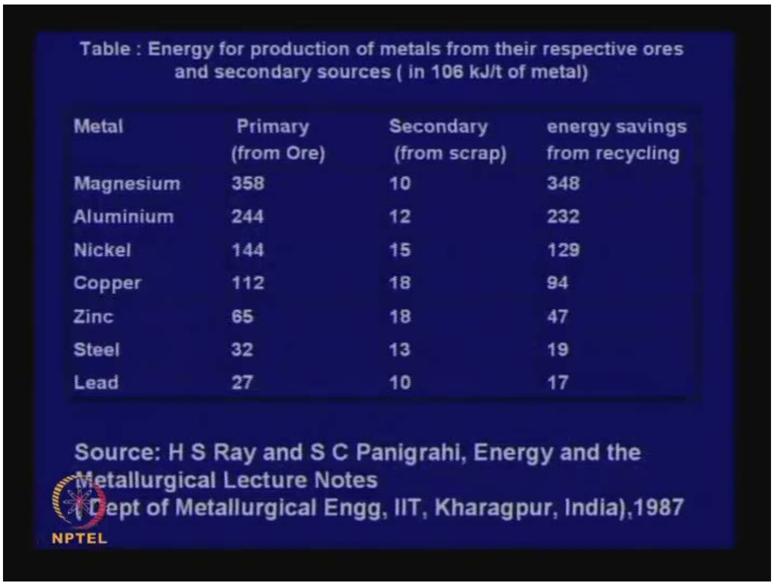

Table : Energy for production of metals from their respective ores and secondary sources (in 106 kJ/t of metal)

Metal	Primary (from Ore)	Secondary (from scrap)	energy savings from recycling
Magnesium	358	10	348
Aluminium	244	12	232
Nickel	144	15	129
Copper	112	18	94
Zinc	65	18	47
Steel	32	13	19
Lead	27	10	17

Source: H S Ray and S C Panigrahi, Energy and the Metallurgical Lecture Notes (Dept of Metallurgical Engg, IIT, Kharagpur, India),1987

Now, I have given you some figures on process fuel equivalent. Let, let us give it, consider some figures for straight energy requirement, forget about PFE, energy required for production of metals from their respective ores and secondary sources; we are not talking about now PFE, just energy for the processing step.

Now, magnesium, from primary ore is 358 kilojoules per ton, take this 10 to the power 6, you must make it 10 to the power 6 kilojoules, from primary ore is 358, very high, but for secondary scrap it is so low because you know, secondary scrap is where everything has almost being done. So, energy savings from recycle will be very high, almost, almost, I mean nothing is there in the secondary metal energy requirement.

Aluminium, primary 244, from secondary 12, this is much, much saving; nickel, primary from ore, from nickel scrap, this will be the saving; copper, this will be the saving; zinc, this will be the saving; steel, this will be the saving; lead, this will be the saving. The saving is less in the case of steel and lead because to start with, they did not require so much of energy in production, but in all these cases, specially where there is an electrolytic step, enormous amount of energy saving is there if you can recycle the scrap.

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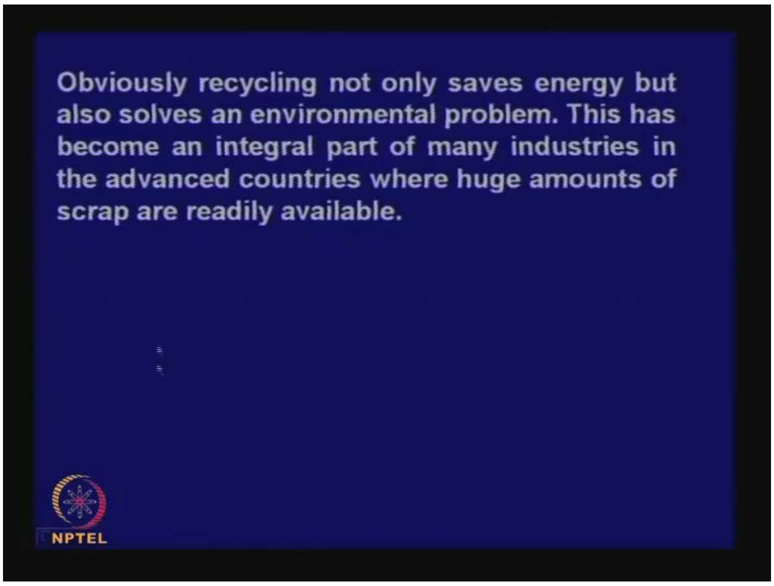

So, we can say, obviously recycling not only saves energy, but it solves an environmental problem. This has become an integral part of many industries in the advanced countries where huge amounts of scrap are readily available.

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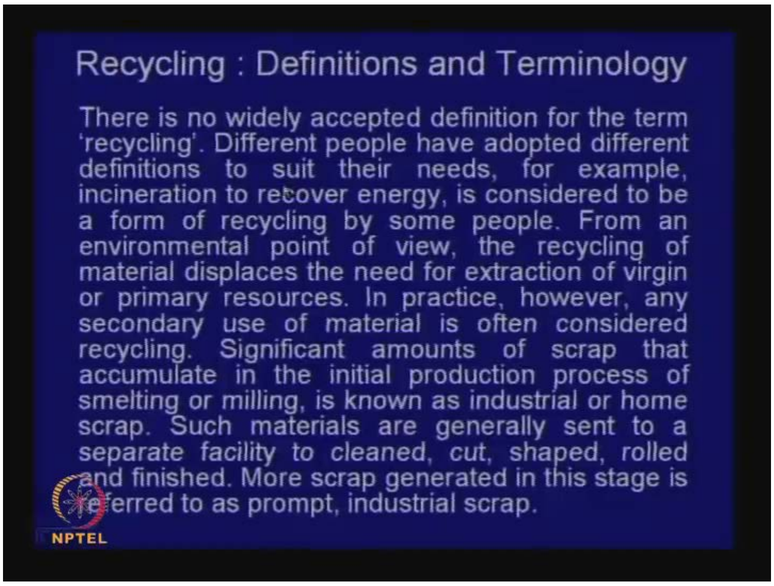

Let me give you some definitions again, something related to recycling. There is no widely accepted definition for the term recycling, although we use it very, wide, loosely, there is no precise definition. Different people have adopted different definitions to suit their needs. For example, incineration to recover energy is considered to be a form of recycle by some people. Say, the municipal garbage that accumulates in homes. In many cities, all that garbage is collected, sorted out, they remove plastics, glass, the some other perishables, they, with paper, things like that, that are easily combusted, they are incinerated and when you get energy, they say, they have recycled the material because from the waste they have got energy. But some people do not consider it to be recycling.

From an environmental point of view, the recycling of material displaces the need for extraction of virgin or primary resources. Some people say, the recycling should really imply, that you are doing something about the primary resources; they are increasing its life.

In practice, however, any secondary use of material is often considered recycling. So, if you have produced something, if you can find another use of it, which means, you have, not, do not need material to produce that from fresh resources, so that some people consider recycling.

Significant amounts of scrap that accumulates in the initial production process of smelting or milling is known as industrial or home scrap. In any plant, not everything that you have produced goes for final product. We will find, there will be some intermediate saline here and there, that will call industrial or home scrap, that can go back again in the production step.

Such materials are generally sent to a separate facility to be cleaned, cut, shaped, rolled, and finished; more scrap generated in this stage is referred to as prompt, industrial scrap. So, the scrap is generated within the plant that can be very easily recirculated.

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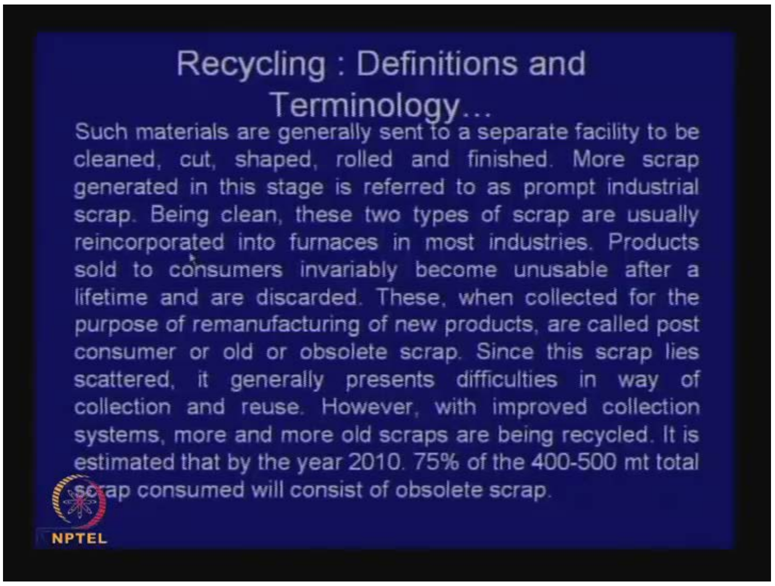

Being clean, these 2 types of scrap are usually reincorporated into the furnaces in most industries.

Products sold to consumers invariably become unusable after a lifetime and are discarded, these when collected for the purpose of manufacturing of new products are called post consumer or old or obsolete scrap. Since this scrap lies scattered, it generally presents difficulties in way of collection and reuse. However, with improved collection systems, more and more old scraps are being recycled.

It is estimated, that by the year 2010, 75 percent of the 400-500 million ton of total scrap consumed will consist of obsolete scrap only.

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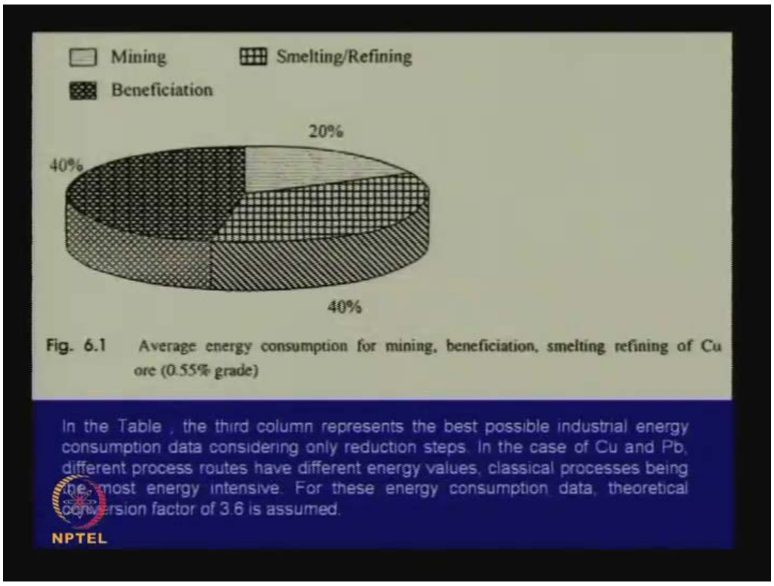

Now, coming back to again energy consumption, in general let us talk about one industry, the average energy consumption from mining, beneficiation, smelting, refining of copper, where we start up with 0.55 percent copper grade, you know, that is by floatation of graded, that it owns for different steps: roasting, smelting, converting.

40 percent of energy in the copper industry goes for beneficiation step because you are getting a conceptual from such a low grade ore. And whatever you do, floatation process or whatever, there will be energy requirement for operating those facilities. Mining requires about 20 percent, smelting and refining requires this.

So, if we talk about energy saving in the copper industry, we simply cannot talk about smelting, converting, roasting, etcetera. We have to do an energy audit of the whole system, we have to have a review of the entire system and you will find, if you really want to save on energy, we have to look at the mining side also because perhaps there may be more scope, there it may be easier to save energy in the mining sector than in this sector.

If something can be saved in this sector, then the mining sector we do, but chances are from mining to beneficiation, that there will more scope, so we have to see that. So, we say, the 3rd column represents the best possible industrial energy consumption data.

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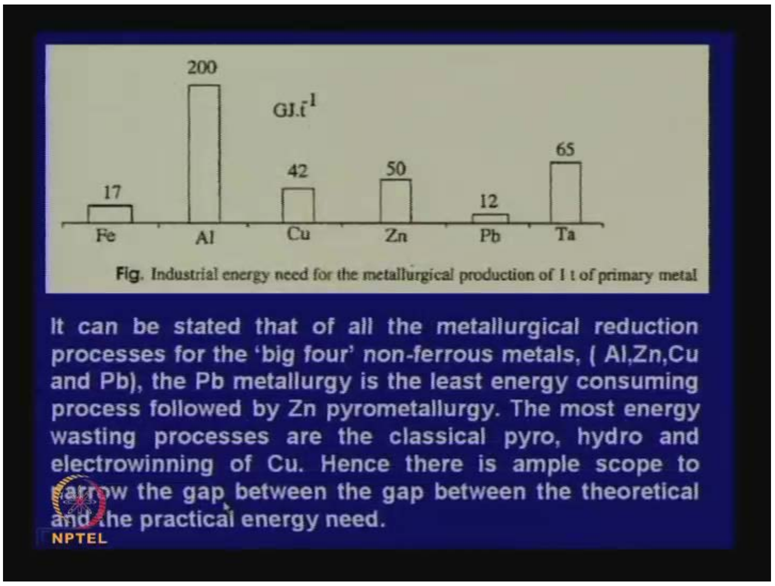

Now, this is coming next. Now, here is some industrial energy need for metallurgical production of one ton of primary metal and just to comparison, aluminium needs, most metal, most energy, then you have zinc, copper, lead, iron.

Now, all that of all the metallurgical reduction process, say for the big 4 non-ferrous metals: aluminium, zinc, copper and Lead, the lead metallurgy is the least Energy consuming process, followed by zinc pyrometallurgy. The most energy wasting processes are the classical pyro, hydro and electrowinning of copper. Hence, there is ample scope to narrow the gap between the theoretical and practical energy need.

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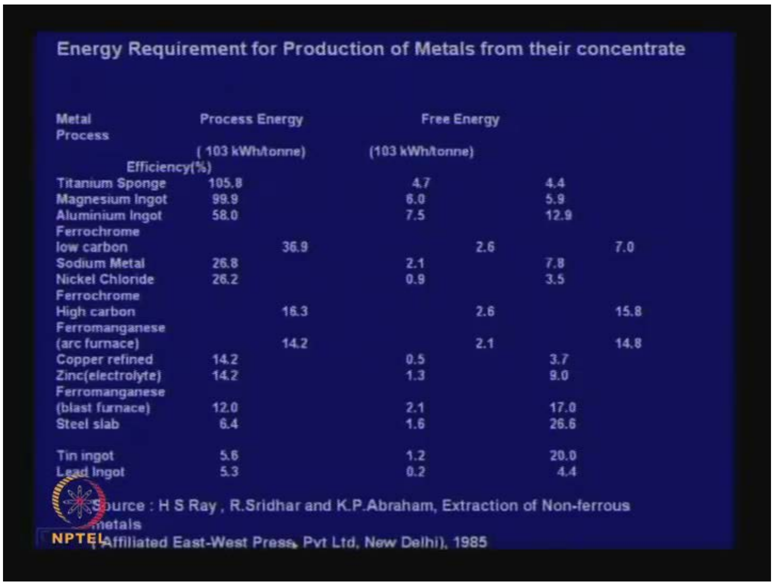

Energy Requirement for Production of Metals from their concentrate

Metal Process	Process Energy (103 kWh/tonne)	Free Energy (103 kWh/tonne)	Efficiency(%)
Titanium Sponge	105.8	4.7	4.4
Magnesium Ingot	99.9	6.0	5.9
Aluminium Ingot	58.0	7.5	12.9
Ferrochrome low carbon	36.9	2.6	7.0
Sodium Metal	26.8	2.1	7.8
Nickel Chloride	26.2	0.9	3.5
Ferrochrome High carbon	16.3	2.6	15.8
Ferromanganese (arc furnace)	14.2	2.1	14.8
Copper refined	14.2	0.5	3.7
Zinc(electrolyte)	14.2	1.3	9.0
Ferromanganese (blast furnace)	12.0	2.1	17.0
Steel slab	6.4	1.6	26.6
Tin ingot	5.6	1.2	20.0
Lead Ingot	5.3	0.2	4.4

Source : H S Ray , R.Sridhar and K.P.Abraham, Extraction of Non-ferrous metals (Affiliated East-West Press, Pvt Ltd, New Delhi), 1985

Now, this is the part 2, too much of data here. So, I think, I will read it for you. The data is not important, but there is a fundamental thing inside this, in this table, that you should understand.

You know, when we extract a metal from an ore, essentially we try to upgrade the ore to a concentrate; ideally we should get a pure mineral. And if you had a pure mineral available, then the energy, that should be required, should equal the free energy of formation because some energy is required for formation of the mineral. So, we can separate, decompose the mineral using that same value of free energy of formation, should equal to free energy of decomposition. Why is that we need lot more? Because 1st of all, we do not have a pure mineral and 2nd, to come to that mineral, we have to come through beneficiation steps. We are starting with a pure grade ore and coming not again to something, which is almost pure mineral, but it is close to that, but it is the, we need lot of energy in upgrading the ore and that is why, we need so much more energy.

Now, let us see how, how it is here. You see, titanium sponge production needs so many kilowatts hours per ton, but actually free energy of formation, if you go, it will be only 4.7. There are 2 sets of figures, what these are I will explain later. One magnesium ingot production takes 99.9 kilowatt hour per ton, but really, free energy of formation is so much smaller. But if you come to lead, its free energy of formation value is low, it requires less process energy also because it is not consuming so much of energy in upgradation.

I will look at this table once again, the reference is here, I think something has been typed wrongly; I will get it corrected after this lecture. And if you see the book, there is lot more discussion on this, but essentially, what I am trying to say, that we cannot take the free energy of formation as a guide to find out in practice, how much of energy it will require for decomposition because for actual process we need a lot of energy to prepare the ore to bring it to a stage from where the decomposition will be done, either pyrometallurgically or hydrometallurgically or electrometallurgically, we separate out the metal in elemental form.

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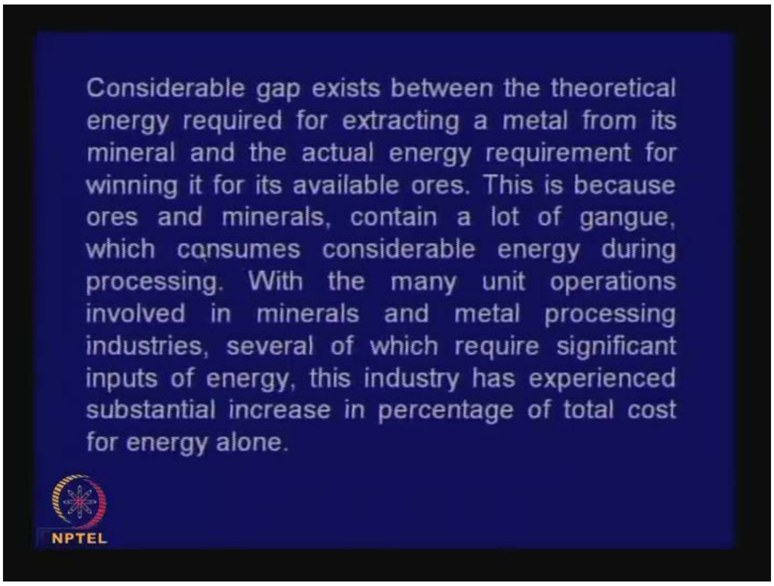

So, this is important, that considerable gap exists between the theoretical energy required for extracting a metal from its mineral and the actual energy requirement for winning it, for its available ore, from its available ore. This is because ores and minerals contain a lot of gangue, which consumes considerable energy during processing. With the many unit operations involved in minerals and metal processing industries, several, several of which require significant inputs of energy, this industry has experienced substantial increase in percentage of total cost for energy alone. So, initial steps cause too much of energy.

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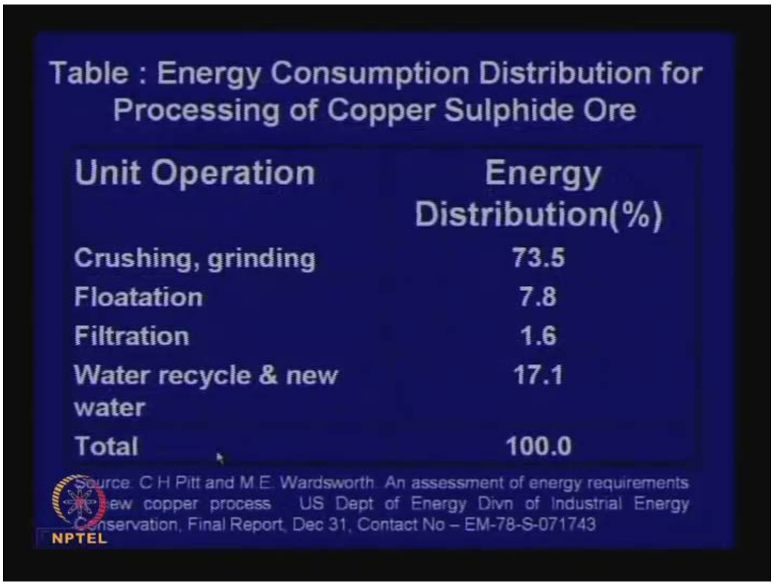

Table : Energy Consumption Distribution for Processing of Copper Sulphide Ore

Unit Operation	Energy Distribution(%)
Crushing, grinding	73.5
Floatation	7.8
Filtration	1.6
Water recycle & new water	17.1
Total	100.0

Source: C H Pitt and M E Wardsworth. An assessment of energy requirements ew copper process. US Dept of Energy Divn of Industrial Energy Conservation, Final Report, Dec 31, Contact No – EM-78-S-071743

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There is some data to substantiate what I am saying, that energy consumption, distribution, processing of copper sulphide ore, unit operation and energy distribution percentage.

In copper sulphide ore processing, 73 percent is going into crushing and grinding, something we very often forget. How energy consumption this is, that what we have extracted from mines, it has to be first crushed to a smaller particle size, then ground and for floatation, it has to be ground to very fine size, minus 300 mesh.

Then, floatation cells operations require some energy, filtration some, water cycle and renew water. So, it is the initial steps, which have consumed large amount of energy and that is why, even if there is a mineral, which is not so stable, you need a lot of energy because to come to that upgradation of the ores, you have done so much.

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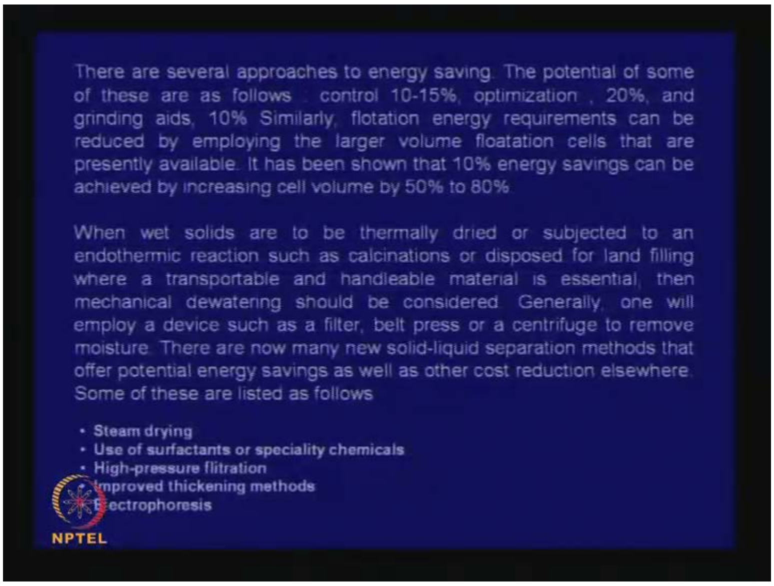

Now, we will now quickly discuss approaches to energy saving. The potential of energy saving are in many areas: control 10 to15 percent, optimization 20 percent and grinding aids, 10 percent. Flotation energy requirements can be reduced by employing the larger volume floatation cells that are presently available. It has been shown, that 10 percent energy savings can be achieved by increasing the cell volume by 50 to 80 percent. We go for a bigger floatation cell, it will consume less energy.

When wet solids are to be thermally dried or subjected to an endothermic reaction, such as calcinations or disposed for land filling, where a transportable or handleable material is essential, then mechanical dewatering should be considered. So, dewatering itself is the energy consuming process.

There are many techniques one can employ, a device like a filter belt press or centrifuge. There are now many new solid-liquid separation methods, that offer potential energy savings as well as other cost reduction elsewhere, some of these are listed here: steam drying, use of surfactants, specialty chemicals, high-pressure filtration, improved thickening methods, all kinds of things. So, technology is advancing, new and newer things are coming, there is tremendous scope for energy saving.

I will continue this discussion and try to solve 1 or 2 very common sense problems little later. Thank you.