# Life Cycle Assessment

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## Lecture - 23
## Inventory Data and LCIA

Let us look at we will kind of go further. If you remember towards the end of the last module we were looking at the different data base. So, in this module we will start with giving you some example of what kind of when we say the database is what kind of data are actually there in the database. So, we will look at some I will have an example of how the database looks like. So, when you are say when we say you go for the eco invent database to get some data what kind of data they collect, I told you that right now we are working on a project with eco invent trying to collect data for textile industry in India.

So, when we are trying to collect those data what kind of data is actually usually show up and these are mostly unique data. So, we work on unique data to be hope.

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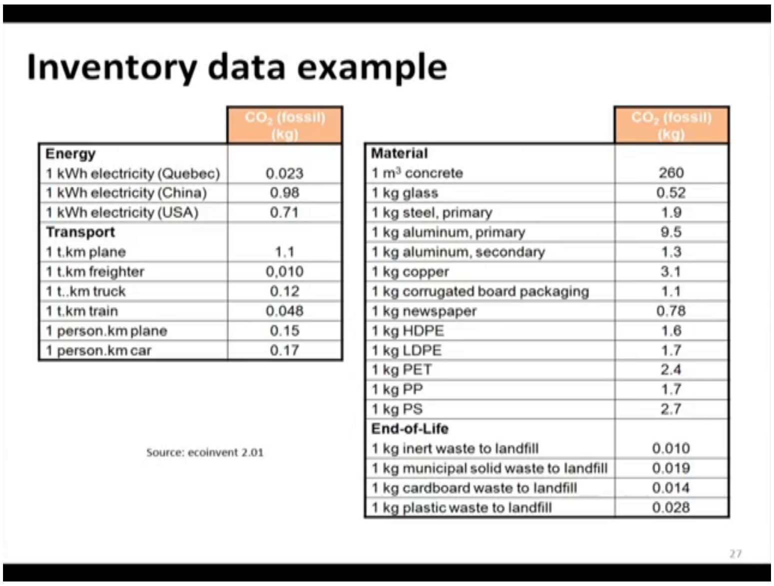


So, if you look at these 2 tables that we have. So, let us start with the table on the left hand side first. So, here we have this is an example again these are not the complete database again. This came from eco invent this is from the eco invent data. I have just pulled 2 tables for you to illustrate some points. So, if you look at this particular table on the left hand side, where we have most of these data we express in terms of the CO2 equivalent. And how we do that I will also show you example of that later in this particular in this class, but we express things in terms of you would like a $CO_2$ equivalent.

So, if you look at the first kind of the table over here, on the left hand side here we have the energy some energy data and some transport data. Now if you look at the energy data. So, that is some of these are really interesting, and I would like encourage you to pay good attention to that. So, if you look at this 1 kilo watt hour of electricity all this 3 whether you look at this all these 3 data are for 1 kilo watt hour of electricity, but depending on where you are in the world the data changes quite a bit. So, if you are in Quebec which is actually in Canada. So, Quebec is in Canada, if you just above the new England is states of US Montreal and Quebec, those are those Quebec is a province in this part of Canada where Quebec. Also is a province which French is very popular French is a one of the official language there as well. So, with in terms of if you are in Quebec your $CO_2$ equivalent is 0.023 kilogram, to produce 1 kilo watt of electricity, you release in terms of the $CO_2$ equivalent the fossil your release is 0.023 kg, but if you are in china that becomes 0.98 kg.

So, that is how that is why we almost what equimolar if you nearly more than 50 times something around that nearly less than 50 times, but it is in terms of that much high impact is there, and then in terms of US it is straightly less than china, but much higher than Quebec now if we had numbers for India it would be again very similar to what we have for china. Now why the numbers are different? Again the why question why the numbers are so different that is why whenever we told when I was talking to you earlier that when you do the LCA exercise the energy mix. The energy mix of that particular region or the country is very important. Quebec it is mostly hydro it is mostly hydral power. And some may be nuclear, but mostly hydropower. So, since Quebec is mostly hydropower the impact is with much less.

In china it is mostly thermal power as in India, china is now going a lot in terms of china is building lot of renewable energy systems as well, but this one this data was collected with the data the kind of data we are looking at my suspicion is that it is mostly thermal power. So, that is why you see like a lot of much higher impact. And because thermal power plant remember we talked about that thermal power plant it is a coal mining water during the coal mining also you need water during the thermal power plant you need lot of water, and then your all the emissions associated with that. So, that is a lot of impact in terms of the thermal power plant.

In USA it is kind of in the middle because USA is a mix you have some thermal and predominantly thermal in many places in US, US is a big although Canada is bigger than US, but in terms of area, but in terms of it is population it is almost just as only to one 10th of the US population. So, it is very low number of people and most of the people actually lives along the US border. So, that is where most of the Canadian population is staying. So, that is, but it is in US we have the thermal and then make sure some nuclear some other like a renewable energy as well. So, but it is mostly coming from an US depends on where you are if you are in new England Massachusetts choose it is those road island and those places you will have a better carbon footprint, you will have a better in energy makes in terms of the environmental performance. Or if you go to Texas and other places you will have mostly like gasoline fossil fuel based energy. So, that is the energy data.

Similarly if you look at the transport data; so in transport data they have been mentioned in ton kilometer. So, the first 4 data is in ton kilometer. So, that is for freight moving things around. The last 2 is for person kilometer in terms of a person in in like a people travelling around. So, in terms of ton kilometer like for the plane it is around one point 1 kg for. So, what does it mean 10 kilometers it means to move one ton of the freight by 1 kilometer. So, you are taking one ton of freight over a distance of 1 kilometer if you are taking it by plane you are on 1.1 if you are taking it by freighter which is the you go on the ship it is 0.010. So, ship transport is much better in terms of the environmental footprint.

If you are doing out on truck it is 0.12 by train 0.048. So, if you have to rank say if somebody asks you which one is the in terms of the transport of taking goods around in the world, which is the best in terms of environmental performance, it is the ships those big marine ships taking things around, that is number one followed by the train, then the truck, and then the plane. And the plane comes out to be it is more than that, but in terms of person travelling in terms of one person kilometer in plane; that means, one person travelling a kilometer by taking a plane or by taking a car as the numbers are here they are pretty much similar. The car comes out to be little bit higher than the plane. So, because the plane there are so many people can go in one plane car may be 2 to 3 people in a car. So, based on that it comes out to be much little bit less, but it is pretty much if you do a statistic probably it would be similar.

So, that is how in terms of the inventory data for energy and transport. Now if you look at on the right hand side the some of the examples for the material and towards the end towards the bottom of that we have some example for end of life. So, one meter cube of concrete you have 260 $CO_2$ fossil fuel. This is one meter cube of concrete, 1 kg of glass 0.52, 1 kg of steel like primary steel, not the secondary. Secondary steel means you are producing steel from recycle steel. So, that is your secondary steel, so 1 kg of primary steel 1.9. Look at aluminum or in India we say aluminum as well aluminum so, but 1 kg of aluminum the primary production is 9.5 $CO_2$ like in kg.

So, for 1 kg of aluminum we have a release of 9.5 kg of $CO_2$. That is a prime report action, but if you go for a secondary production it goes down to 1.3. So, that is 0.3 is almost (Refer Time: 09.08) like we are looking at 7.5 to 8 times reduction. So, that is a lot of reduction in terms of whenever we go for secondary. So, that is why if you look at recycling of like waste material, if you have taken a solid waste course or if you have absorbed the solid waste industry, you know that recycling of aluminum cans is considered like is done a lot. The reason for doing that is aluminum cans when you go for the secondary aluminum can amount of emission is almost one-seventh to one-eight.

Since emissions are less what does it mean the process is less intensive as well? So, it is less costly like one-seventh of a price it is one-seventh one-sixth of a price of making a new aluminum can from recycle aluminum as a post to go for the primary production. That is why you see a lot of aluminum being recycled, that is the logic that is what you see over there.

So, then we have a copper 3.1 kg $CO_2$ like carbon dioxide, corrugated board packing that is your corrugated cardboard used for packaging material 1.1, newspaper 0.78. So, these are different examples HDPE LDPE PET PPPS these are all different types of plastics. So, in terms of PET which is the highest recycle as well we have 2.4 kg of $CO_2$ per kg of PET HDPE is less than that. So, PET has better has more carbon footprint more environmental footprint and again these are your $CO_2$ equivalent.

So, all the environmental footprint has been converted to $CO_2$ equivalent. So, that is what you are looking at all the environmental footprint the different criteria have been converted to 1 unit that is your CO2 equivalent that is over there. So, it is. So, 1 kg of the PET in terms of better more no sorry polystyrene PS has highest which is 2.7 which you see at the end. So, polystyrene is the highest followed by PET and polypropylene and LDPE they are similar, and then the lowest one is the HDPE, HDPE, PET is what you see in terms of the glass bottle sorry the water bottles if you buy a say Aquafina Kinley or Bisleri and those kind of water bottle the bottle that you have that is the PET bottle.

And HDPE is what you buy when you go for this when you buy this detergent or those like a saffola, those oil cooking oil and all that that container is HDPE container. So, those are and then there are other usages as well, but there are different carbon footprint environmental footprints. In terms of things going to the land flow if it is an inert waste you have 0.010 kg of CO2. So, municipal solid waste almost doubles of that cardboard kind of in the middle. Plastic waste you see even much higher. Now why for these are the 4 different types of waste. Again whenever you see this kind of data just do not take the data by the phase value. Always think like why the numbers are different. What is going on here why the municipal solid waste will handful is almost twice of the inert waste?

The reason for that is municipal solid waste when you talk about municipal solid waste it has lot of organic material. Inert waste will have negligible organic material. It may have some heavy metals and other things present in there, which may eventually leach go to the leached collection system and that is why you see some impact, but for and of course, there is some impact because the landfill operation has to happen the roller has to move on top of the landfill for the compacting of the garbage. So, there is an emission associated with that there will be a dust coming out at the landfill side. So, those things are of course, been used.

But in terms of municipal solid waste, but those things are common. It is common for all the 4 criteria. Those basic landfill operations are common. Whether it is a inert waste municipal solid waste cardboard waste or plastic waste. Municipal solid waste since it carries lot of organic material. Organic material in a landfill environment will degrade. And when they degrade they will produce methane because they are organic. They are supposed to produce methane they are when they degrade. So, methane is a has a greenhouse gas potential. So, that is and you will have some not only methane there are other gases produced that will also have an impact.

So, cardboard again cardboard is not easy to degrade, but it will have some degradation. That is why you see some impact like kind of in the middle inert as well as the municipal solid waste. Plastic does not degrade, but the plastic has a problem is that it stays in the landfill for a very long time. And it is since it does not degrade; that means, you have to you have to kind of manage the landfill for a longer period of time. And that has a bigger environmental footprint associated with that. Plastic waste is the biggest problem in the world right now. It is actually if you if you follow waste management if you just google plastic waste issues, and you will see lots and lots of news articles videos and other things out there.

We are having a big problem especially those of us who loves sea food, if you like a sea food if you like the fish from the oceans and then most of those fish are getting contaminated by plastics and that is not good for our health. So, plastic is a big problem of in terms of a waste management right now in the world.

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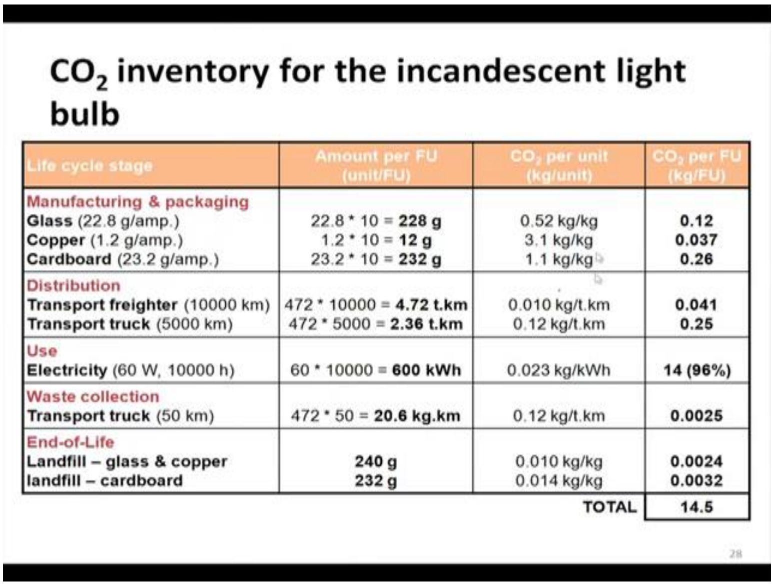

## $CO_2$ inventory for the incandescent light bulb

| Life cycle stage | Amount per FU (unit/FU) | $CO_2$ per unit (kg/unit) | $CO_2$ per FU (kg/FU) |
|---|---|---|---|
| **Manufacturing & packaging** | | | |
| **Glass** (22.8 g/amp.) | 22.8 * 10 = **228 g** | 0.52 kg/kg | **0.12** |
| **Copper** (1.2 g/amp.) | 1.2 * 10 = **12 g** | 3.1 kg/kg | **0.037** |
| **Cardboard** (23.2 g/amp.) | 23.2 * 10 = **232 g** | 1.1 kg/kg | **0.26** |
| **Distribution** | | | |
| **Transport freighter** (10000 km) | 472 * 10000 = **4.72 t.km** | 0.010 kg/t.km | **0.041** |
| **Transport truck** (5000 km) | 472 * 5000 = **2.36 t.km** | 0.12 kg/t.km | **0.25** |
| **Use** | | | |
| **Electricity** (60 W, 10000 h) | 60 * 10000 = **600 kWh** | 0.023 kg/kWh | **14 (96%)** |
| **Waste collection** | | | |
| **Transport truck** (50 km) | 472 * 50 = **20.6 kg.km** | 0.12 kg/t.km | **0.0025** |
| **End-of-Life** | | | |
| **Landfill – glass & copper** | **240 g** | 0.010 kg/kg | **0.0024** |
| **landfill – cardboard** | **232 g** | 0.014 kg/kg | **0.0032** |
| | | **TOTAL** | **14.5** |

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So, that is how you have the database. So, that is the previous slide this slide can show you how the databases are available in the data, how the data is available in the database sorry. So, the format in which the data is available you saw everything was for 1 1 1 1; that means, unit is not it unitary method remember. We always go back to like 1 unit 1 of this. So, similarly here if you want to do this life cycle stages of that CO2 inventory for the incandescent light bulb, we can again draw the same problem remember we did that problem earlier where we had amount per functional unit, we had that life cycle stage, manufacture and packaging distribution use waste collection end of life and we use some of these numbers over there. So, glass 228 grams, copper 12 grams cardboard 232 grams. So, this is how these numbers came because we had that data for unit any multiplied by 10. So, this is how we got the numbers coming out.

So, then you can calculate $CO_2$ release per unit because 200 and 20 this is per kg we know the numbers. So, we can calculate what is for the 228 grams. So, that we get in terms of per functional unit per unit, and then you get it for per functional unit and then you calculate for the total that is the $CO_2$ total $CO_2$ equivalent coming out. So, this is this much kg per functional unit of the material. So, this is how you do your calculation. First you find out what is the amount per functional unit that you need, you know $CO_2$ per kg of the material per kg, and then since you need 228 grams. So, you can take the 0.52. Kg is per kg of the material, but here you need only 228. So, you need to do kind of do the math over here and you get 0.12 similarly you do it for others and then you find out the total $CO_2$ per functional unit.

So, this is what actually we did in that particular exercise. In, but these calculations if you are using a I will see a software, these calculations are already done in the software, but to again as I said earlier you as a researcher has to make sure that the calculations are correct. You cannot just say that the calculation is already done and this is what I got from the computer. You need to understand it and you need to make sure that the calculations are correct. So, that was in terms of the data and the databases and the data how the data is available in the database, and how we use this database in terms of doing the calculation.

Since, again most of these are done by the computers we kind of take it as a black pox, but you need to careful when doing that. So, once you have all these data now if you look at the last slide the bottom part here we have this 14.5 $CO_2$ equivalent per functional unit. So, now, this has an impact. So, we have an impact of because of this carbon dioxide emissions or equivalent carbon not only carbon dioxide there are other factors in there as well other emissions in there they are all has been put a as a as c s as $CO_2$. So, because of that there is an impact.

So, now we will look at how we do those impact assessments. So, what does that mean that this much CO2 equivalent is released to the atmosphere. That is great this much CO2 s equivalent is released. So, what we get with impact or what kind of impact it has on the environment. When we say environment is a big thing, what kind of impact it has on certain parameters what which we measure for water waste water sorry water air soil and other factors which we will look at in you may be look at this impact assessment which is again.

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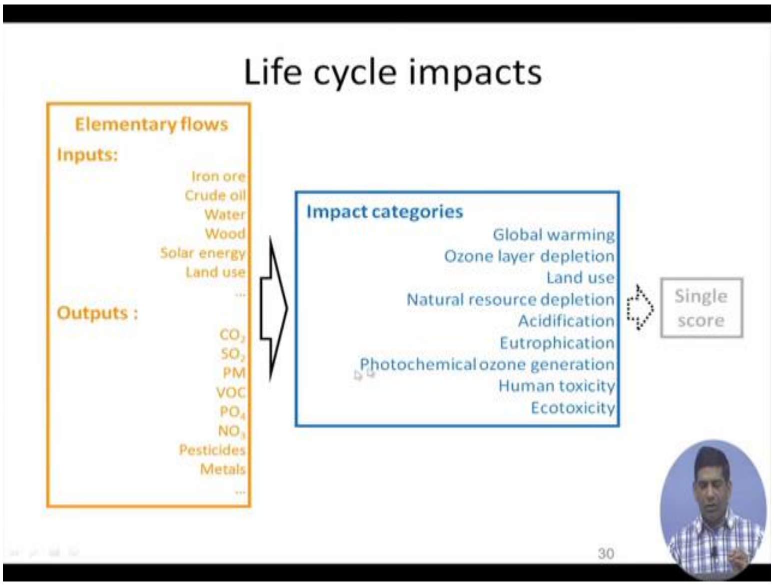


This slide you saw earlier this is the elementary flow. From the elementary flow we had this input and output. From this input and output we got that CO2 equivalent coming out you just saw an example how we calculate that. Now we want to see with the CO2 equivalent that coming out, what kind of impact we need to consider. There are different impact categories we looked at. There was global warming ozone layer depletion change in land use natural resource, acidification, eutrophication, photochemical, ozone generation, human toxicity, Eco toxicity. So, all those different aspects are there different impact categories are there. And then you can come up with a single score, that is what we talked about that earlier as well it was very similar to when you have a like a BSC sunsets or nationally stock exchange those kind of stuff.

So, in terms of the impact categories we will look at. So, different impact categories we had this global warming; so global warming.

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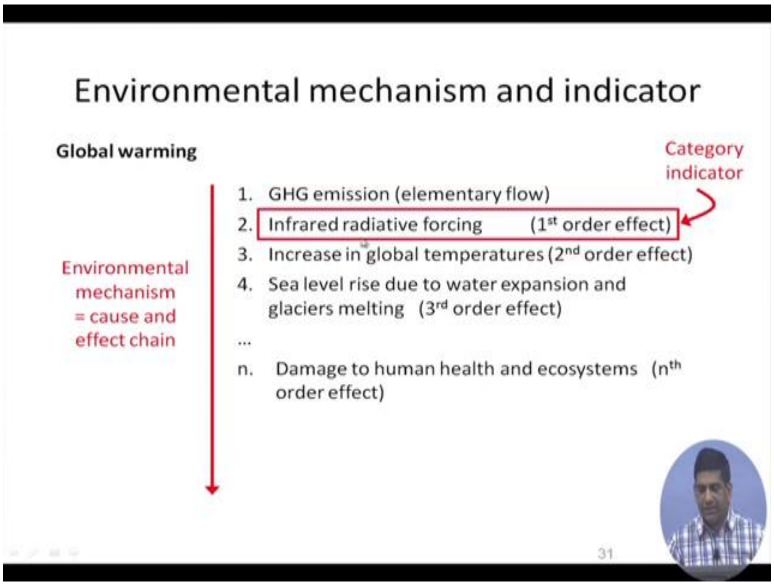


So, we will look at some of this say the GHG emissions. Again it is a like it has a global warming environmental mechanism. It is a there is a cause and effect chain, because when she has the GHG emissions that is your elementary flow, that leads to infrared radiative forcing. That is the first order effect that can again further lead to increase in global temperature. That is the second order effect. Then can be sea water rise due to water expansion. Because if there is an increase in global temperature what happens. If you remember from thermal coefficient, of thermal coefficient, when the water gets heated up water will expand is not it. So, when we looking at the small volume of water that may not be a big deal, but when we are looking at a big volume of water that also has some impact. So, the sea level has a rise because of water expansion and glaciers are also melting. So, that we consider third level impact.

And then similarly fire leg you will have a nth level impact, we will use it say has a damage to human health and ecosystem. So, that is our nth order impact nth order effect. So, this is how different levels of impact that you have in terms of the greenhouse gas. And some different greenhouse gases have taken different time, and different level in terms of this different kind of impact. So, infrared radiative forcing we have taken it as a one indicator. We have taken a category indicator in terms of global warming as infrared radiative forcing the first order effect that we have taken it for that.

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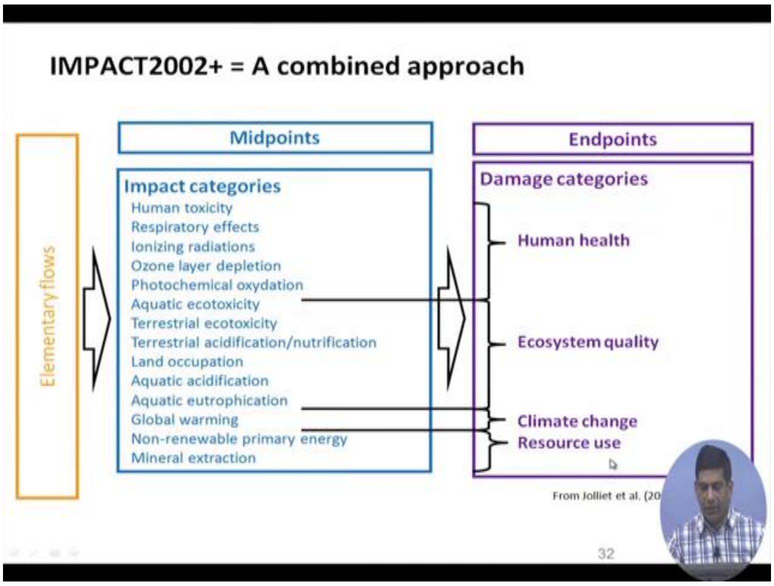


So, elementary flow again, in elementary flow you have different impact categories, where you have human toxicity, respiratory, ionizing, radiations, ozone layer, photochemical and all that say, then aquatic acidification nonrenewable primary energy and all that. So, these are these are called mid points here this is an impact 2002 plus which is a combined approach, where we have both midpoint and endpoint kind of approach. And this is published on this particular paper Jolliet et al 2003. And we many places are still this. This is a popular again as I said earlier there are different approach, we used in terms of impact assessment depending on which coach you are more comfortable with people go with that, but this impact 2002 plus, and recipe 2009 those are the most popular ones look at recipe 2009 as well later on in the course.

So, in terms of these are the mid points, those are the impact categories for midpoints. And then from this midpoint we go to the endpoint. For example, we take certain of these criteria which leads to human health issues some other criteria lead to the ecosystem quality the global warming is related to the climate change and then the last 2 is related to the resource use. So, in terms of these midpoint categories this is your endpoint category. This is also known as the damaged categories the midpoints are also known as the impact categories.

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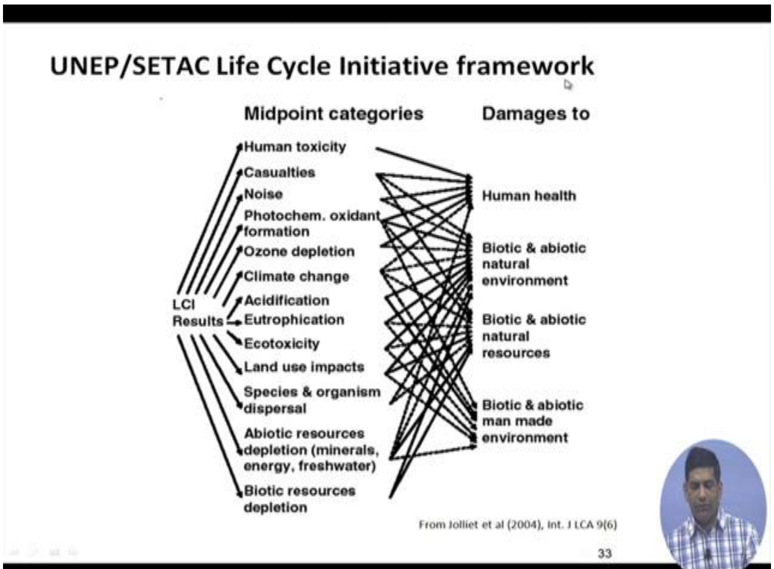


**Table 2.14.** *Lifetimes, radiative efficiencies and direct (except for $CH_4$) GWPs relative to $CO_2$. For ozone-depleting substances and their replacements, data are taken from IPCC/TEAP (2005) unless otherwise indicated.*

| Industrial Designation or Common Name (years) | Chemical Formula | Lifetime (years) | Radiative Efficiency (W m⁻² ppb⁻¹) | Global Warming Potential for Given Time Horizon: SAR‡ (100-yr) | 20-yr | 100-yr | 500-yr |
|---|---|---|---|---|---|---|---|
| Carbon dioxide | $CO_2$ | See below[a] | [b]$1.4\times10^{-5}$ | 1 | 1 | 1 | 1 |
| Methane[c] | $CH_4$ | 12[c] | $3.7\times10^{-4}$ | 21 | 72 | 25 | 7.6 |
| Nitrous oxide | $N_2O$ | 114 | $3.03\times10^{-3}$ | 310 | 289 | 298 | 153 |
| ***Substances controlled by the Montreal Protocol*** | | | | | | | |
| CFC-11 | $CCl_3F$ | 45 | 0.25 | 3,800 | 6,730 | 4,750 | 1,620 |
| CFC-12 | $CCl_2F_2$ | 100 | 0.32 | 8,100 | 11,000 | 10,900 | 5,200 |
| CFC-13 | $CClF_3$ | 640 | 0.25 | | 10,800 | 14,400 | 16,400 |
| CFC-113 | $CCl_2FCClF_2$ | 85 | 0.3 | 4,800 | 6,540 | 6,130 | 2,700 |
| CFC-114 | $CClF_2CClF_2$ | 300 | 0.31 | | 8,040 | 10,000 | 8,730 |
| CFC-115 | $CClF_2CF_3$ | 1,700 | 0.18 | | 5,310 | 7,370 | 9,990 |
| Halon-1301 | $CBrF_3$ | 65 | 0.32 | 5,400 | 8,480 | 7,140 | 2,760 |
| Halon-1211 | $CBrClF_2$ | 16 | 0.3 | | 4,750 | 1,890 | 575 |
| Halon-2402 | $CBrF_2CBrF_2$ | 20 | 0.33 | | 3,680 | 1,640 | 503 |
| Carbon tetrachloride | $CCl_4$ | 26 | 0.13 | 1,400 | 2,700 | 1,400 | 435 |
| Methyl bromide | $CH_3Br$ | 0.7 | 0.01 | | 17 | 5 | 1 |
| Methyl chloroform | $CH_3CCl_3$ | 5 | 0.06 | | 506 | 146 | 45 |
| HCFC-22 | $CHClF_2$ | 12 | 0.2 | 1,500 | 5,160 | 1,810 | 549 |
| HCFC-123 | $CHCl_2CF_3$ | 1.3 | 0.14 | 90 | 273 | 77 | 24 |
| HCFC-124 | $CHClFCF_3$ | 5.8 | 0.22 | 470 | 2,070 | 609 | 185 |
| HCFC-141b | $CH_3CCl_2F$ | 9.3 | 0.14 | | 2,250 | 725 | 220 |
| HCFC-142b | $CH_3CClF_2$ | 17.9 | 0.2 | 1,800 | 5,490 | 2,310 | 705 |
| ***Perfluorinated compounds*** | | | | | | | |
| Sulphur hexafluoride | $SF_6$ | 3,200 | 0.52 | 23,900 | 16,300 | 22,800 | 32,600 |
| Nitrogen trifluoride | $NF_3$ | 740 | 0.21 | | 12,300 | 17,200 | 20,700 |
| PFC-14 | $CF_4$ | 50,000 | 0.10 | 6,500 | 5,210 | 7,390 | 11,200 |
| PFC-116 | $C_2F_6$ | 10,000 | 0.26 | 9,200 | 8,630 | 12,200 | 18,200 |

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So, there are lot of impact categories. So, UNEP SETAC life cycle initiative framework if you remember this is from that. So, they have different from the LCI result. Some may have a based on our understanding of toxicity and all that associated with different emissions coming out. Some may lead to human toxicity problem casualties, noise, photochemical, oxidation, ozone, climate change acidification. So, these are different kind of impact over there.

So, these are our midpoint categories, but from these midpoint categories when we go to the endpoint with the damaged category. So, for one particular for example, in if you look at the types of casualties or this casualty because it has a human health issues, it is a biotic abiotic natural environment also biotic abiotic natural resources. So, lot of in terms of the damaged categories, one of the midpoint categories could be in multiple damage categories. So, because they have a multiple kind of (Refer Time: 23:56) it is very difficult to pinpoint which causes what. So, as you can see kind of in this this particular area it is totally kind of mixed up, where one particular midpoint category can end up in several damaged categories.

So, then we when we do that, we need to do what is known as the weighted we need to do an allocation. So, what in terms of midpoint category when it goes to more than one damaged category in what ratio we need to divide those damaged categories over there.

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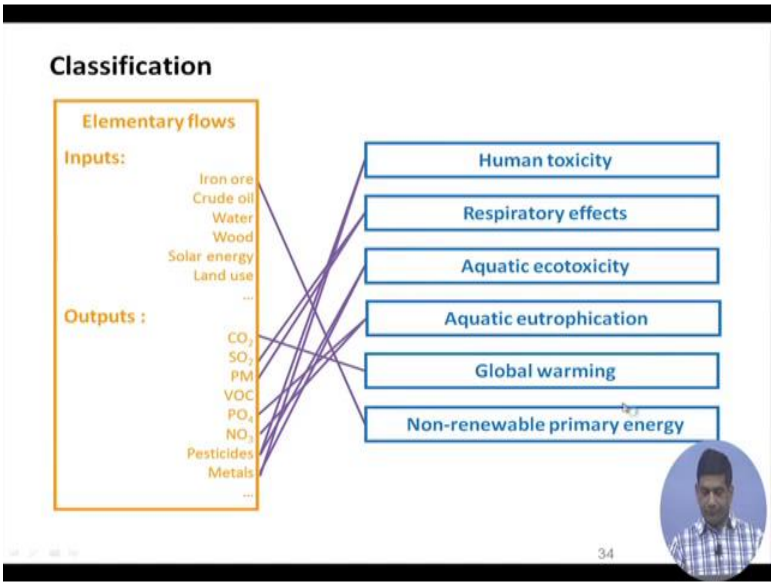


So, from the elementary flow you have this human toxicity respiratory effect, aquatic toxicity, eutrophication, global warming nonrenewable primary energy. So, these are the impact kind of categories which is out there. So, in terms of let us look at some of these characterization scenarios. So, where say if you have look at the global warming scenario 1 kg of CO2 that is considered as the base.

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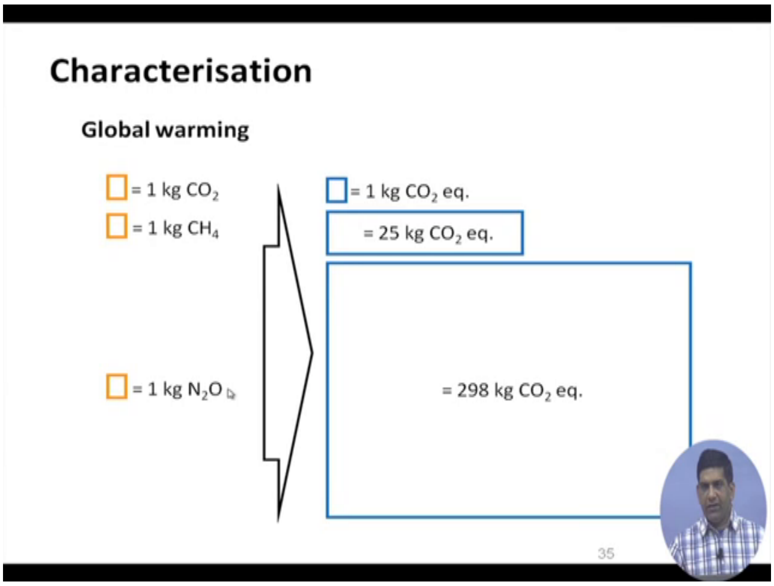


So, if you look at 1 kg of methane, 1 kg of for 1 kg CO2 it is equivalent is of course, 1 kg of CO2, but 1 kg of methane the equivalent is 25 kg of CO2 equivalent. So, it is 25 times more potent than CO2.

In terms of N2O it is 298 kg of CO2 per equivalent. So, N2O which is a nitric oxide, it is a much it is like almost what 12 times more potent than methane. And 298 times more potent than CO2, but you do not hear too much about N2O as you hear about the CO2 or methane emissions in terms of climate change global warming, what is the reason for that? Again these kind of questions should come to your mind when you are looking at this kind of slides you this this type of question should come into mind what is the what we are why this does not like shows up in our scientific literature that much, because N2O although it has a very high impact, N2O does not have an it is not that much present into the environmental system. The release of N2O is at very low level as supposed to release of methane or CO2.

So, that is the reason why you do not see in this N2O being making news that much as you see the news being made in terms of methane released or in terms of the CO2 released into that one. Some N2O does get released in say composed plants, those places there is a there are some papers you will find some papers, where they look at the N2O more closely, but in terms of a bigger picture situation N2O although it is very bad it is a when I say bad it is not a technical term, you see it has more harmful effects in terms of global warming impact it is a more portent global warming impact as oppose to methane or CO2, but still you do not see that much of like attention being paid to that.

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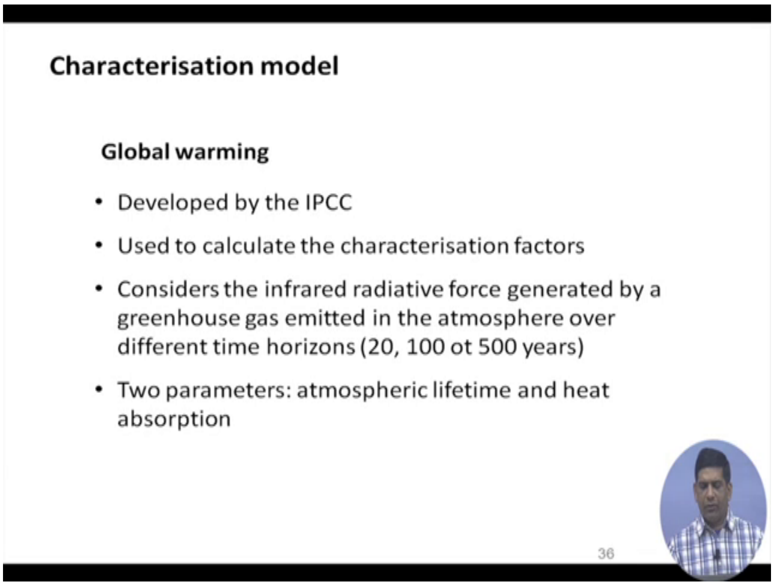


So, there are some characterization model which is developed by IPCC the international like panel for climate change. And they do calculate the characterization factor they do some characterization factor calculation. They use infrared radiative forcing generated by greenhouse gas and with different time horizons 20 years 100 years or 500 years. So, at different time horizon they did that. And they look at 2 things atmospheric lifetime, what it is how long it will last in the atmosphere as well as the heat absorption, how much heat is absorbed from this particular global warming stuff.

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**Table 2.14.** *Lifetimes, radiative efficiencies and direct (except for $CH_4$) GWPs relative to $CO_2$. For ozone-depleting substances and their replacements, data are taken from IPCC/TEAP (2005) unless otherwise indicated.*

| Industrial Designation or Common Name (years) | Chemical Formula | Lifetime (years) | Radiative Efficiency ($W\ m^{-2}\ ppb^{-1}$) | Global Warming Potential for Given Time Horizon: SAR‡ (100-yr) | 20-yr | 100-yr | 500-yr |
|---|---|---|---|---|---|---|---|
| Carbon dioxide | $CO_2$ | See below[a] | [b]$1.4 \times 10^{-5}$ | 1 | 1 | 1 | 1 |
| Methane[c] | $CH_4$ | 12[c] | $3.7 \times 10^{-4}$ | 21 | 72 | 25 | 7.6 |
| Nitrous oxide | $N_2O$ | 114 | $3.03 \times 10^{-3}$ | 310 | 289 | 298 | 153 |
| ***Substances controlled by the Montreal Protocol*** | | | | | | | |
| CFC-11 | $CCl_3F$ | 45 | 0.25 | 3,800 | 6,730 | 4,750 | 1,620 |
| CFC-12 | $CCl_2F_2$ | 100 | 0.32 | 8,100 | 11,000 | 10,900 | 5,200 |
| CFC-13 | $CClF_3$ | 640 | 0.25 | | 10,800 | 14,400 | 16,400 |
| CFC-113 | $CCl_2FCClF_2$ | 85 | 0.3 | 4,800 | 6,540 | 6,130 | 2,700 |
| CFC-114 | $CClF_2CClF_2$ | 300 | 0.31 | | 8,040 | 10,000 | 8,730 |
| CFC-115 | $CClF_2CF_3$ | 1,700 | 0.18 | | 5,310 | 7,370 | 9,990 |
| Halon-1301 | $CBrF_3$ | 65 | 0.32 | 5,400 | 8,480 | 7,140 | 2,760 |
| Halon-1211 | $CBrClF_2$ | 16 | 0.3 | | 4,750 | 1,890 | 575 |
| Halon-2402 | $CBrF_2CBrF_2$ | 20 | 0.33 | | 3,680 | 1,640 | 503 |
| Carbon tetrachloride | $CCl_4$ | 26 | 0.13 | 1,400 | 2,700 | 1,400 | 435 |
| Methyl bromide | $CH_3Br$ | 0.7 | 0.01 | | 17 | 5 | 1 |
| Methyl chloroform | $CH_3CCl_3$ | 5 | 0.06 | | 506 | 146 | 45 |
| HCFC-22 | $CHClF_2$ | 12 | 0.2 | 1,500 | 5,160 | 1,810 | 549 |
| HCFC-123 | $CHCl_2CF_3$ | 1.3 | 0.14 | 90 | 273 | 77 | 24 |
| HCFC-124 | $CHClFCF_3$ | 5.8 | 0.22 | 470 | 2,070 | 609 | 185 |
| HCFC-141b | $CH_3CCl_2F$ | 9.3 | 0.14 | | 2,250 | 725 | 220 |
| HCFC-142b | $CH_3CClF_2$ | 17.9 | 0.2 | 1,800 | 5,490 | 2,310 | 705 |
| ***Perfluorinated compounds*** | | | | | | | |
| Sulphur hexafluoride | $SF_6$ | 3,200 | 0.52 | 23,900 | 16,300 | 22,800 | 32,600 |
| Nitrogen trifluoride | $NF_3$ | 740 | 0.21 | | 12,300 | 17,200 | 20,700 |
| PFC-14 | $CF_4$ | 50,000 | 0.10 | 6,500 | 5,210 | 7,390 | 11,200 |
| PFC-116 | $C_2F_6$ | 10,000 | 0.26 | 9,200 | 8,630 | 12,200 | 18,200 |

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So, let us look at this particular slide and then we will end this module. So, here in terms of different type of here on the left side are our different types of substance controlled by Montreal protocol, per fluorinated compounds carbon dioxide methane nitrous oxide. So, their lifetime is there in terms of in terms of their lifetime methane 12 years' nitrous oxide 100 and 14 years and for the different we have different lifetime given over here. Radioactive sorry not radioactive, it is a radiative efficiency has been calculated for each one of them. And then we can calculate the global warming potential for that for different years based on the model that is being developed and you can see different global warming potentials. So, CO2 of course, it will be all one. So, methane as I said for 100 years it is 25 times and for 100 years nitrous oxide is 298 times. So, there are if you go for 20 years it becomes 72 500 years it becomes 7.6 in terms of the potential as compared to carbon dioxide.

And then there are others as you can see there are most of them are much higher except few which are lower, and that is how you see that different impact is coming up. Again we are not I am not going into the calculation of each one of these, how these were arrived at. So, you need if you are interested you can look at this IPCC report, which towards the end of that report towards the appendix. They do have calculations associated with that how these numbers were calculated, but for this class what you need to understand is based on the different time horizon the impact is different. And then with respect to carbon dioxide we have like these are the ratio in terms of particular how much they are they have higher global warming potential as compared to $CO_2$, $CO_2$ is used as a base.

So, with that we will close this particular module. And then we will start looking at some of this LCI a how life cycle impact assessment is done. So, we will we kind of a started looking at that, but we will do some of those like examples the practical examples of impact assessment towards the next module. So, if you think about. So, far we have started with in terms of LCA methodology, which I have been covering we covered part of it in week 4 and then in week 5, now we are looking at it we started with a goal and scope definition we looked at the function functional unit we look at the LCI inventory.

Now once you have the LCI inventory done, you have to try to understand you have to start looking at the impact. So, right now we are doing this impact assessment and then after impact assessment the last part will be the interpretation. So, once we do that it will be a total cover of a broad LCA exercise steps, and then after that I will also kind of give you a quick overview of what are the key points of a good LCA and then we will move to other topics as we progress in the course.

So, thank you and enjoy like I am enjoying teaching this course. So, I hope you are enjoying watching it, and I look forward to see you again in the next module.