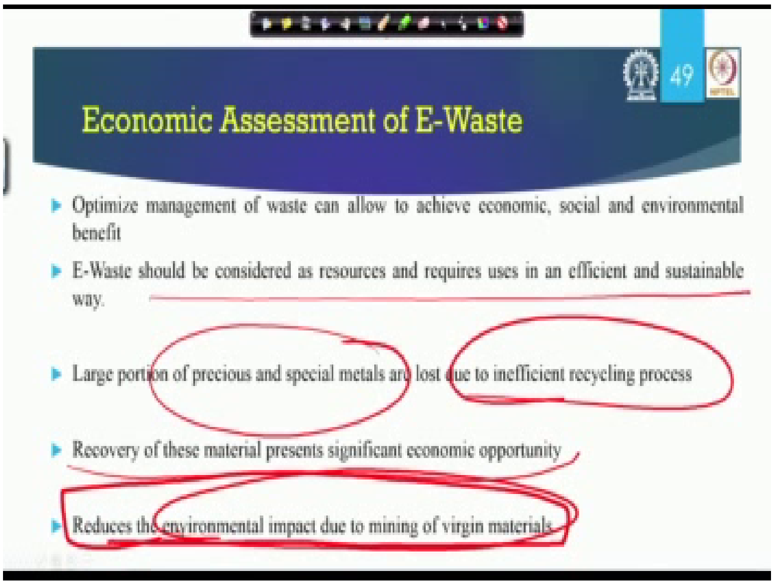
Electronic Waste Management - Issues and Challenges
Prof. Brajesh Kumar Dubey
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture - 05
E - Waste Management Overview (Contd.)

Welcome back. So, in the previous video, we will look at how to estimate the quantity of e-waste that is being produced. So, one another aspect which is very important in terms of the e-waste management is many times even you look at some of this newspaper clippings and other places people say that there is a lot of money that can be made out of e-waste. And this because of all this presence of this, precious heavy metals and other stuff. So, we will try to quantify some of those numbers right know. So, how much actually money is there assuming that 100 percent of this precious metal which is present on in this electronics is available for recovery; and for that of course, we need to have a different recovery technology which will talk about that may be in third of the most likely in third week

So, let us look at so what I am calling it is economic assessment. Say of course, we talked about the (Refer Time: 01:11) is a problem, we talked about the heavy human health issues and we will talk little bit with more in terms of human health issues later on, but and we talked about how to estimate how much e-waste is produced. Now, I want to bring you to show you some data sum calculation where to see that if we collect all this e-waste which is being produced in a particular city, and try to recover all this precious metal how much money can theoretically be made. It is again I am saying theoretically be careful with that because that is assuming that hundred percent of those metal can be recovered which may not happen in most of the cases actually will not happen in most of the cases.

(Refer Slide Time: 01:53)



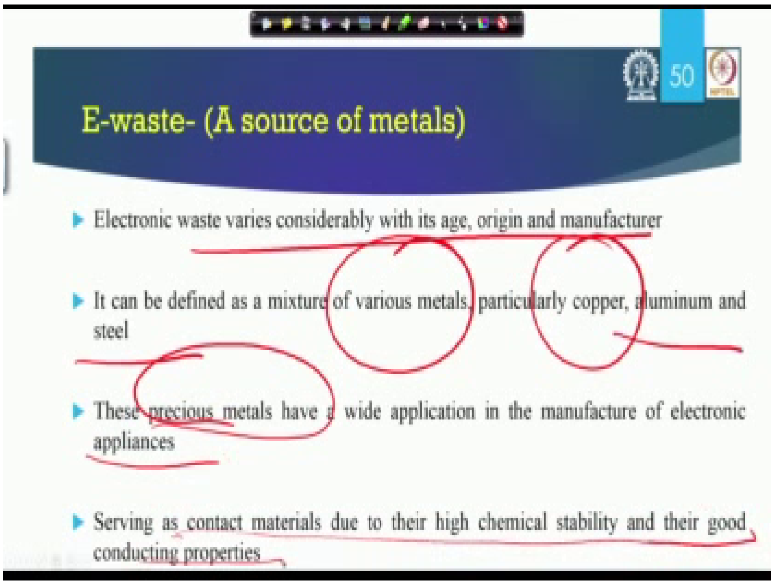
So, we will do what is known as the economic assessment of e-waste in this particular module that is the focus my goal to get to have this economic assessment. So, when we track (Refer Time: 02:02) economic assessment it essentially to find out how much precious an a special metals are there. And they are being lost because of the inefficient recycling process that is where we keep on saying that we need to have a better recycling process informal sector is not able to manage this e-waste recycling because a do not have the they requisite technology to do that. So, we have to provide requisite technology that is we need to have a nice merger of informal and formal sector with informal sector does the collection and may be initial part of the recycling process dismantling and other stuff. And this is specialised recovery a precious and a special metals where actually whereby that is a good amount of money and that should be left into a more a specialising, because otherwise we would using all those acids and burning and all that we are contaminating the environment.

E-waste is considered as resources and requires uses in an efficient and it can be done in a sustainable way. There is recovery of these materials does provide significant economic opportunity, and it can create lots of jobs, but a new type of industry out there of course, that is one area way the country right now is this struggling. We are having our GDP numbers for from most part is going up, and from time to time there will always be some hiccups because of something or the other so but in general economically we are making progress, but many times we see in the newspaper or other places that this progress is jobless, it is a jobless growth.

So, we need to in have industries out there which can create new jobs. And this electronic waste is a problem, but it also provides opportunity to create more job in this particular sector because money can be made and then when we money making is not a bad thing actually for business money making is a must unless the business makes money how it they will invest to produce more job. So, produce more companies needs to be setup in the country to give jobs to all that young people were graduating from different colleges and universities so and that is one aspect.

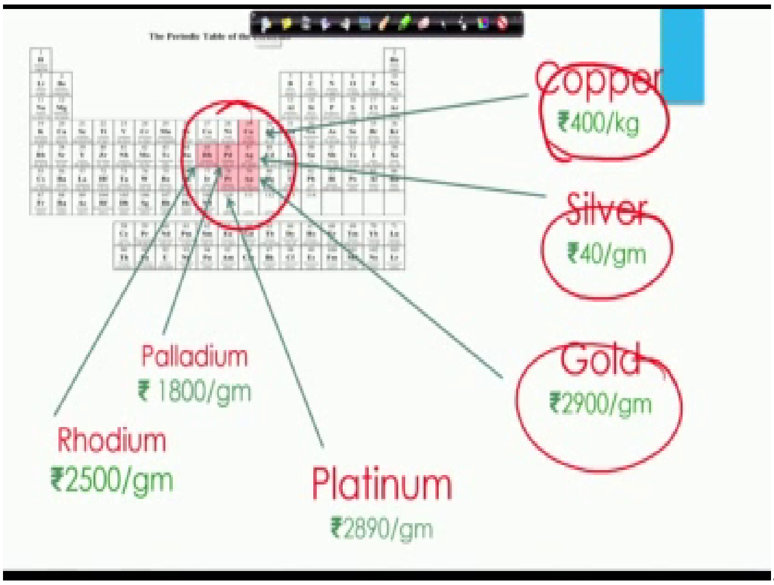
The other aspect is it also helps into reducing the environmental impact due to mining of virgin material. So, we have these materials in electronic ways precious metals, is special metals we call them rare earth metals. The reason we call them rare earth, because there rear they are in very minute quantity available in the mother nature. So, and then mining them is a very tedious process. When you do the mining of this for the this rare earth metals, you are actually ending up contaminant in the environment also like, you use lot of energy use lot of water and this mind telling management overburden. So, these are also leads to environmental problems, if you can do this recovery of electronic, this precious metal from this e-waste ,we have we can reduce the impact, we can reduce the environmental impact due to mining of virgin materials which is also very, very significant impact that is happening from the mining set.

(Refer Slide Time: 05:15)



So, let us try to see it slight check we have there, electronic ways there is a variety it is why we way. So, yeah we were in terms of it is a there are different types of electronic waste out there based on this age origin and manufacture, amount of different types of precious metal present in also various from one electronic to another electronic. So, it is not the same. And then the rate has a various metals are there, there will be we will see lots of a copper, aluminium, steel and there are lots of a gold and other step steel I will talk about these previous metals in a minute. A wide application in the we already talk we saw some of these whenever talking about the health impact and they why they are use because they act as a contact material because of high chemical stability, there good conducting properties, so that is the reason these are heavy metals are used.

(Refer Slide Time: 06:00)

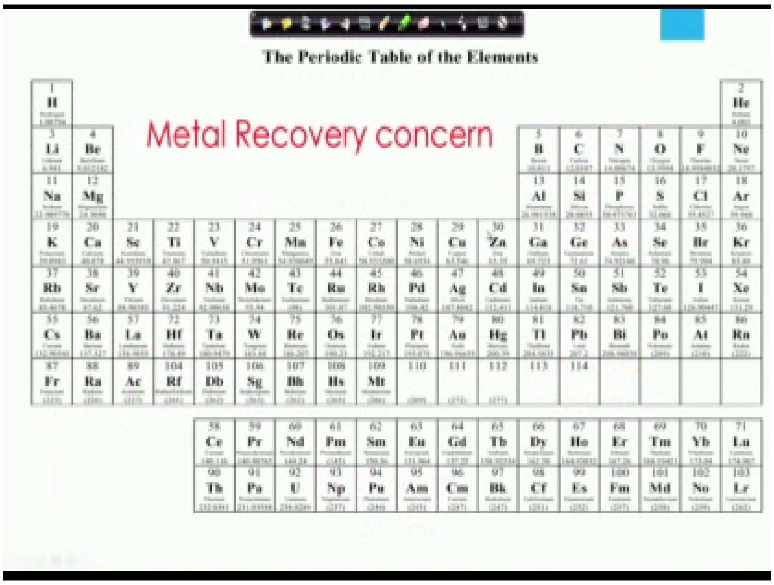


So, let us look at this periodic table. If we remembers the periodic table from your school time and may be from first year of engineering and other places, so that is the periodic table. So, from the periodic table, I have just taken six metals. This is not only the six metal which is there an electronics, but let us look at this six metals. So, we have copper, silver, gold, platinum, palladium and rhodium. The ones which is taken which has good economic value which see is so copper approximately and these numbers are this is the approximate number do not if the numbers a little bit of that is ok because we are just trying to do some maths here for calculation.

So, if because this prices also keeps on fluctuating with this is an approximate number the copper is there on 400 rupees per kg. Silver is 40 rupees per gram, so it would be multiplied by 1000 to get how much it to be used for kg. Gold is around 3000 rupees per gram which is 30,000 for 10 grams which is although on the day out demonetisation, it was sold sometimes 60 to 65,000 for 10 grams, but regular price is around 3000 rupees per gram. Platinum is around 2900 per gram, palladium is 1800 per gram, rhodium is 2500 per gram.

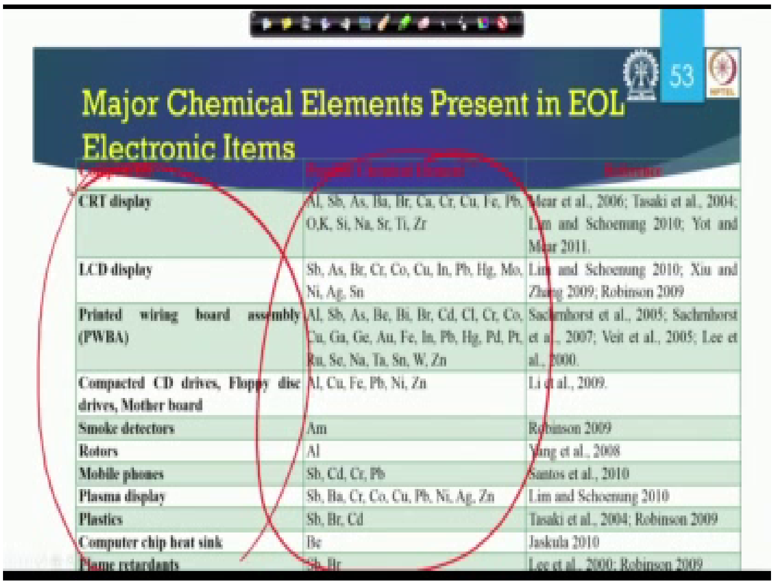
So, this is platinum and rhodium is very much similar to gold, sometimes actually there are more expensive then gold. Palladium is also its pretty like expensive metal. Copper we know copper is recycle good values, silver good value. So, based on all these numbers, there is a importance of these heavy metal. If we can recover these heavy metals, if we can recover it from these electronics they are used in electronics capper maybe in more quantity. Silver, gold, platinum, palladium, rhodium not in a great quantity as you will see, so if you just look at one cell phone the number does not is not that significant as you will see when to do the calculation, but when you look at the entire amount because lots and lots of e-waste is coming in. So, in terms of the since the volume is so much, we are actual we can recover a substantial amount of money if you think about the economic assessment from these electronics.

(Refer Slide Time: 08:22)



So, let us so this is I take up just these base prices for some of the system. And then we have a metal recovery concern because things are there in the periodic table and they are rather than mining it again and again, it is better to recover from the waste stream and try to reuse at because that is way we reduce the impact from mining and all that which we talked about.

(Refer Slide Time: 08:39)

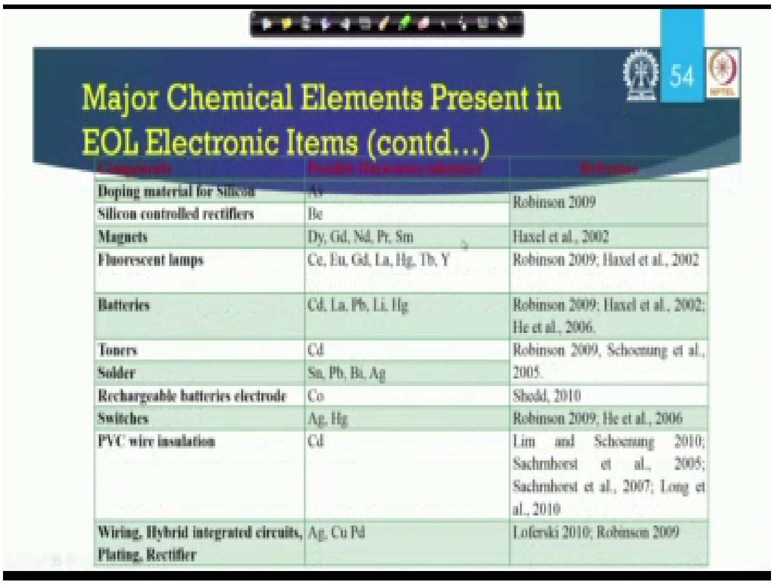


[illegible]	[illegible]	Reference
CRT display	Al, Sb, As, Ba, Br, Ca, Cr, Cu, Fe, Pb, O,K, Si, Na, Sr, Ti, Zr	Mear et al., 2006; Tasaki et al., 2004; Lim and Schoenung 2010; Yot and Mear 2011.
LCD display	Sb, As, Br, Cr, Co, Cu, In, Pb, Hg, Mo, Ni, Ag, Sn	Lim and Schoenung 2010; Xiu and Zhang 2009; Robinson 2009
Printed wiring board assembly (PWBA)	Al, Sb, As, Be, Bi, Br, Cd, Cl, Cr, Co, Cu, Ga, Ge, Au, Fe, In, Pb, Hg, Pd, Pt, Ru, Se, Na, Ta, Sn, W, Zn	Sachmhorst et al., 2005; Sachmhorst et al., 2007; Veit et al., 2005; Lee et al., 2000.
Compacted CD drives, Floppy disc drives, Mother board	Al, Cu, Fe, Pb, Ni, Zn	Li et al., 2009.
Smoke detectors	Am	Robinson 2009
Rotors	Al	Yang et al., 2008
Mobile phones	Sb, Cd, Cr, Pb	Santos et al., 2010
Plasma display	Sb, Ba, Cr, Co, Cu, Pb, Ni, Ag, Zn	Lim and Schoenung 2010
Plastics	Sb, Br, Cd	Tasaki et al., 2004; Robinson 2009
Computer chip heat sink	Be	Jaskula 2010
Flame retardants	Sb, Br	Lee et al., 2000; Robinson 2009

And this is where these are some of the components, where they are used, this is what are the possible chemical elements that are used. And based on coming from different papers that has being done over there. You should be we can provide you the this reference to the detail on through the online portal to the discussion forum, we will put it like a pdf with all this papers with their references if you are more interested in that just let us know. But as you can see in terms of the major chemicals present, if these are lots of chemicals and although we have a just focusing on six, but there are several more out there, which is used in electronics in different components. So, lot of lot of heavy metals that can be recovered and its all depends on economy of scale.

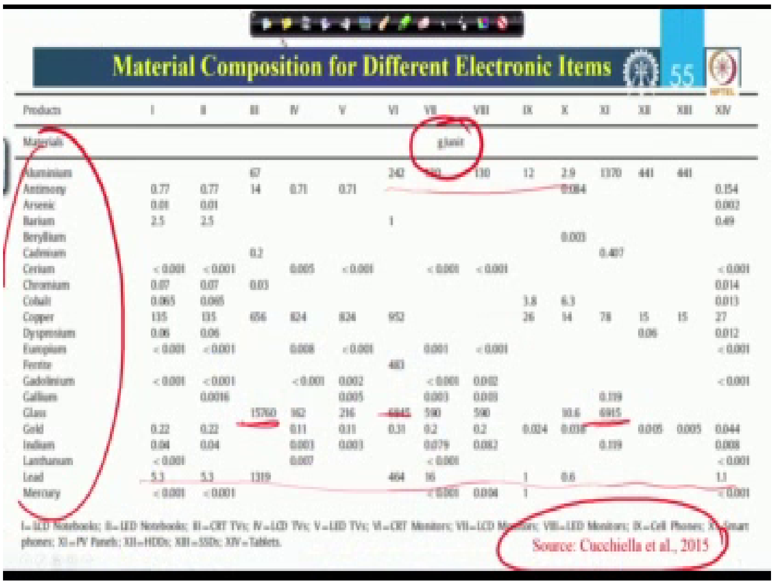
Then another example of the same thing we have the doping materials, silicon controlled, fluorescent lamp, wiring and all that. So, this then these are the possible heavy metals present there. Let see this is your possible chemical elements present there, these are the references from which we got that. So, we did some homework in terms of getting all this information together for this course.

(Refer Slide Time: 09:50)



So, then we looked at this already.

(Refer Slide Time: 09:53)

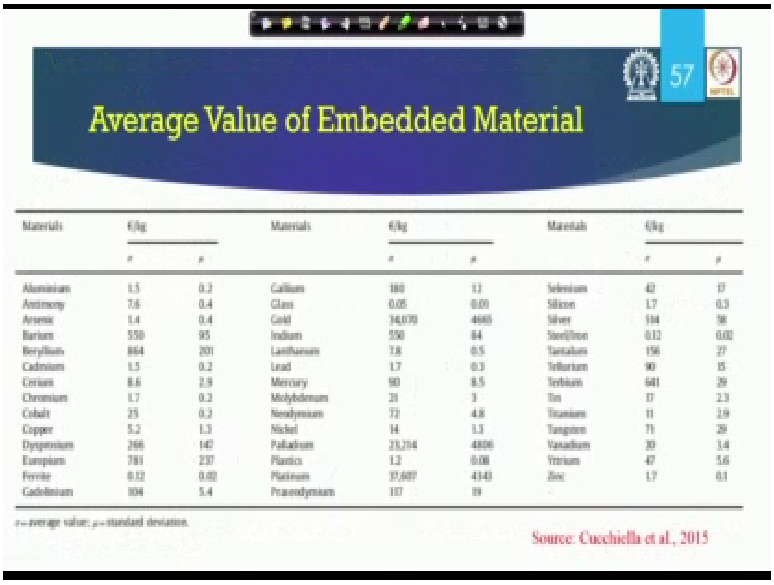


So, if you look at the material composition of the different electronic items, again the numbers are a bits is small for you to see on this particular screen that is why the pdf will be provided to you. But here what is the thing is that these are the different from the different sources. One is the LCD and notebook, two is LED notebook, three is the CRT, four is the LCD TV, five is the LED TV, six is CRT monitors, seven is LCD monitors eight is LED monitors, nine is cell phone, ten is smartphone, and eleven is photovoltaic panels, twelve is hard disk drive, thirteen is SSD drives, and fourteen is a tablet computers. And here are the materials, so all the different materials that are used. And like how much gram of these is present per unit of these materials. As you can see some materials are used quite more.

For example, antimony pretty high; aluminium in this ranges is 242, 130, 130, then glass sometimes you see pretty high glass amount being used especially for you when number three which is the CRT TVs, number six which is the CRT monitors lot of glass. Number eleven, again is a photovoltaic panel lot of glasses there. So, based on different types of stuff, lead lot of lead you see pretty high lead also showing up lead quantity showing up pretty high so that is mercury is being used as well.

So, in some items it is being used some items it is not being used, but this is the material composition of different electronic item. This particular study they have summarized it and put it in this nice table for us to use. So, why this is important will take this data will take this data and the price data, and then we will try to come up with. And this is your material again this is for another material molybdenum, nickel, palladium, plastic platinum, steel, iron and you can see all these how much gram per unit in different types of electronic items. And this is from this particular source. So, again this tables and the previous tables shows as in terms of the different elements present in what is their gram per unit.

(Refer Slide Time: 12:10)

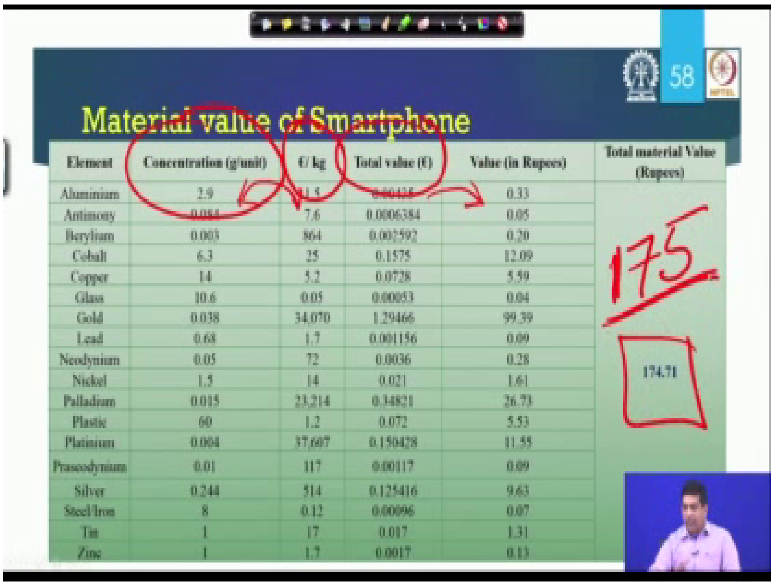


Materials	€/kg		Materials	€/kg		Materials	€/kg	
	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
Aluminium	1.5	0.2	Gallium	180	13	Selenium	42	17
Antimony	7.6	0.4	Glass	0.05	0.01	Silicon	1.7	0.3
Arsenic	1.4	0.4	Gold	34,070	4665	Silver	514	58
Barium	550	95	Indium	550	84	Steel/Iron	0.12	0.02
Beryllium	864	201	Lanthanum	7.8	0.5	Tantalum	156	27
Cadmium	1.5	0.2	Lead	1.7	0.3	Tellurium	90	15
Cerium	8.6	2.9	Mercury	90	8.5	Terbium	641	29
Chromium	1.7	0.2	Molybdenum	21	3	Tin	17	2.3
Cobalt	25	0.2	Neodymium	72	4.8	Titanium	11	2.9
Copper	5.2	1.3	Nickel	14	1.3	Tungsten	71	29
Dysprosium	266	147	Palladium	23,214	4806	Vanadium	20	3.4
Europium	781	237	Plastics	1.2	0.08	Yttrium	47	5.6
Ferrite	0.12	0.02	Platinum	37,607	4343	Zinc	1.7	0.1
Gadolinium	104	5.4	Praseodymium	107	19			

[illegible] = average value; [illegible] = standard deviation.

Then we need to know what is the average value of those embedded material this is again from that particular paper itself where they have put euro per kg this is done in European union, so that is the average value, and the mu is the standard deviation. So, if this is the average, and that is the standard deviation for aluminium, antimony, arsenic, beryllium for all these different elements, which is there an electronic waste. What is the typical price and see this prices due fluctuate a little bit. So, you can always take plus minus 10, 10, 15, 20 percent, but like a for just for the calculation sake just to get a rough idea of how much money is there in that particular range we can use this number. So, we have taken this average value. We have taken this average value for all these materials which is out there and we took the data from these two tables, this table and the next table, we take the data from there we took the average value of the embedded material from there.

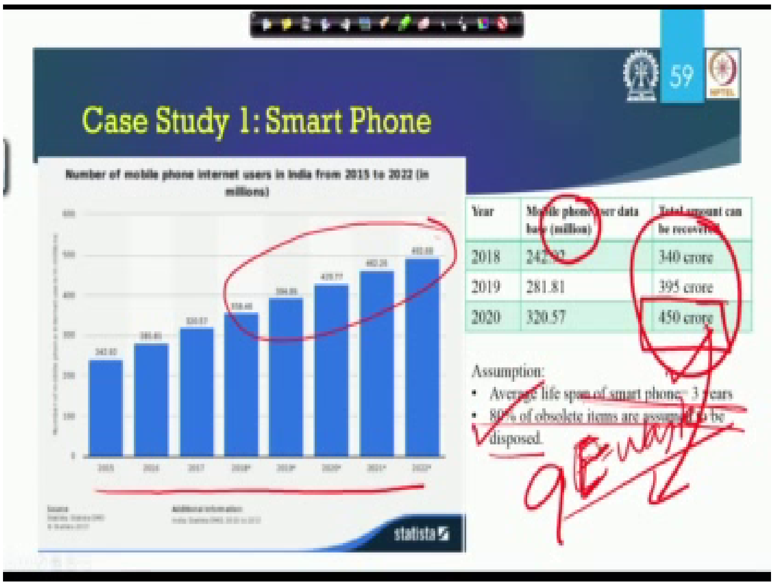
(Refer Slide Time: 13:05)



And then we came up with material value of a typically Smartphone, I am sorry this slide does not show up very clearly will change the colour before putting in the PDF of that. But here the number essentially this is the first here the concentration is given in gram per unit this is the prices in euro per kg, total then we calculated total value and euro. So, we multiply this by this taking into consideration particular unit. And then we from euro we took it to Indian rupees and then this is the total value we get which is 175 average value is like a 175 rupees. So, we are getting a value of 175 rupees per average Smartphone.

So, in one Smartphone from the heavy metal itself from the heavy metals present, there are other things present there too. You can think 175 rupees what is the big deal in that it is such a small number. But again you have to be taken that we are taken all the models, all the makes old phones, new phones, some other mostly older phones, newer phones actually maybe little bit more pricy, more fancy things over there, but that is 175 in one phone.

(Refer Slide Time: 14:20)



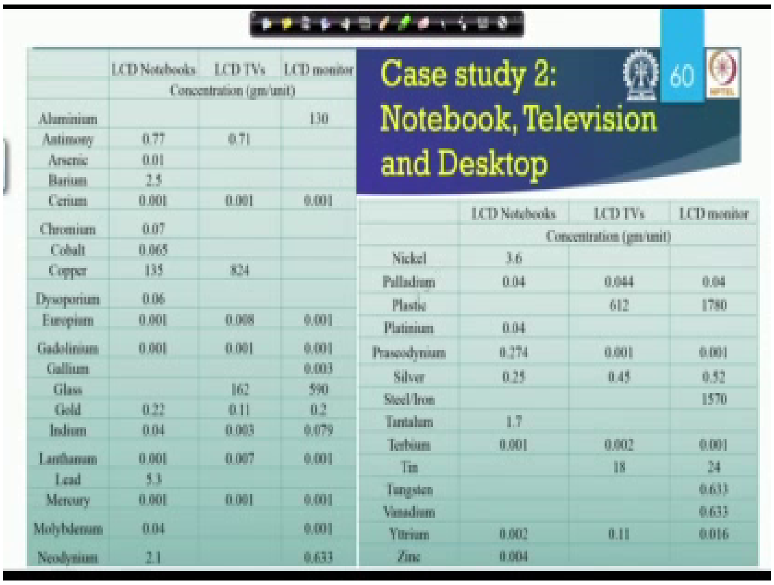
And if you think about all those numbers that we estimated in the previous video and with the increase in usage of cell phone in India over the coming years as you can see in this graph from 2015 to 2022, these are the projected numbers. And as you can see more and more more and more cell phones will be used; that means, more and more will be discarded taking a lifespan of 3 years average lifespan of a Smartphone is 3 years, and 80 percent of the are assume to be disposed. So, 20 percent will be stored but 80 percent will be disposed.

So, if we take three years as the average lifespan 80 percent of the as the obsolete item being disposed. If you can do the mobile phone how much money is out there just from the mobile phone in India in 2020, we are looking at a figure of 450 crores. So, 450 crores of worth of these heavy metals are present in just because we are looking at see here million numbers, numbers are pretty high. So, although it is 175 for one phone, when you add up to all the phones that is going to be disposed in to the environment, we are looking at a 450 crores. To setup a very good frency waste to like a electronic recycling plant, see it cost around 52 crores just in average it maybe little bit more then that say even if it is 50 crore.

So, what you are looking at 9 good waste to energy, 9 good e-waste recycling plant, if my number is off just let me know because I am not set up e-waste plan. And if you can I am just making an estimate here based 50 crores it is a pretty good number I think for a good e-waste recycling plants. So, if we can set up ah with the expense of say 50 crores for an e-waste plant e-waste recycling plant, we can set up nine plants in the country. Just from the e-waste that is being to just from the mobile that is being good going to be disposed in 2020 – 80 percent of that. So, 80 percent of the mobile coming in which would be thrown away which the thrown like which will be of people will not stop using it which will become a electronic waste in 2020. If all of them is captured and brought it to a it nice e-waste recycling facility where we can recover this material out with still have a value of around 450 crores and that is based on today's number. If the metal prices goes up the number may be little higher and the number can go down as well as the prices go down because mark market to fluctuate, but most of the time it has a tendency to go up on the at least with a inflation and all.

So, that is a lot of number. So, and that is why there is there is an interest in electronic waste of course, the electronic waste interest is there because of the human health impact the environmental impact and that the problems associated with that. But at the same time the interest is also there, because there is a lot of money there is lot of money can potentially be made which you can be used for like a making a good industry out of that. So, it does present a good chance of having a very good study in industry in terms of electronics in terms of e-waste to recycling industry in the country.

(Refer Slide Time: 17:38)

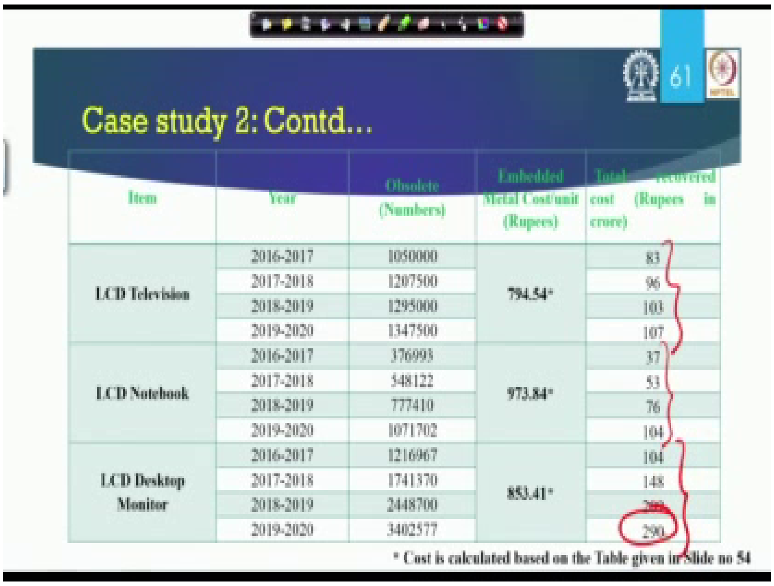


	LCD Notebooks	LCD TVs	LCD monitor
	Concentration (gm/unit)		
Aluminium			130
Antimony	0.77	0.71	
Arsenic	0.01		
Barium	2.5		
Cerium	0.001	0.001	0.001
Chromium	0.07		
Cobalt	0.065		
Copper	135	824	
Dysoporium	0.06		
Europium	0.001	0.008	0.001
Gadolinium	0.001	0.001	0.001
Gallium			0.003
Glass		162	590
Gold	0.22	0.11	0.2
Indium	0.04	0.003	0.079
Lanthanum	0.001	0.007	0.001
Lead	5.3		
Mercury	0.001	0.001	0.001
Molybdenum	0.04		0.001
Neodymium	2.1		0.633

	LCD Notebooks	LCD TVs	LCD monitor
	Concentration (gm/unit)		
Nickel	3.6		
Palladium	0.04	0.044	0.04
Plastic		612	1780
Platinium	0.04		
Prasoodynium	0.274	0.001	0.001
Silver	0.25	0.45	0.52
Steel/Iron			1570
Tantalum	1.7		
Terbium	0.001	0.002	0.001
Tin		18	24
Tungsten			0.633
Vanadium			0.633
Yttrium	0.002	0.11	0.016
Zinc	0.004		

So, this is the another case study to will looked at that was for mobile phone, now if you look at the LCD notebook, LCD TVs and LCD monitor, if you get all these gram per unit same thing, same way for this.

(Refer Slide Time: 17:52)



Item	Year	Obsolete (Numbers)	Embedded Metal Cost/unit (Rupees)	Total recovered cost (Rupees in crore)
LCD Television	2016-2017	1050000	794.54*	83
	2017-2018	1207500		96
	2018-2019	1295000		103
	2019-2020	1347500		107
LCD Notebook	2016-2017	376993	973.84*	37
	2017-2018	548122		53
	2018-2019	777410		76
	2019-2020	1071702		104
LCD Desktop Monitor	2016-2017	1216967	853.41*	104
	2017-2018	1741370		148
	2018-2019	2448700		[illegible]
	2019-2020	3402577		290

* Cost is calculated based on the Table given in Slide no 54

And then you try to do in terms of how much LCD television, LCD notebook and LCD desktop monitor in different years, how much will be obsolete and then embedded metal cost. So, here we are looking at in for the different years say in terms of LCD desktop monitor, which is at the bottom. Here we are seeing a value of 290 crores in 2019-2020;

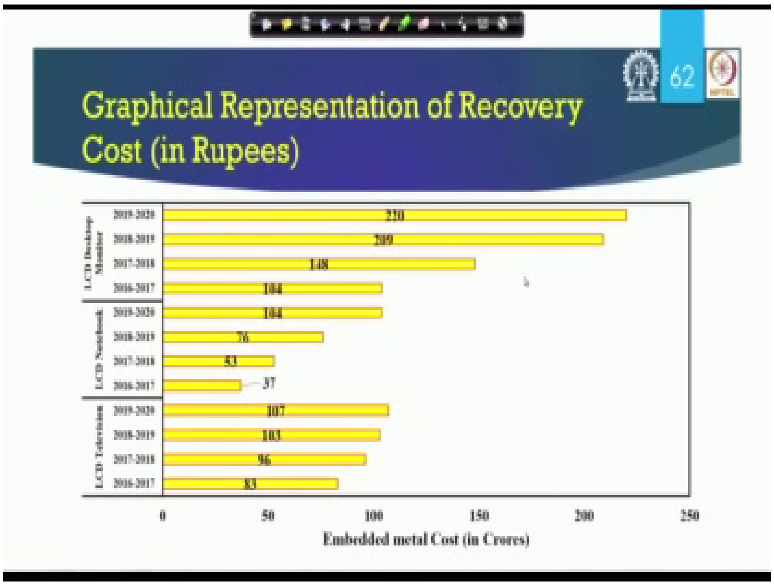
and for this is 83 crores for from LCD television 83-107 crores over those 4 years; for LCD notebook 37 to 104 crores; LCD desktop computer 104 to 290 crore. So, more and more LCD desktop computers say will be actually desktop monitors when we start showing up into the disposal stream.

So, again there are this again reemphasizes the same thing which I was telling just a few minutes back that there is a value there is a value in this e-waste. And e-waste as when we talk about municipals solid waste are when you here that I am waste to wealth waste to wealth a for a next municipals solid waste the way we managed in India is it is still a long battle. Because I do not think with the mixed municipal solid waste that we have available in the country as of now and those of you who may have taken my course in the previous semester, where we had this integrated waste management course we talked about that in great detail. That it is difficult to make money out of that because of the heterogeneity of the material, so materials are all mixed together, they do not its the process does not work efficiently because the input to that process inputs technology is not proper we have things mixed up.

If we to do the source separation yes we can potentially make some good money out of their potentially and that too requires lot of investment and other things to happen. Electronic waste is much easier because it is very easy to separate e-waste from other waste streams. They looks they look different it is easy to easy to ask people to keep it source separate because you do not disposed electronics everyday like you do for municipal solid waste. And e-waste do it make a ones may in may be ones are twice in a year for certain items. So, you can always have a collect it separately.

So, if we collect it separately and recycle it and try to the cover this heavy metals, lot of money can be made and that can lead to a actually very nice sophisticated engineering and technology job in the country hiring in everyone from like a diploma holder, to ITI, to a graduate engineer. So, it is uneven management people. So, it is a good market potential. So, e-waste I hope there are some companies coming up there is struggling to get the e-waste. Hopefully with this e-waste management rules they would be able to able to get some electronic waste to recycle, and they can do this material recovery. Many of this precious metal recovery many of this precious metal recovery many of the plan that we have right now there unable to do this precious metal recovery, and we do end up sending them for Belgium and other places in Europe. But if we can do it over here, we can generate a good revenue from there as well.

(Refer Slide Time: 21:07)



So, the same the numbers now presented in terms of graphical representation as you can see the desktop monitor it is kind of leading it with embedded metal cost in crores. So, it is 220 crores which is we expect from there. LCD notebook is the next, then LCD television is kind of in the middle in compare to LCD television and notebook for 2019, 2020 seems to be very similar, but others years we see that television will be higher than the notebook and then monitor will be much higher. So, that is kind of gives you the economic assessment of electronic waste we talked about the economic.

So, so far what we have done in this, this is kind of I think this is the last year this is the last video for the week one. So, if we can think about week one what we have done in the week one just a quick recap. So, we started with looking at what is electronic waste. We classified it. I did emphasize that based on where you are in the world, whichever literature you are looking at the classification will be a little bit different. So, you need to be careful with that. When you look at any report you are different ways of classification, some places this big ticket items like a refrigerator, washing machine, dishwashers they are not included in e-waste in other countries they do, European union they do it. So, in India also we do that we do include them in the electronic waste, but if you are in e-waste they do not they call it white goods and it is handled separately.

In general, very general definition of e-waste is anything with a circuit board is an electronic waste. So, even those while if you are in railway station or in a airport where you see a small kid walking with their lights flashing in their shoes or making some that sound that small musical things in the shoes that also can put in that also is an electronic item as for the definition of electronic waste. And the ones that shoes is discarded it is an electronic waste as well so as per the European union definition, but it is not in electronic waste if you are in US. So, US do not call it a, but we follow European union in India, so for us also that will become an electronic waste, so that is in terms of how you need to be careful in terms of the definition.

Then we talked about what are the concerned, we looked at what are the different types of heavy metals present. And what is the why we are we should be concerned how where in India it is being produced, how much it is being produced in India, which city is a producing more which is states are producing more. Then we went into looking at that health impact like a briefly in the health impact which will do little bit more details in the first video in the second week. And then we talked about how to estimate, we like a if you have to do the forecasting of electronics how to estimate the learn we had a case study of Delhi where I showed you how to do that estimation of e-waste generation.

Followed by our focus was on in terms of the estimate of e-waste generation if you know the quantity of e-waste from the different waste is stream. And if you want to see what is the market potential of setting up have a e-waste recycling company, how much money theoretically could be made from all those precious metals and other things which is out there. So, we can update those calculation using the data available in the literature. Again we have used lots of information from different literature sources, we will try to put some of those important ones on the website so that on our NPTEL website for this course as additional reading material along with this lecture slides. But if you need some more information if you get more feel free to contact us through the discussion forum will be more than happy to answer any questions.

So, let us that brings a closer to the week one video. So, now we will go into the week two in the subsequent video. Again you there would be in assignment as happens to any NPTEL course. So, go through the assignment questions and you will have I think it is a where on a week or ten day with which the directions have been provided to you anyway. So, you can look at when the assignment is due, you pay attention to that. And again assignment questions if you have any confusion, put it on the discussion forum discussion forum will definitely get answer within 24 hours. So, anything you putting on discussion forum, I promise you that will get back to you in 24 hours in most of the cases unless there is something happening of, but in general will get back to you with in 24 hours.

So, with that thank you for enrolling to this course week one is over. So, 25 percent is done, another 75 percent left because it is only a four week course. You have done by week one and you will get other weeks as well. And I hope you continue enjoying this course.

Thank you.