Energy Resources, Economics, and Sustainability

Prof. Pratham Arora

Hydro and Renewable Energy Department

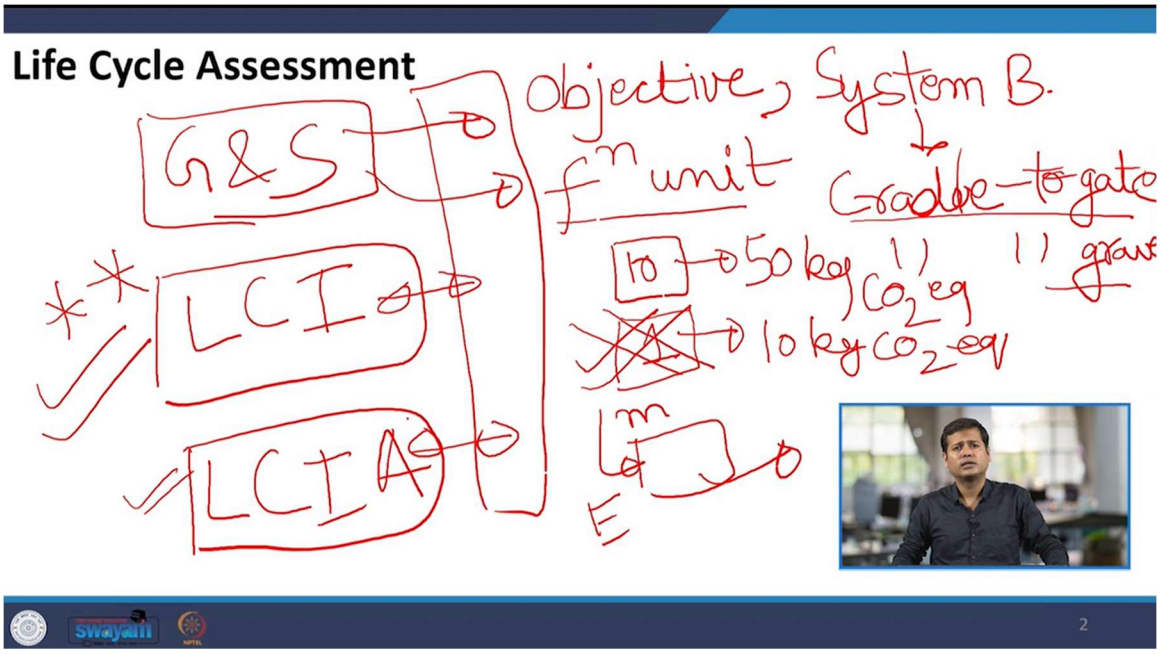
Indian Institute of Technology Roorkee, Roorkee, India

Week – 08

Lecture – 04

Lecture 40 - SimaPro Tutorial

Hello everyone, welcome to another lecture of the series Energy Resources, Economics and Sustainability. My name is Ankur Singhal, I am a research scholar working under the guidance of Prof. Pratham Arora at the Dept. of hydro and renewable energy. So in the previous classes, we have studied the basics of life cycle assessment. In this class, we will see how in actuality a life cycle assessment modeling is conducted on a software itself. So the software that I have chosen for this class is SIMAPRO. So it is a license based software and we will see how SIMAPRO works. So before we begin, let us brush up our concepts of life cycle assessments that I will be using in today's class.



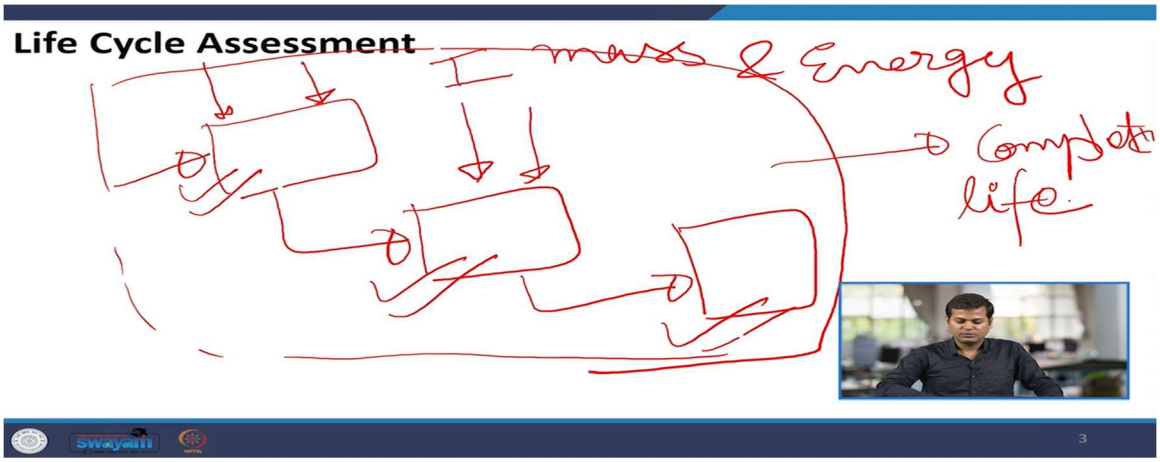
So as we all know and we have read in the previous classes, the life cycle assessment consists of four basic steps. So the first step is goal and scope. So goal and scope consists

of the objectives of the study. So objective means why are we conducting this life cycle assessment? What is the need to do the life cycle assessment of the particular process or system? Now the next part in goal and scope itself is the system boundary.

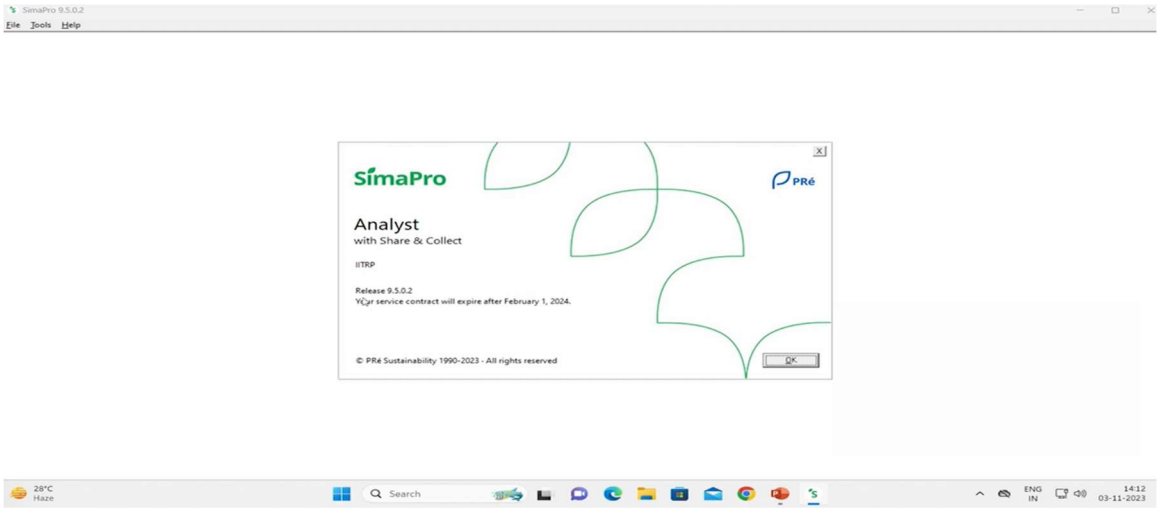
So the system boundary needs to be defined before we conduct a modeling of the life cycle assessment. So system boundary can be cradle to gate or even cradle to grave. So the basic difference between these two system boundaries is if we conduct a life cycle assessment of cradle to grave, so the grave part consists of the disposal phase as well. Whereas in cradle to gate system boundary, we do not consider the disposal phase. So the next thing that is included in goal and scope is the functional unit of the study. We need to define the functional unit of the study beforehand before we model the life cycle assessment of that system or process. So functional unit, why is it necessary? It is important to understand functional unit acts as a vantage point to compare the results of two or more systems or processes. So let us consider an example. Let us say a factory produces 10 units of a commodity which results in 50 kg CO2 equivalent emissions. Let us take another example where another factory produces 1 unit of the same commodity but it produces 10 kg CO2 equivalent emissions. Now if we want to compare which of these factories is more environmentally sustainable, then we need a functional unit because at the first glance we can see that 50 kg CO2 equivalent seems more. But if we define the functional unit to be 1 unit of the commodity, 1 piece of the commodity, then we can see the second one is larger and hence it performs worse in terms of emissions. So this portion covers the goal and scope which I will be using in the software as well. Now the second step of life cycle assessment is LCI which is life cycle inventory. This is the most important step in a life cycle assessment modelling because this consists of collection of data.

So whatever processes we are modelling, the inputs to them, the outputs to them, inputs can be both mass, energy, all these data collection is known as life cycle inventory, building the inventory of the model. So if the data is comprehensive, if the data is precise, then only life cycle assessment results will come out to be precise. So that is why this is the most important step of a life cycle assessment modelling. Now the third step is life cycle impact assessment. In this step, we actually get the results how much emissions will occur, how much human toxicity will occur, how much resource scarcity will occur.

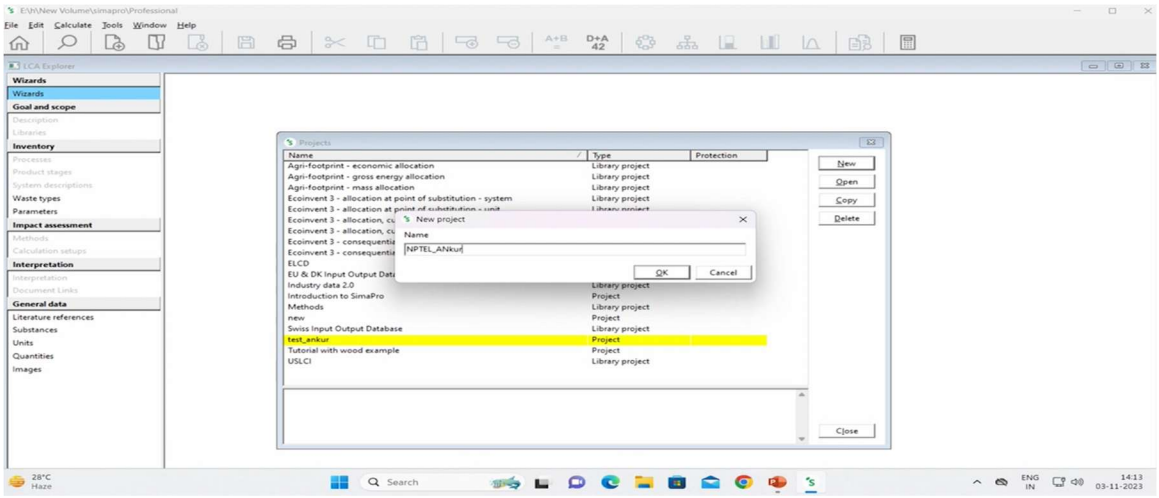
So this is the final step in which we get the results whereas the fourth phase is also there the interpretation phase which goes on simultaneously with all these three steps. So these are the basic steps that are involved in a modelling of life cycle assessment.



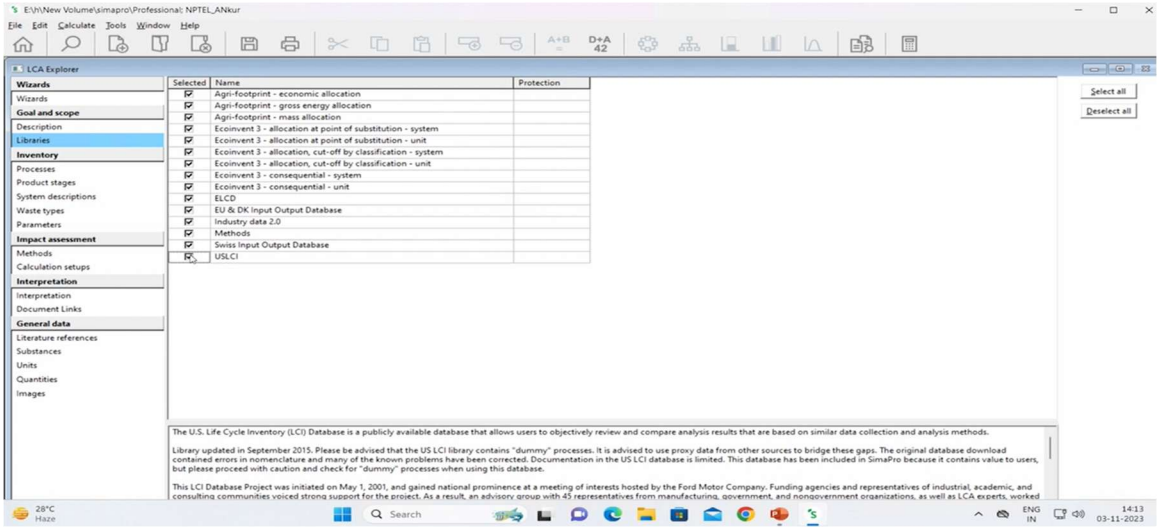
Now before we do modelling in the software, we need to know the various process blocks of a system. For example, if we are doing a life cycle assessment of a certain system boundary, a system we need to define various process blocks or items for that. We need to divide that portion into various process blocks and all the inputs to those process blocks need to be defined all the outputs. The output of one process block might go into the input of another process block and other inputs might also occur. So this kind of diagram needs to be drawn on paper beforehand before we do the modelling in the software. So these inputs can be both mass and energy. It can be anything, it can be materials, it can be the energy that we are consuming, it can be electricity, it can be gasoline energy, anything that we are using and then we need to define the system boundary and we will get our process block diagram. So these unit processes that I have shown in the diagram now, these can be modelled in SimaPro and then we will combine them to get the complete life cycle of the system. So now I will be shifting to the software to get ourselves a know-how. So how a life cycle assessment is conducted in SimaPro.



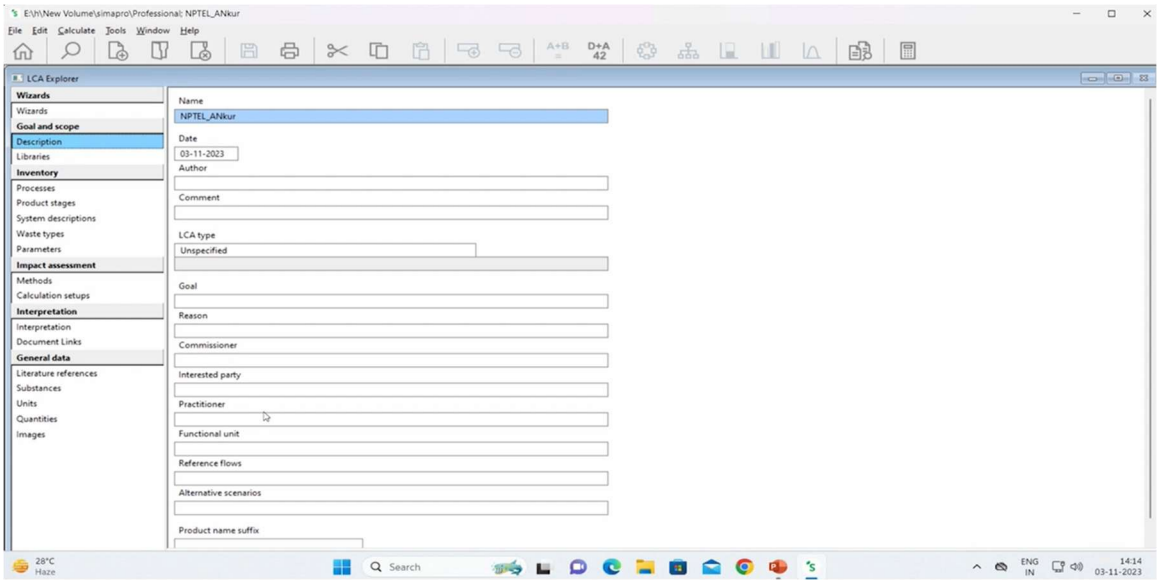
So I will be shifting to the software now. So this is the icon of SimaPro. I will double click it to open. So I have already registered it with my license as you can see the username. So I will click on OK. Now it is showing opening database, reading data.



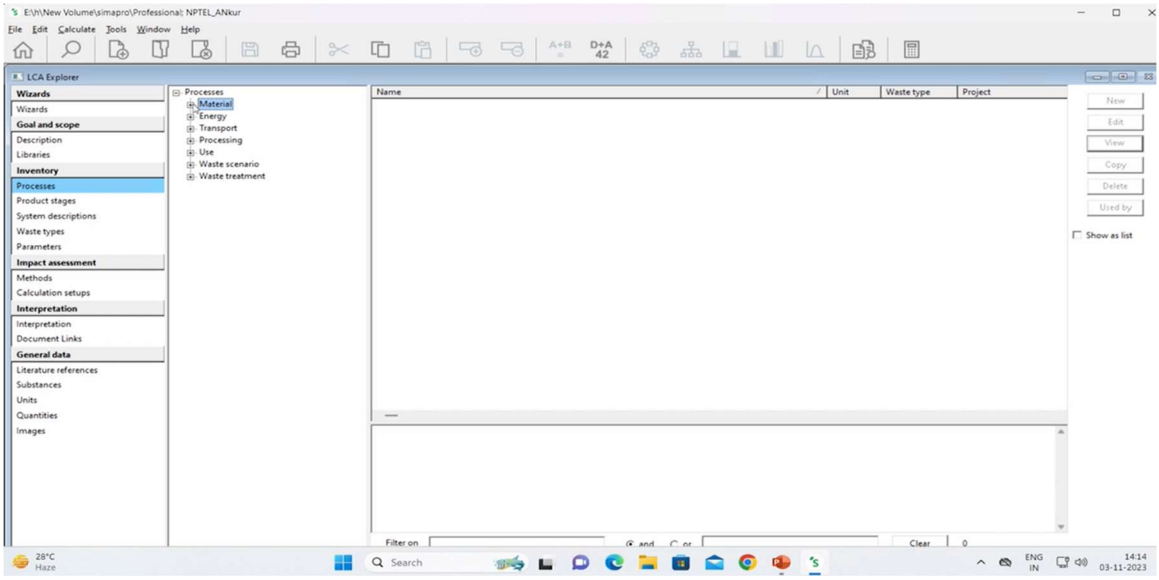
So after activation of SimaPro, you can see that there are various projects that are shown. So these are previous projects, the databases that are already present in the software. This one is made by me already. So what we can do is we can make a new project. Let's name it Nptel, my name, Ankur.



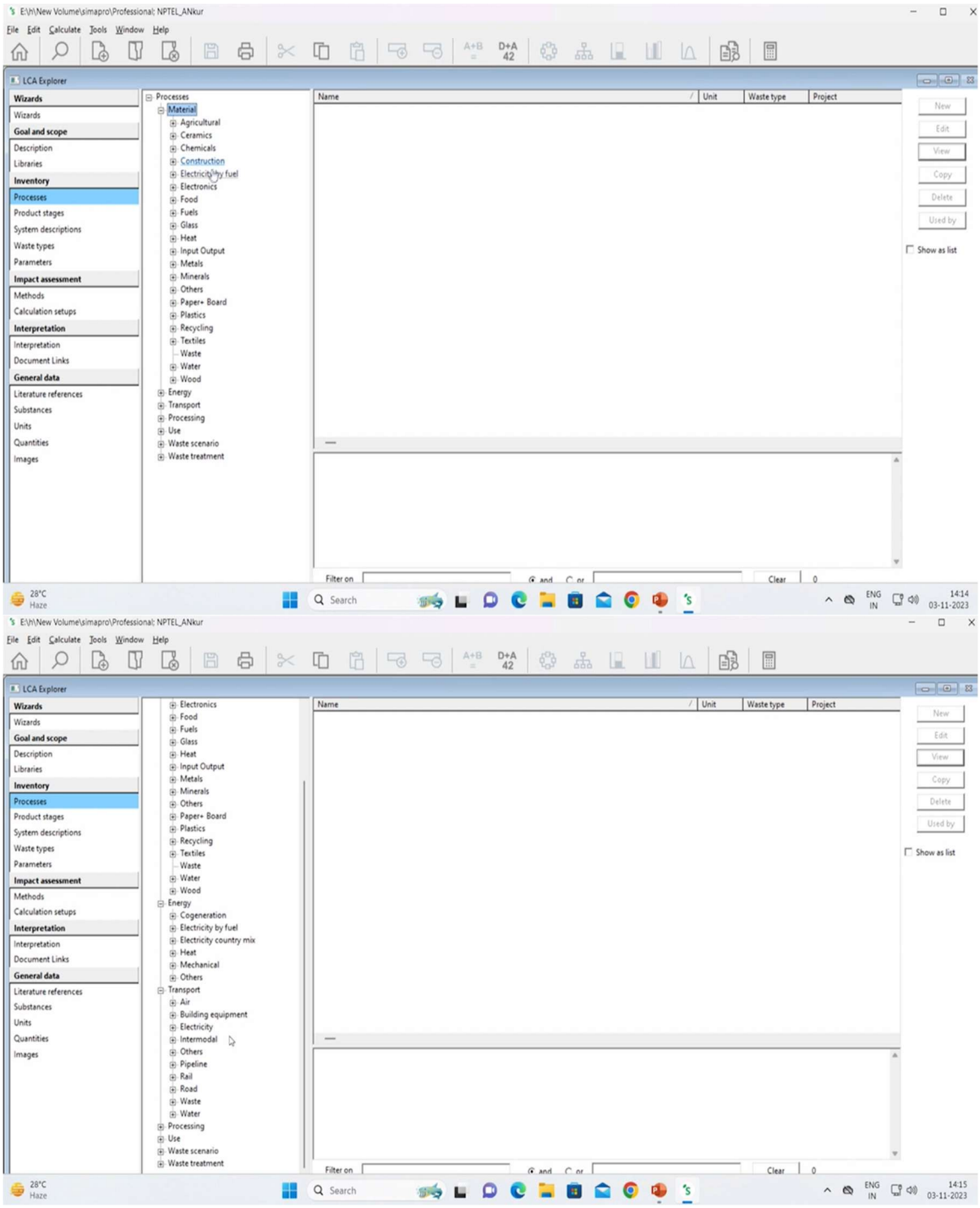
So as you can see a new project has been created in SimaPro and it is asking me to select the libraries I wish to use. So as you can see there are a variety of libraries that are available. I will click as you can see Agri-Footprint, Economic Allocation. So I will click all of them. EcoInvent database is also available or I can select one of them as well like EcoInvent, ELCD. Just to show you I will select all of them. So I can select these databases and I will click select all and these are the databases that will be available. So on the left side of the software, you can see description.



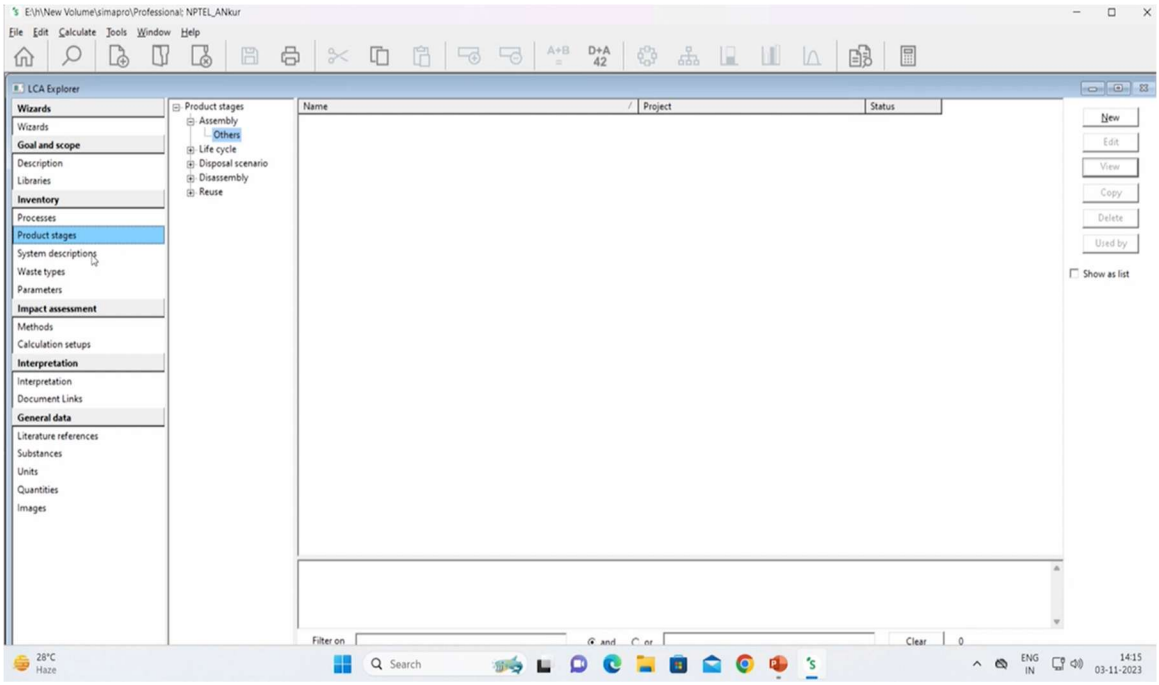
So it will be reading from the database, the description of the software, the databases. So this is my project name. So this is the date on which I have created. I can write whatever I want to, goal of the study for which I am going to conduct LCA and the functional unit, the reference flows, the alternative scenarios as we have discussed in the basics of life cycle assessment model. Now these are the libraries as I have already shown you.



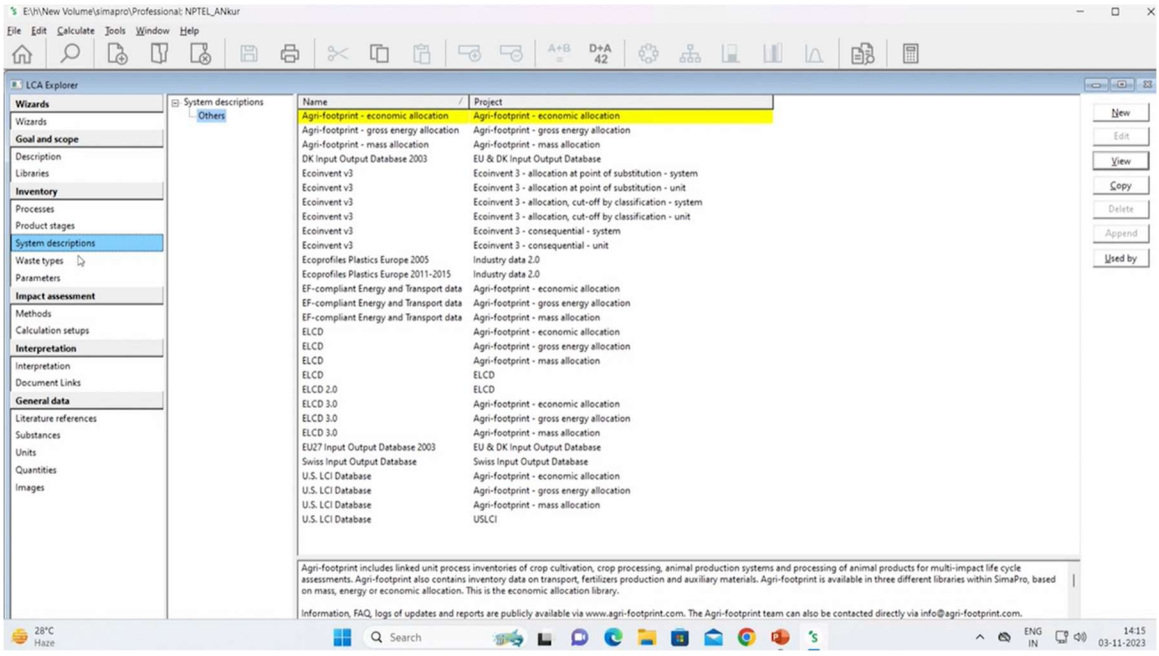
Now coming to the inventory part which is the most important part and these are the various processes that are available already modelled in SimaPro itself. So as you can see it is divided into materials, energy, transport, processing, use, waste scenarios and waste treatment. So these are the things that are already modelled in them.



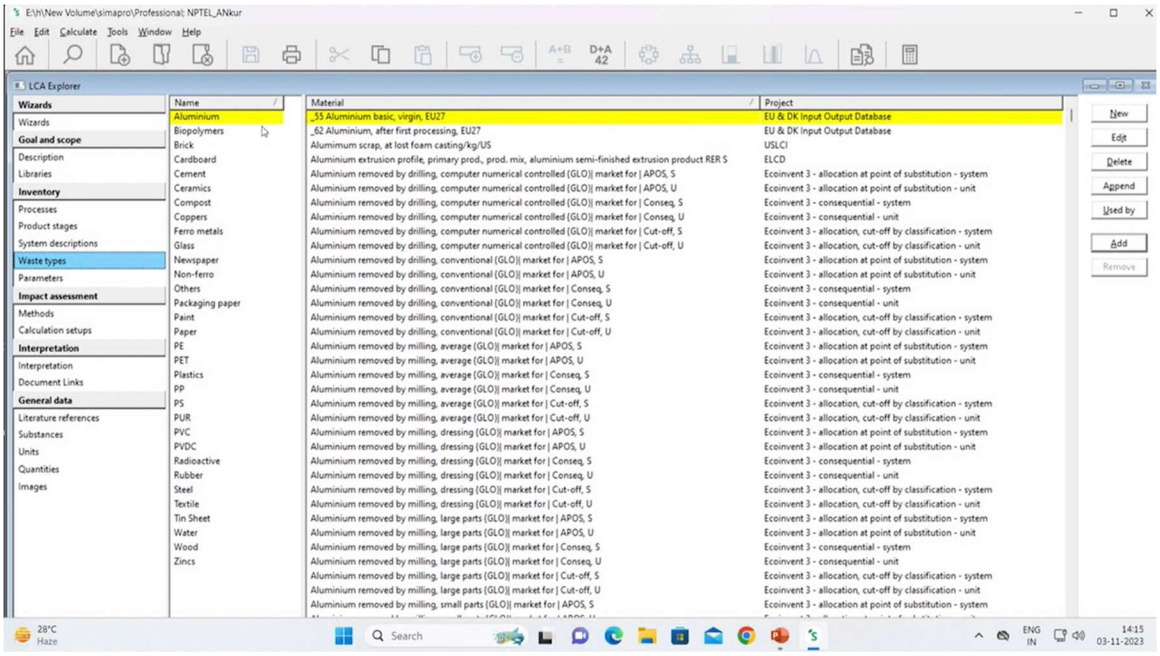
So in materials as you can see electronics, electricity by fuel, construction, fuels, glasses, heat, all those things are present. Energy is also there, co-generation, electricity by fuel, transportation, various methods of transportation is available. As you can see by air, building equipment, electricity. So all those things are available to us. Various industrial processes are also available and we can use them. We will come to this processes department later.



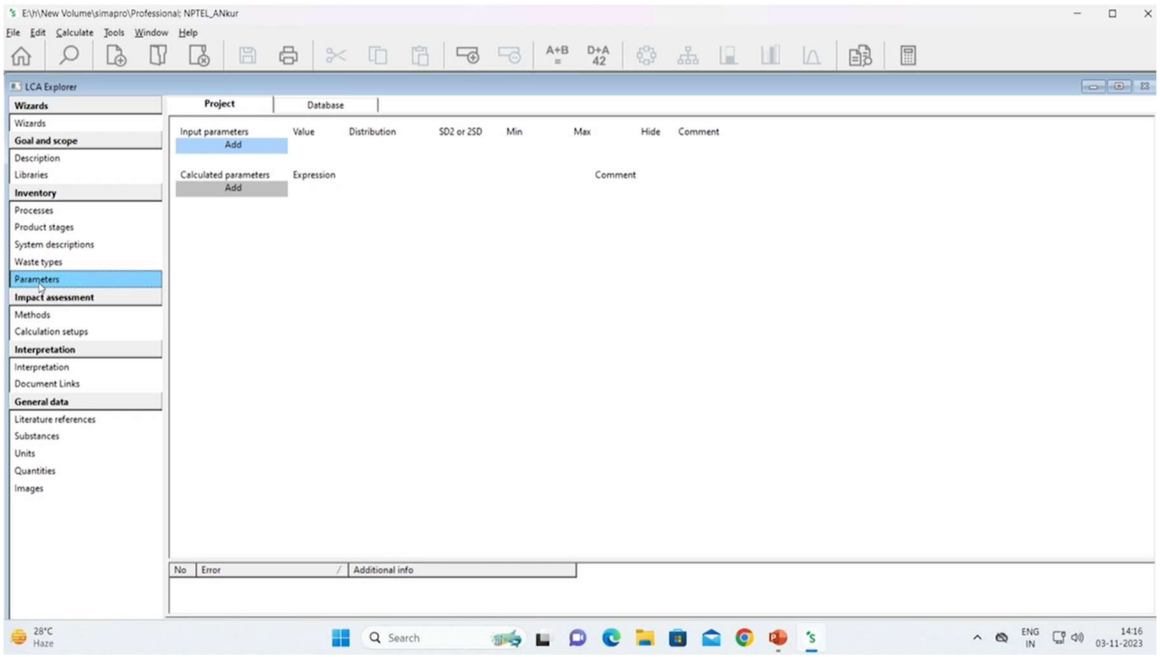
Now let's proceed to product stages. So here we can see assembly, life cycle, disposal scenario, disassembly and reuse. We need to model them and I will show you after we get a know how of the software interface that how we can create an assembly, a complete life cycle, disposal scenarios and all those things.



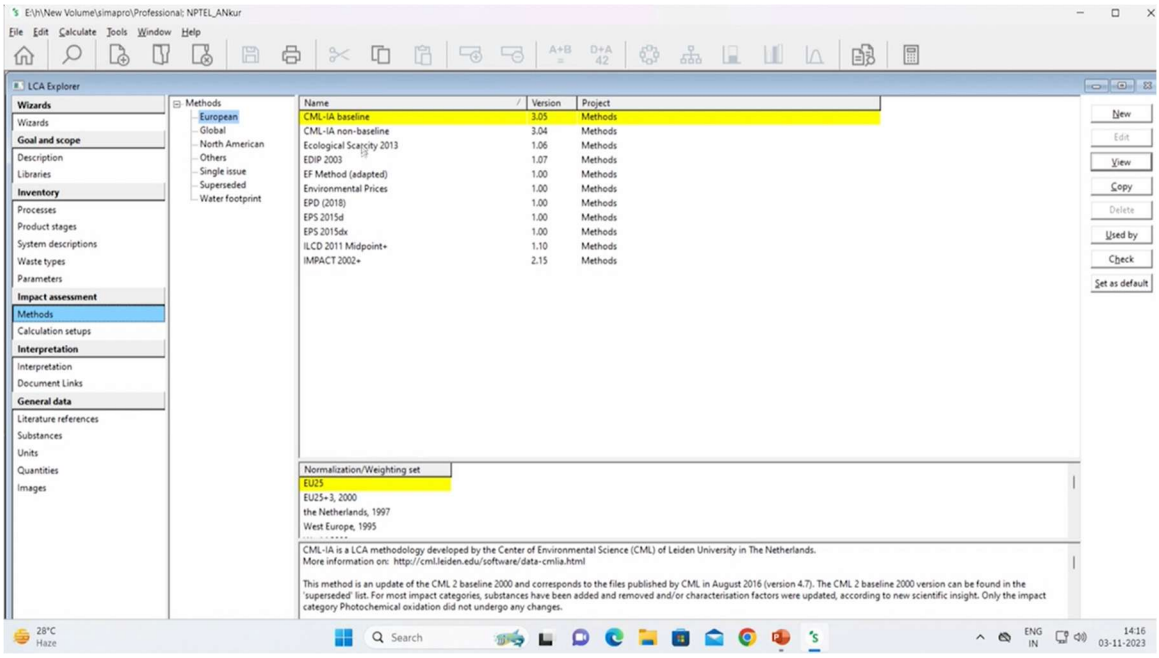
Now coming to the next part that is the system description of the databases that I have selected, the various waste types that are available as you can see particularing to the metals, glass, paper, all those kinds of waste types are available.



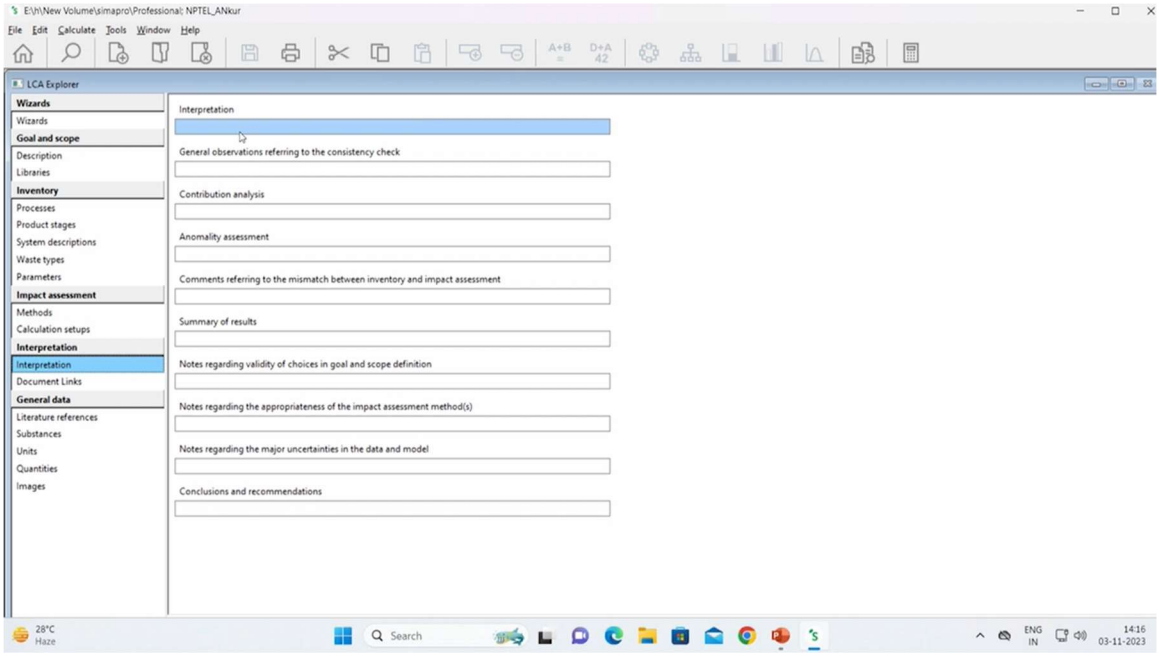
So as you can see this is for European Union and this is the eco-invent one. So all those things are available.



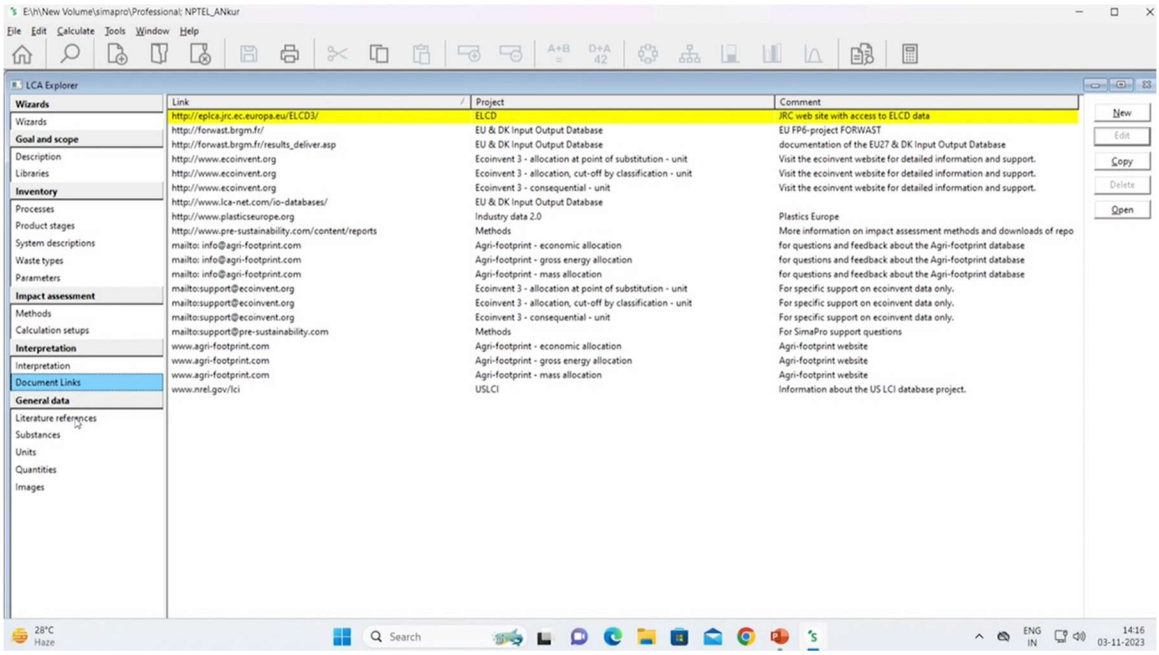
Now coming to the parameters, we will discuss on that how to do parameters and coming to the impact assessment methods.



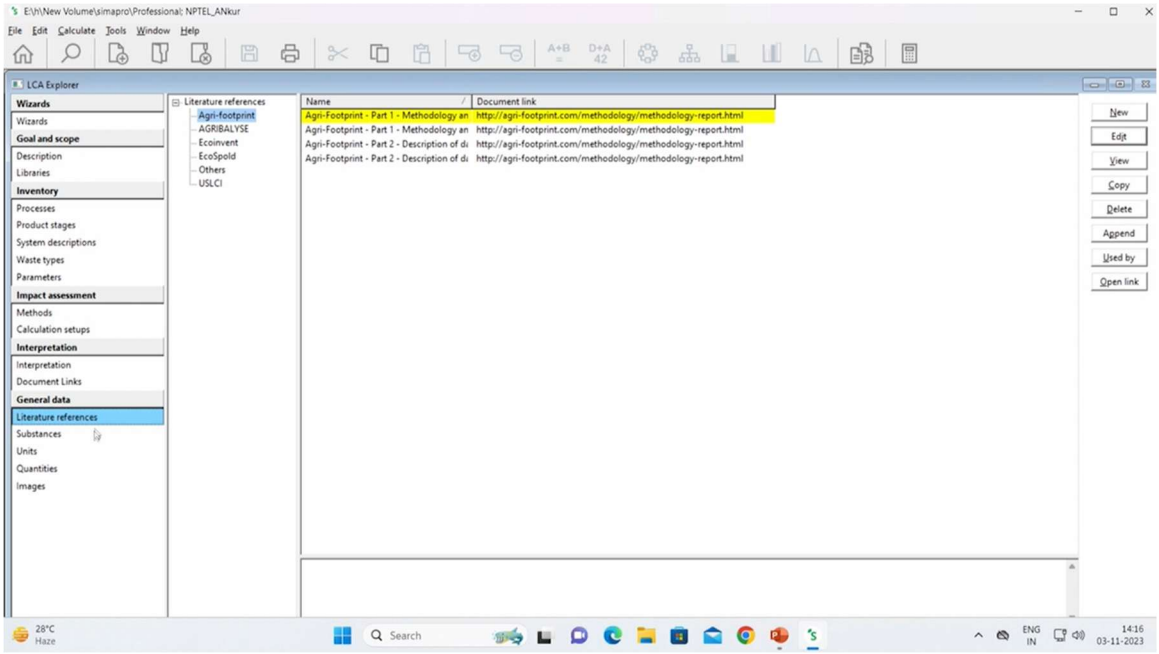
So CML is available for the European ones. The global methods are also available, recipe which is the most widely one used and all other things for impact assessment methods are available as well. Now these are the calculation steps. I can add whatever I can.



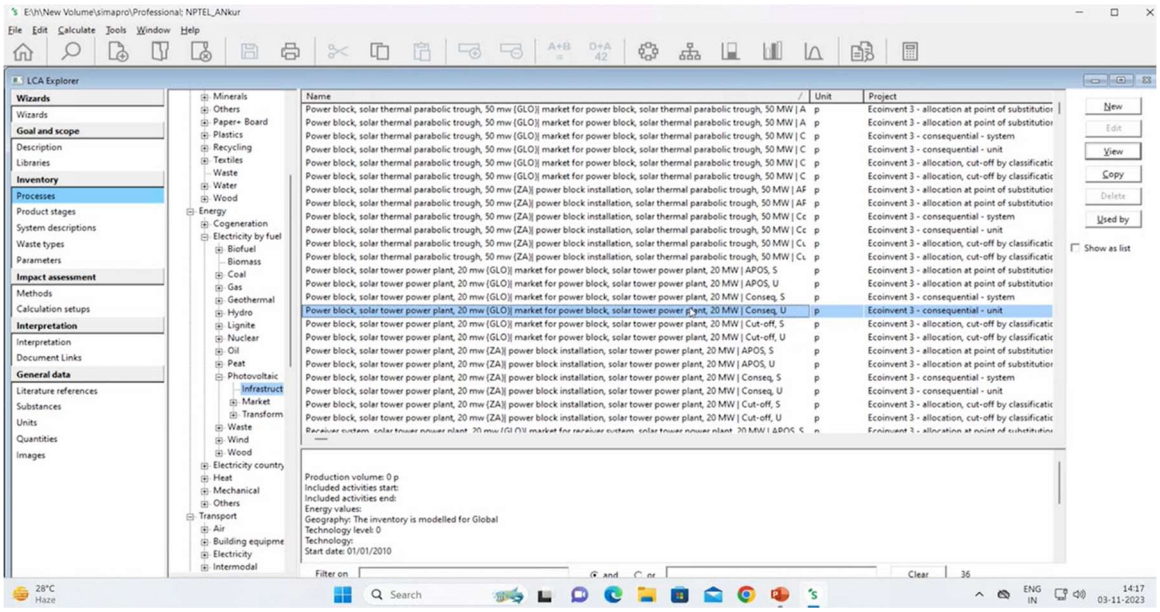
And coming to the interpretation phase, I can write interpretation of my results of my various steps.



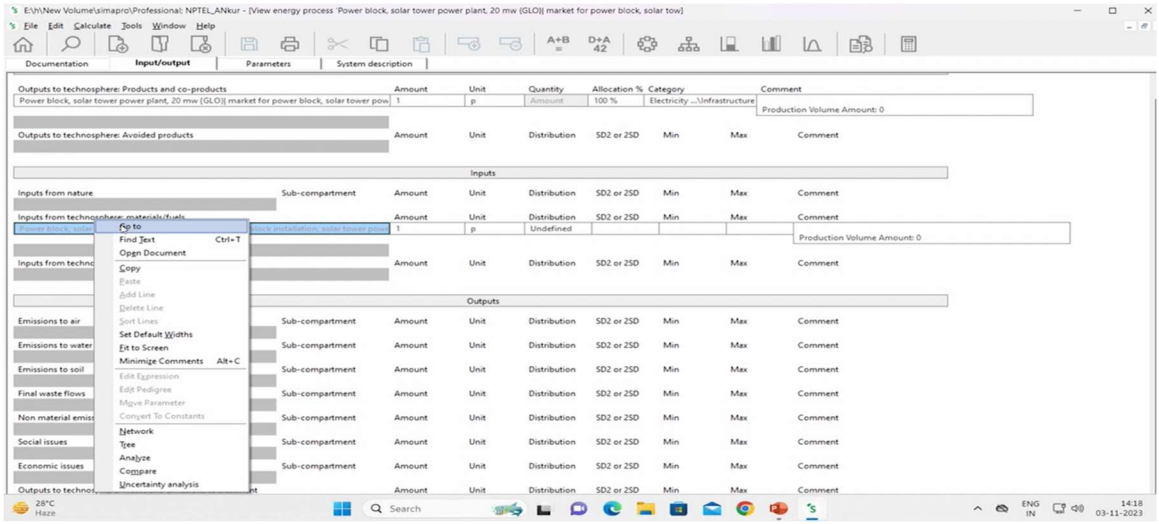
So this is the interface of the software and these are the links available for the documents and these are the links for references.



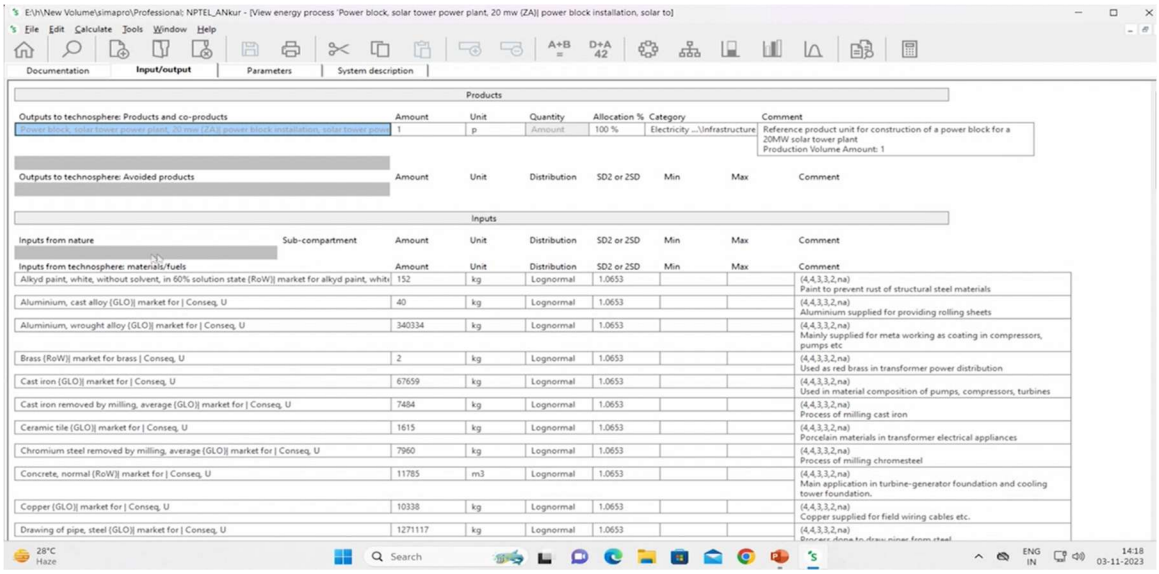
Now these are the literature references as you can see the substances, raw materials are available, acids, actinium and all other elements and units, what are the units used in this modeling, quantities and some images.



Now what we will do is, we will create a process. The first model that we will create, we will create a process so that we can compare its results to another one. Let's create a process or let's create a new material that we can use. Let's go to energy and electricity by fuel. So let's see what things are available already in there. So since we are talking about renewable energy, we can go to photovoltaic. So these are the processes that are already available.These are already modeled. Now let's have a look how they look like. How they are modeled in Simapro itself. So as you can see this is for global and also though power rating is also given, this is for 20 megawatt. So let's have a look about that.



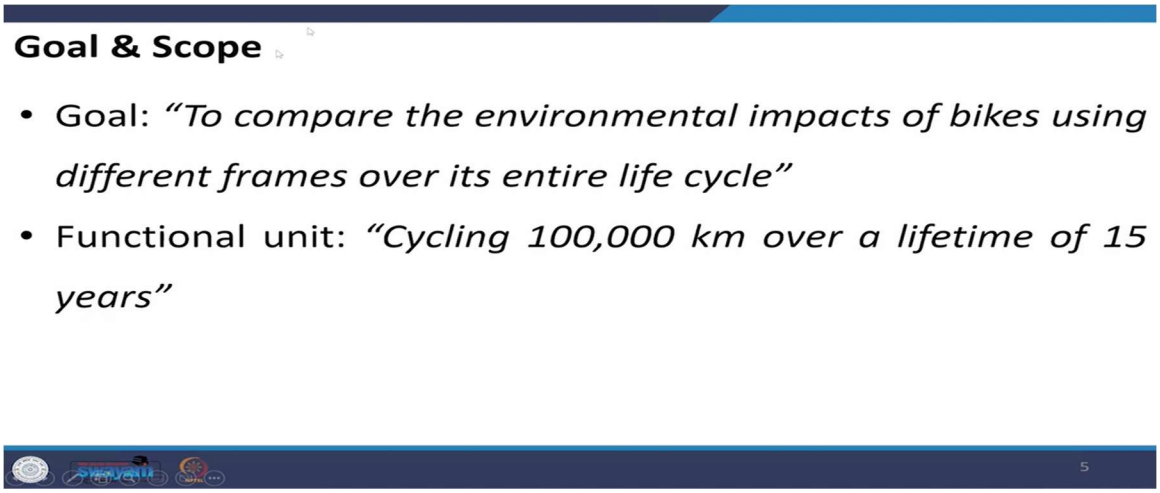
So whenever I double click on the process, I can see various tabs there. So this is the input and output tab. So output is power block, solar tower plant, 20 megawatt which is modeled for global. So for the inputs, I can right click and go to, I will double click again. So I just want to show you how a process is modeled.



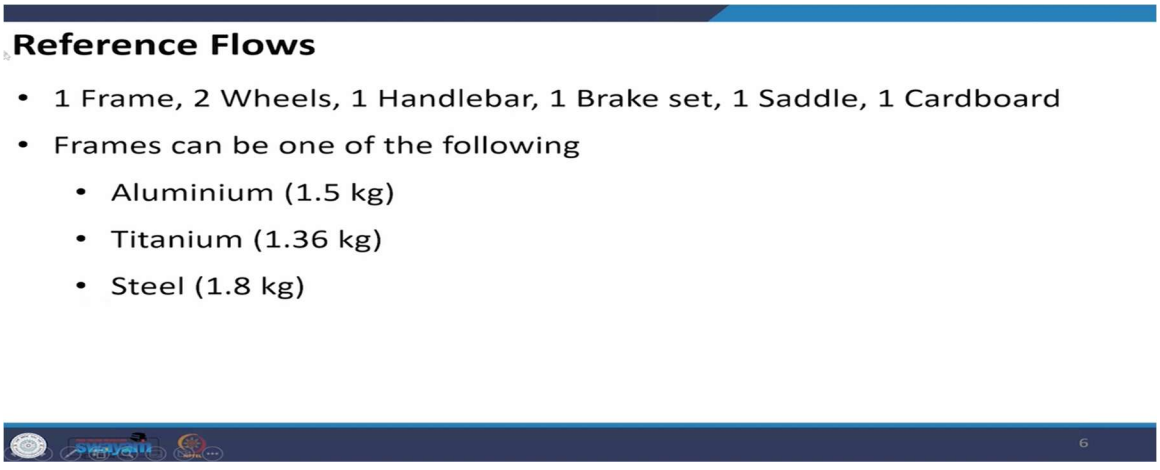
Now you can see this power block is modeled with inputs from technosphere. So these all are the inputs that are going into the process block of this power block. So as you can see there are various materials available, cast iron, ceramic tile and also the energy part is also inputted. So these are a lot of inputs in this process as you can see. And also I can add emissions to air. These are the output parts. So to the particular process block, I can add emissions that are going to water, air, soil, final waste flows and even to the technosphere. So as you can see here in this process, hazardous waste has been sent back to the technosphere and municipal solid waste, MSW as well and all the units are defined. And there is also a description given. So these are all modeled by SimaPro databases. Now we will see, we will conduct an example, a very simple example but comprehensive one.

So we need to model as you can see on your screens right now that we need to model a bicycle. So as we have discussed earlier, we need to define the process blocks for the

production and disposal of a bicycle. So the first step would be to model the process blocks. So as you can see a bike consists of frames, various parts. So that would be the assembly stage of the bike, then packaging and transportation and this would be the maintenance processes and all those things would come into the use phase and then the disposal phase, the incineration, landfill, disassembly and reuse.



So the first step of LCA is goal and scope. So what is the goal? The goal is to compare the environmental impacts of bikes using different frames over its entire life cycle. The system boundary has been defined to be cradle to Grave. Now the functional unit chosen for this study is the cycling of 100,000 kilometers over a lifetime of 15 years. So as you can see, the functional unit can be service based as well as in this case, we are using a functional unit of 100,000 kilometers over a lifetime of the cycle.



Now these are the reference flows that we need to draw on pen and paper so that we can model this bike. So the bike consists of one frame, the frame can be of aluminum, titanium or steel. We will model them, all three of them and then compare the results as

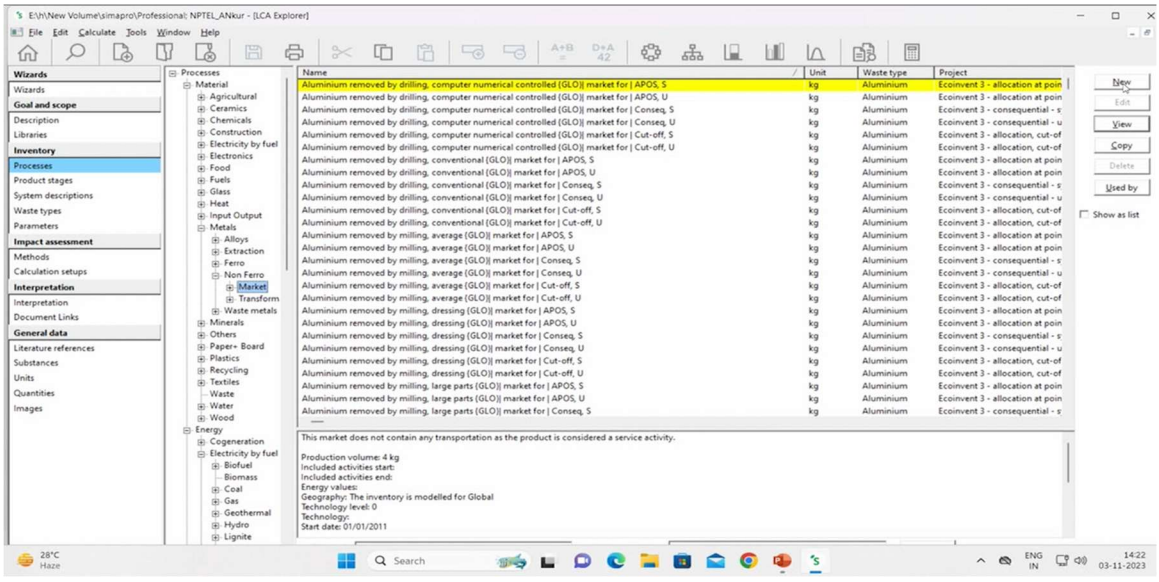
well. It consists of two wheels. So this is the assembly part of the bike. So we will be doing this in SIMA Pro.

LCI (Aluminium Frame-1.5 Kg)

Input Data	SimaPro Category	Amount
Aluminium, primary, ingot {IAI Area, EU27 & EFTA}	Processes > Materials > Metals > Non Ferro > Market	1.579 kg
Powder coat, aluminium sheet {GLO}	Processes >Processing > Metals > Coating > Market	0.375 m^2
Impact extrusion of aluminium, 3 strokes {GLO}	Processes > Processing > Metals > Chipless shaping > Market	1.51 kg
Welding, arc, aluminium {GLO}	Processes > Processing > Metals > Welding >Market	0.75 m
Electricity, medium voltage, aluminium industry {IAI area, EU27 & EFTA}	Processes > Energy > Electricity country mix > Medium voltage > Market	31.5 kWh

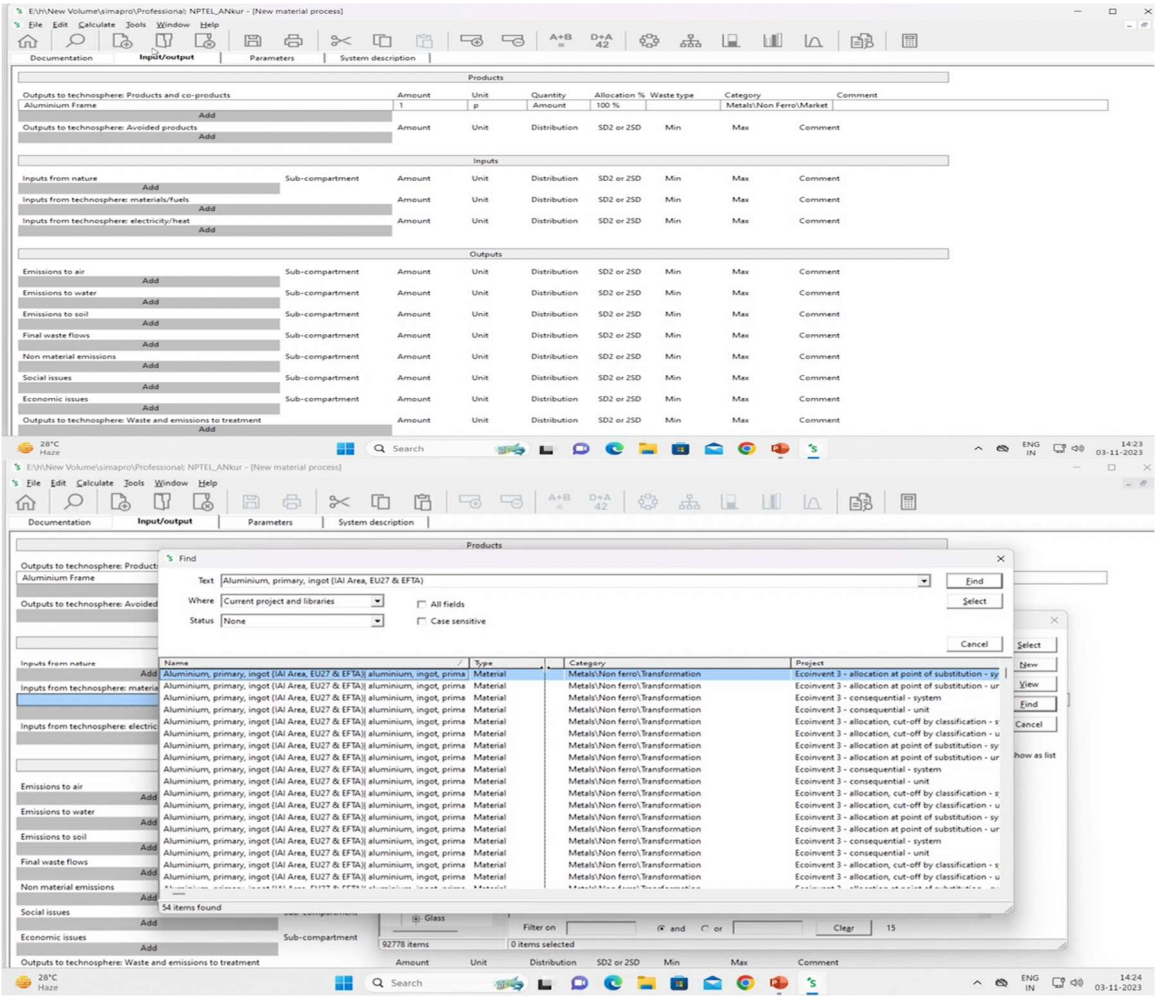
Output Data (Waste treatment)	SimaPro Category	Amount
Aluminium (waste treatment) {GLO}	Waste treatment > recycling > transformation	0.079 kg

So let us first build the inventory of aluminum frame that is for 1.5 kg of aluminum frame. So what we will do right now is we will model one piece of aluminum frame which is of 1.5 kg weight through this inventory that we have built from various. So inventory can be from various literature sources or industry sources. So I have taken some reference from the SIMA Pro tutorials and this is the inventory that they have built for 1.5 kg of aluminum frame for one bicycle. So now let's see how we can model this in SIMA Pro.



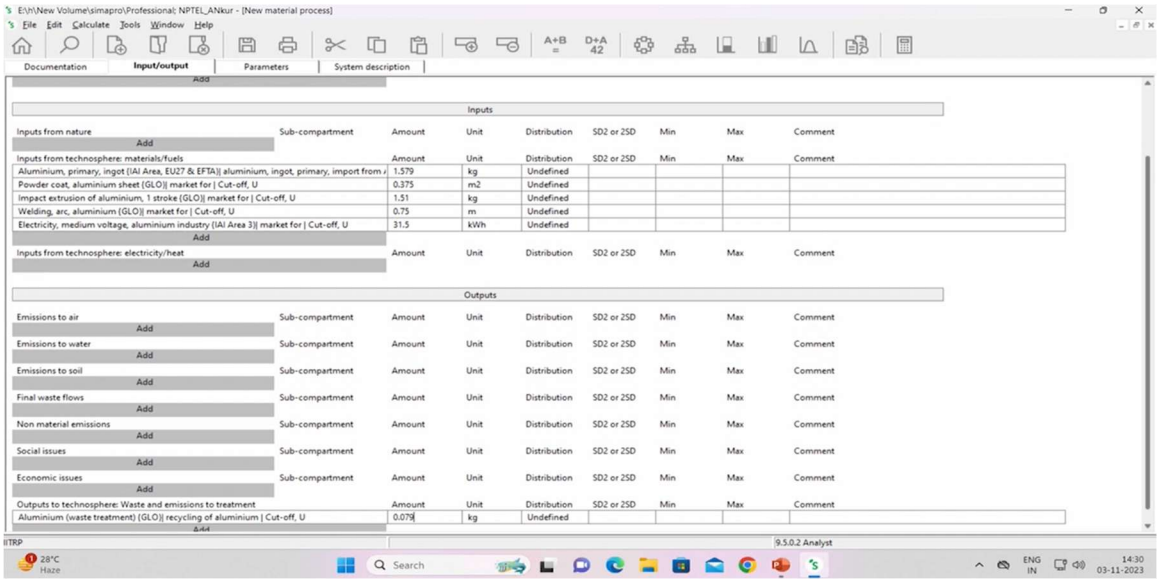
What I can do is I can create aluminum frame here as well and in the product stages, assembly stage as well. So let us go into materials and I can select anything, let's say

metals. So we will go to non-ferrometals, the market and as you can see on the right side, I can create these are the already made ones, I can create a new one by clicking on new.



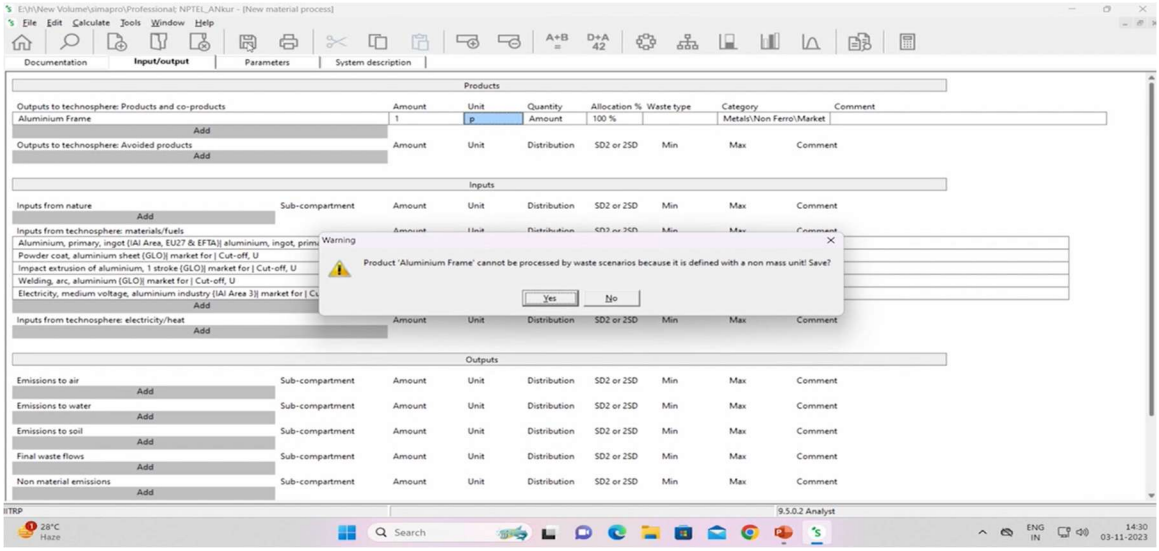
So the output that we will get from this modeling is an aluminum frame. So I will write that as aluminum frame and instead of kg, I can put that as one piece of aluminum frame. So as you can see amount, one aluminum frame for one bicycle. So this is the output that I will be getting from this modeling. So as you can see this is the tab for input output and this is the first modeling that we are doing. So it should be very simple. Now the input that goes into making of one piece of aluminum frame, the first part that goes is the aluminum metal itself, it's very logical and as you can see the aluminum that we have chosen is primary ingot and EU27. So the SimaPro category that for this type of aluminum has been mentioned as well. So let's see, so we will go to input technosphere materials because aluminum is not from nature, it's getting, we are getting it from technosphere. So by nature I mean the natural materials that have been being processed. So whenever I double click on that input from technosphere, I will get this. So either I can manually choose the particular element that I want to add or I can use the find option as well. So what I will do is, I will select this by clicking on find, I will paste it here and

let's see what pops up. So it is current project and libraries, I will select the current project and libraries if you cannot find it in the current project alone. So as you can see, these are the type of different types of materials that I am looking. So it is imported from Africa, import from Asia, you can select any one of them. So let us select that import one from Africa.



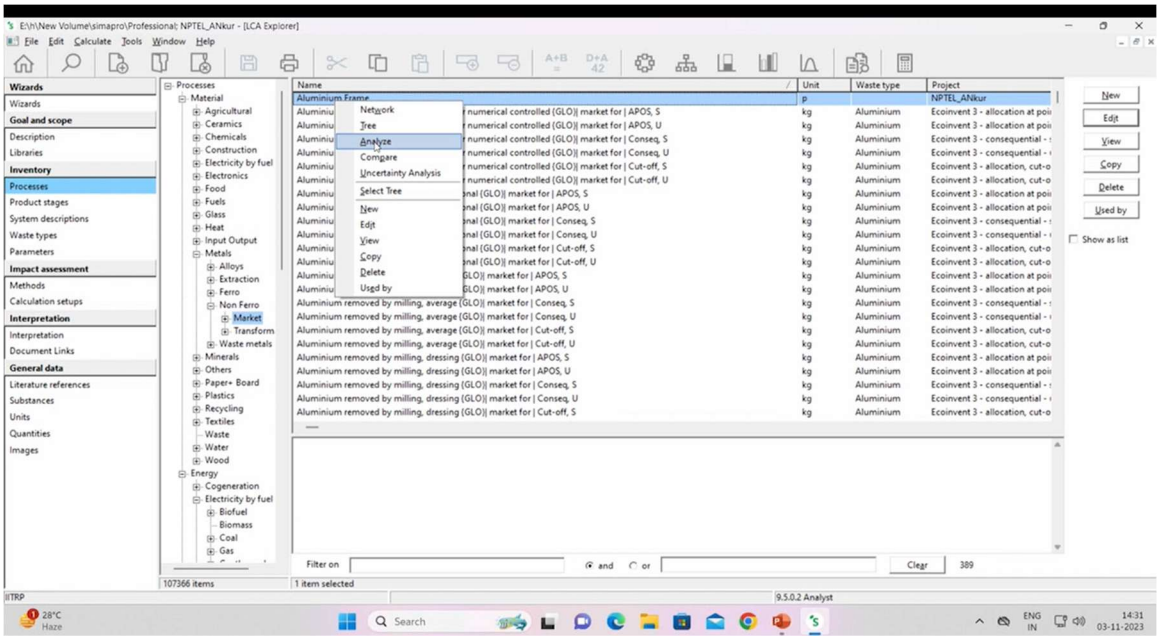
Click on select, as you can see this material has been added into the inputs from technosphere and since my frame is of 1.5 kg, the aluminum required to produce that much amount of frame, that much weight of frame is required as 1.579 kg. The aluminum required is 1.579. So I will write that as 1.579. So this is the first material that we have added to produce one piece of aluminum frame. Now we will add our second material. The second material is powder coat of the aluminum sheet. So I will copy this, I have already built this inventory, you can do that on your own using literature or industrial sources. So by double clicking there, I will go to find or I can do manually as well. Let us see what pops up. So I will just select, so there it is, powder coat, aluminum sheet, market for, I will use this one, the global one. You can select based on your region and so as you can see the unit has now changed to meter square. We will look into an inventory. So 0.375 meter square of powder coated aluminum sheet is required. So I will write that down as 0.375. So this is the second material. Similarly I will add the impact extrusion of aluminum. By double clicking it again, going to the find option, pasting it here. So impact extrusion of aluminum, one stroke as you can see, it is a very comprehensive database provided by simaPro. Two strokes, I can select any one of them. Let us select the one stroke one for the global one. So how much kg is required? 1.51 kg is required. So in the inventory it is three strokes one. I have selected one stroke one, that does not matter. Right now I am using it just as an example. 1.51 kg of impact extrusion of aluminum. The next is welding arc of the aluminum. So this would be a process rather

than a material and the welding is required for 0.75 meter. So doing it again, double clicking, going to find. We can also find by pressing Ctrl F like we do in word. So it is not showing currently. So we will just search welding arc aluminum. So as you can see welding arc aluminum, global one is available and we will add 0.75 meter of it. Now the next thing is to add energy. Energy is also required in the process of manufacturing of aluminum frame. So we are using a medium voltage for the aluminum industry and 31.5 units of energy is being used for kilowatt hours. I will go and find again. Enter my data which is not getting shown right now. I will just type it to aluminum industry and as you can see there is a lot of options available the medium voltage. I will select one of them like Ia area 1, Ia area 2 that is a very comprehensive database. So I will select this one. So the units that are required are 31.5 units or kilowatt hours. Now there is some output data as well for the waste treatment for the production of aluminum frame. That will go into the output one. So far we have done the input materials that were going. So aluminum waste treatment global 0.079 kg. So we will look for the output as well. As you can see if I scroll down the output to waste treatment is also there. Yes, now double clicking it. I will search aluminum. So as you can see the global waste treatment of aluminum is being shown which includes the recycling of aluminum as well. So I will select this one and 0.079 kg was the data for that. Now after I have entered all of these I need to click on save.

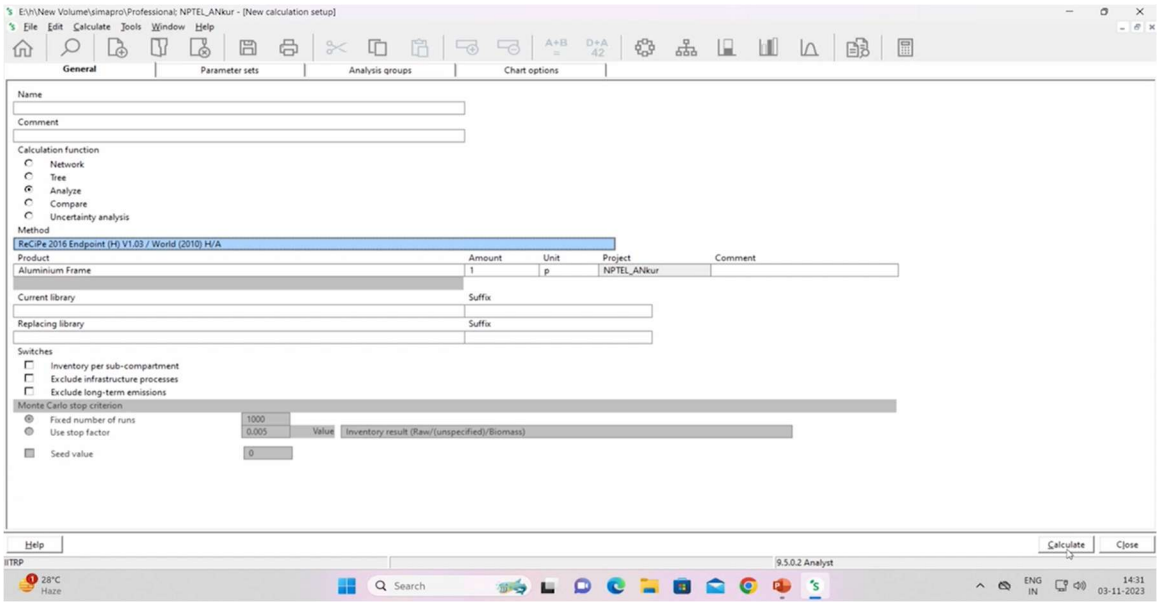


You can see the save icon here. So since I have constructed a piece of aluminum frame.

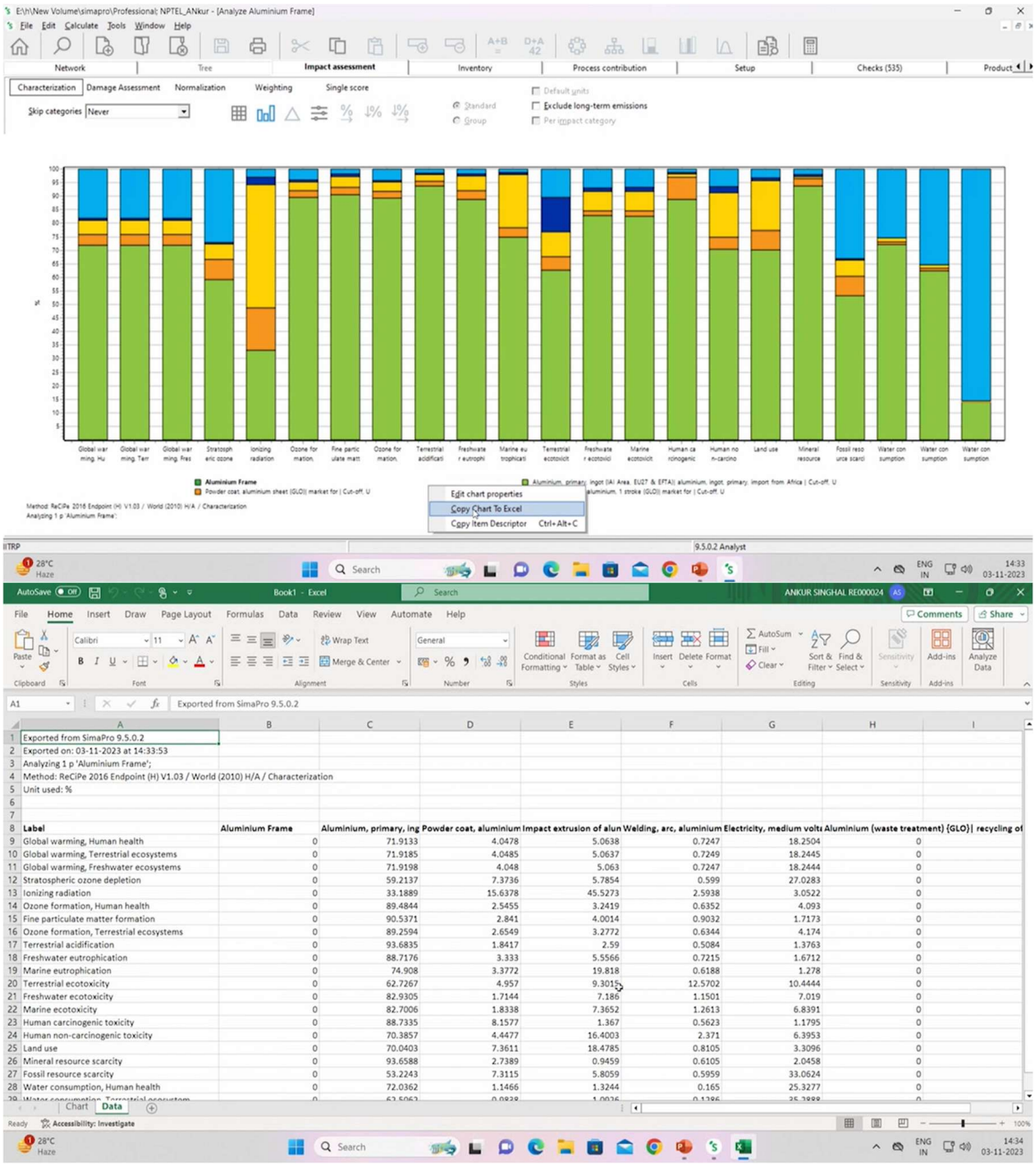
So that is why the warning was showing and now it saved.



When I close it I saved it in materials non-ferro. As you can see our new process the first process that we have created in Simapro is now available. What I can do is I will right click on this and click on analyze.



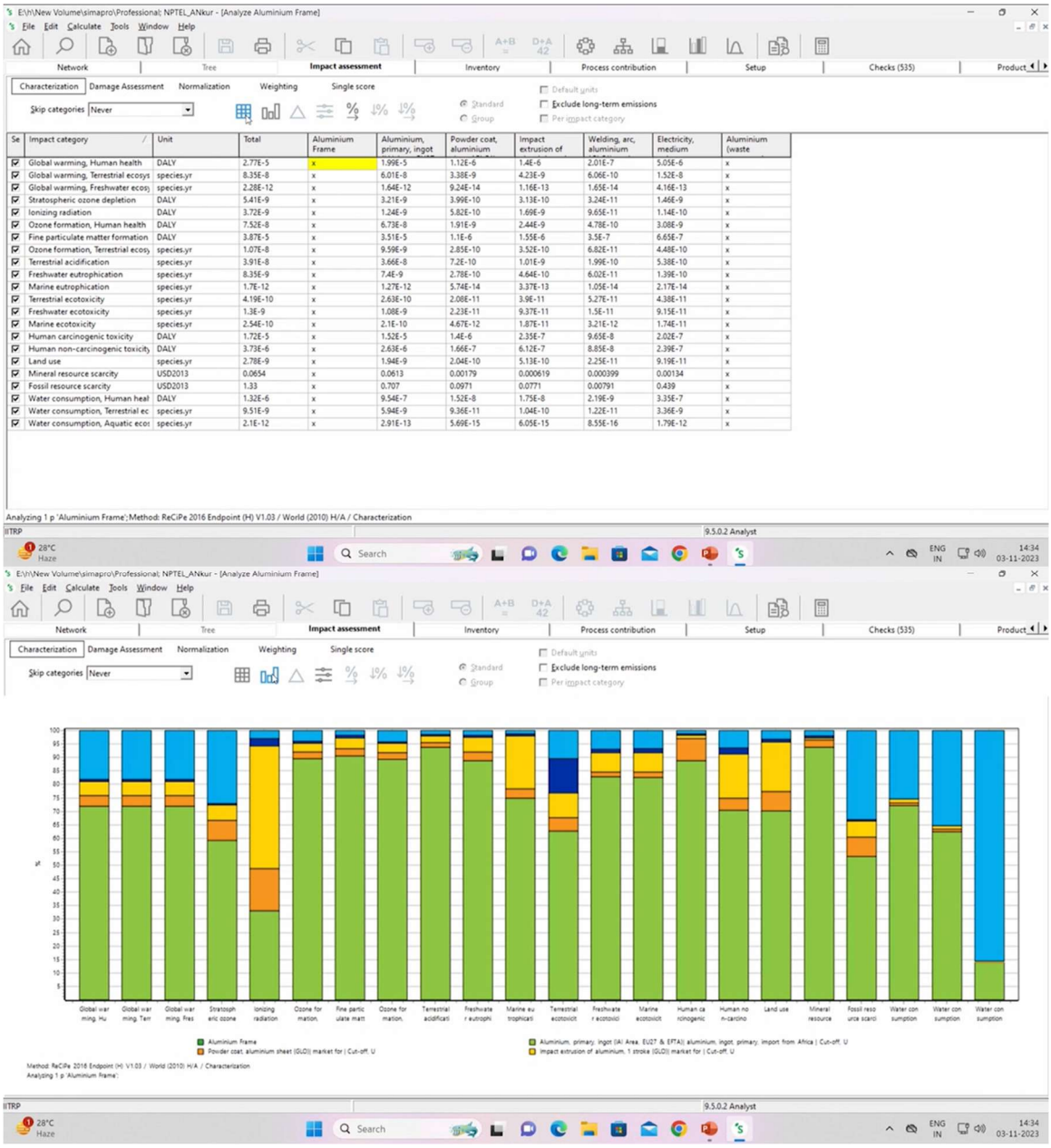
So in analyze I can do the life cycle impact assessment of this one piece of aluminum frame. Now here in the method section I will double click. Let us say I choose the recipe 2016 endpoint method for impact assessment. After selecting the method I will click on calculate.



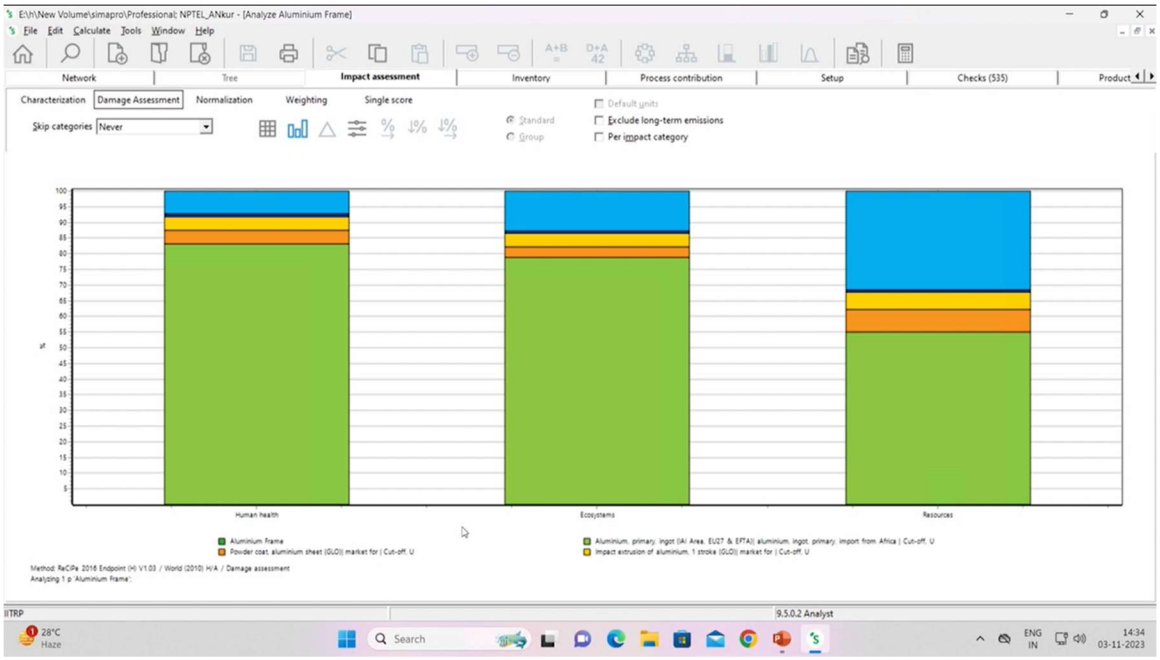
Label	Aluminium Frame	Aluminium, primary, ing	Powder coat, aluminium	Impact extrusion of alun	Welding, arc, aluminium	Electricity, medium volta	Aluminium (waste treatment) {GLO}| recycling of
Global warming, Human health	0	71.9133	4.0478	5.0638	0.7247	18.2504	0
Global warming, Terrestrial ecosystems	0	71.9185	4.0485	5.0637	0.7249	18.2445	0
Global warming, Freshwater ecosystems	0	71.9198	4.048	5.063	0.7247	18.2444	0
Stratospheric ozone depletion	0	59.2137	7.3736	5.7854	0.599	27.0283	0
Ionizing radiation	0	33.1889	15.6378	45.5273	2.5938	3.0522	0
Ozone formation, Human health	0	89.4844	2.5455	3.2419	0.6352	4.093	0
Fine particulate matter formation	0	90.5371	2.841	4.0014	0.9032	1.7173	0
Ozone formation, Terrestrial ecosystems	0	89.2594	2.6549	3.2772	0.6344	4.174	0
Terrestrial acidification	0	93.6835	1.8417	2.59	0.5084	1.3763	0
Freshwater eutrophication	0	88.7176	3.333	5.5566	0.7215	1.6712	0
Marine eutrophication	0	74.908	3.3772	19.818	0.6188	1.278	0
Terrestrial ecotoxicity	0	62.7267	4.957	9.3015	12.5702	10.4444	0
Freshwater ecotoxicity	0	82.9305	1.7144	7.186	1.1501	7.019	0
Marine ecotoxicity	0	82.7006	1.8338	7.3652	1.2613	6.8391	0
Human carcinogenic toxicity	0	88.7335	8.1577	1.367	0.5623	1.1795	0
Human non-carcinogenic toxicity	0	70.3857	4.4477	16.4003	2.371	6.3953	0
Land use	0	70.0403	7.3611	18.4785	0.8105	3.3096	0
Mineral resource scarcity	0	93.6588	2.7389	0.9459	0.6105	2.0458	0
Fossil resource scarcity	0	53.2243	7.3115	5.8059	0.5959	33.0624	0
Water consumption, Human health	0	72.0362	1.1466	1.3244	0.165	25.3277	0

So this will calculate the impact assessment according to our 2016 endpoint recipe method and show us the results. Once it is done we will see we will have a look how the results look like for one piece of aluminum. So this is our first modeling in Simotro. Let us wait for a bit. Now as you can see if I select the characterization tab I can see the global warming and also I can see the bifurcation of it. So the maximum impact is coming from aluminum metal that I am using. As you can see more than 73-74% of the global warming impacts are coming from aluminum primary ingot. So this is our total net result of the impact assessment. I can change the colors as well. I can change the I can edit it to chart properties. Then I will see the various colors scheme that I can change.

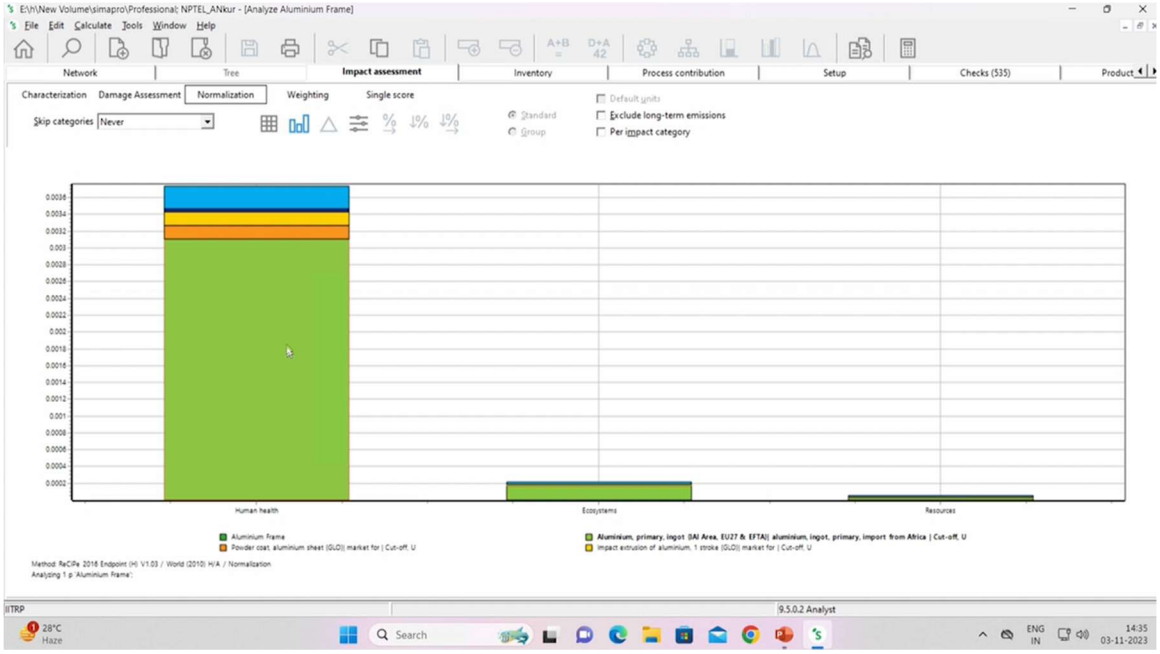
Also I can copy this to excel as well. So when I click right click and I will select copy chart to excel. So it will collect all the data all the graph and it will copy the chart to excel as well. So now it is as you can see the chart has been copied to excel. For all the impact categories global warming, terrestrial ecosystems, freshwater ecosystem and in another tab you can see the data as well.



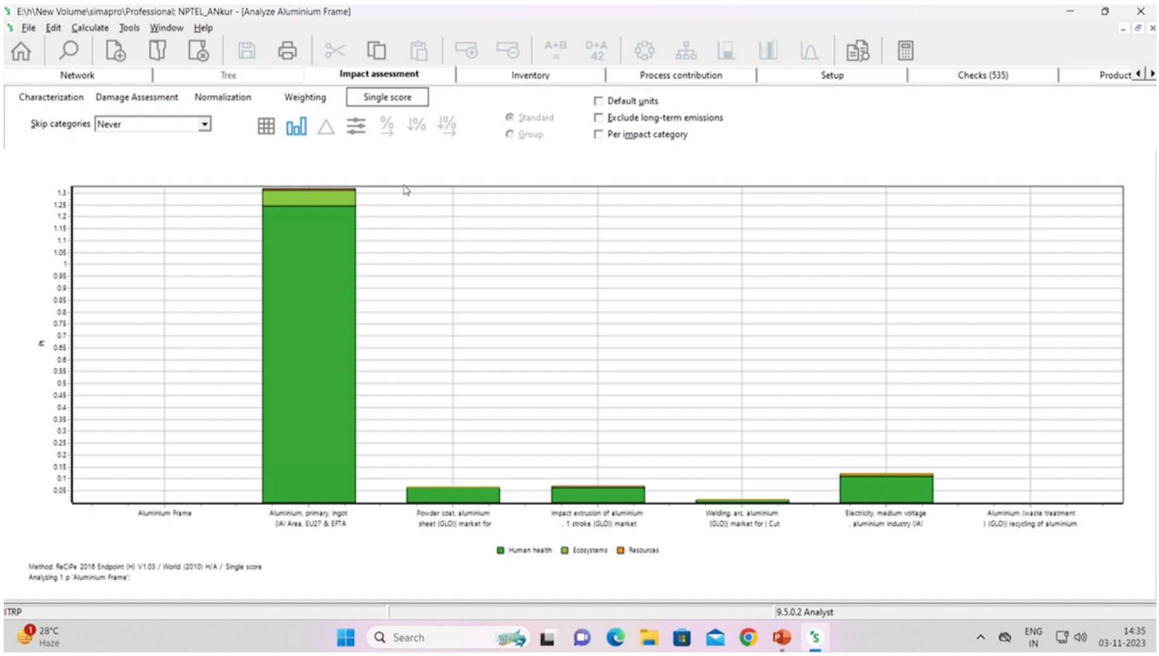
So now if I click on this show table then rather than graph it will show you the exact values of the impact assessment. So this e means 10 raised to the power. So 2.77 10 raised to the power minus 5 and as you can see the highest impact categories are also shown. When I click on this graph icon I can move back again to the graph.



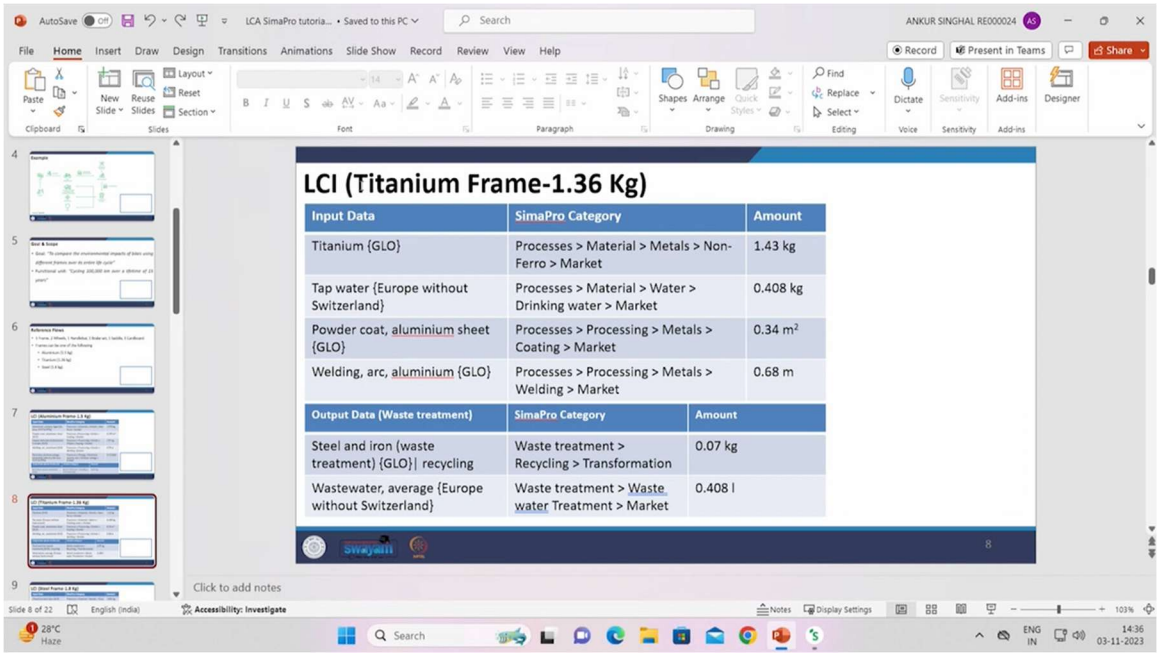
Now clicking on damage assessment. So now it is showing me the end point categories. So end point are more general more bigger umbrella category as you can see the damage to the ecosystems, the resources damage and the human health damage. Still the highest contributor is the metal aluminum.



Now if I click on normalization. So what does normalization mean? We have normalized these result with respect to some other values. So that other value in SimaPro is considered to be the emissions created by one human in a year.



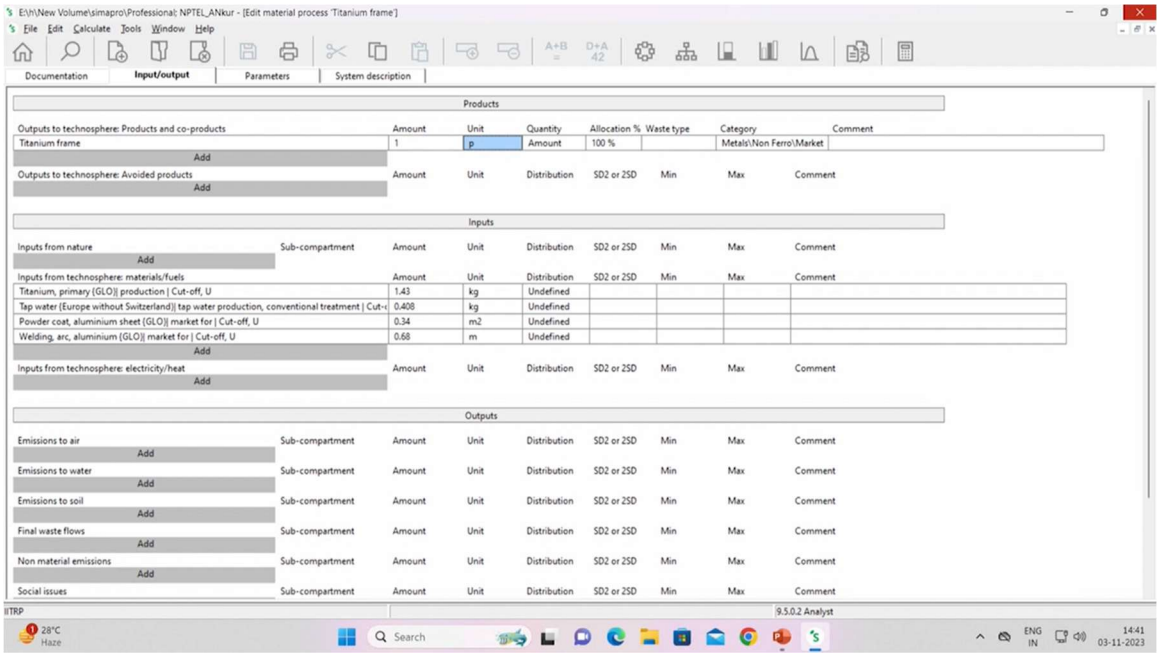
So I can convert that to single scores as well. So this PT one PT represents the damage conducted by one person in one year. So this is how we model a particular process, a particular material and then we can look at impact assessment as well. So this is our first model the aluminum frame. This is model by us, input outputs all entered by us.



LCI (Titanium Frame-1.36 Kg)

Input Data	SimaPro Category	Amount
Titanium {GLO}	Processes > Material > Metals > Non-Ferro > Market	1.43 kg
Tap water {Europe without Switzerland}	Processes > Material > Water > Drinking water > Market	0.408 kg
Powder coat, aluminium sheet {GLO}	Processes > Processing > Metals > Coating > Market	0.34 m^2
Welding, arc, aluminium {GLO}	Processes > Processing > Metals > Welding > Market	0.68 m
Output Data (Waste treatment)	**SimaPro Category**	**Amount**
Steel and iron (waste treatment) {GLO}| recycling	Waste treatment > Recycling > Transformation	0.07 kg
Wastewater, average {Europe without Switzerland}	Waste treatment > Waste water Treatment > Market	0.408 l

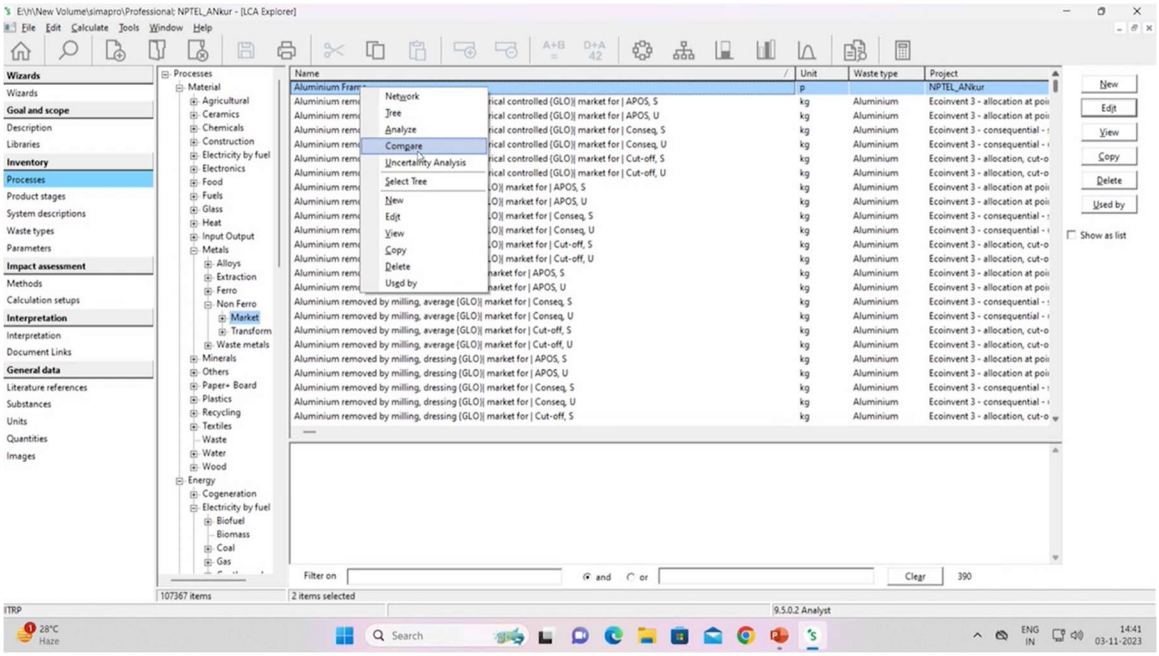
Now what we need to do is we will build a titanium frame as well. So and we will compare it with the aluminum frame.



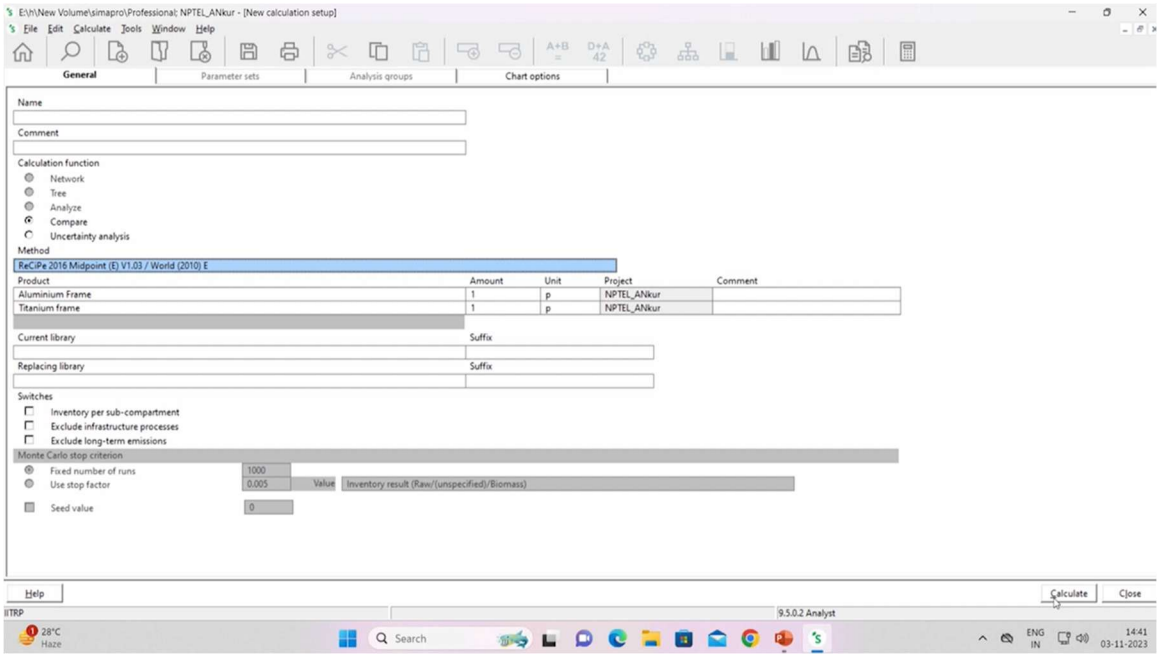
So let's go to new on the right side and this we will name as titanium frame. And I will again the quantity I will define it to be one piece. So this time the frame is being made from titanium alone. So I will be requiring the global titanium metal as predicted and 1.43 kgs of titanium is required. So I will double click and then click on find. So as you can see various metals and materials consisting of titanium have been shown. So I will select this one and 1.43 kgs of it is required for one single frame. The next would be the tap water that is required for this one.

So I will select this. I will again double click, click on find. So tap water for various nations is shown various regions rather. We can select any one of them. This one is the year of the outsells. I will select this one and the amount required is 0.408 kg. So these inventory building sometimes comes from experience from industrial experience or literature as I have already told you. So powder coat aluminum sheet 0.34 meter square then again using the processes. So I will select this one 0.34 meter square. Now welding arc aluminum 0.68 meters of that is required for the titanium frame one. So I will select the global one. Now there are some output waste flows as well. So the steel and iron waste treatment recycling. That is of 0.07 kg. I will go to output waste treatment. 0.07 kg of that. Next waste treatment is of the waste water. Europe without Switzerland and that is of 0.408 liters. So I will search for the Europe without Switzerland one. As you can see I have found it 0.408 liters. Here the unit is meter cube I need to change it to liters. As you can see there are variety of units available. Now the most important part is after entering all the inputs and outputs I will click on save. So this titanium frame one piece has been saved here.So I will close it and as you can see the aluminum frame is modeled

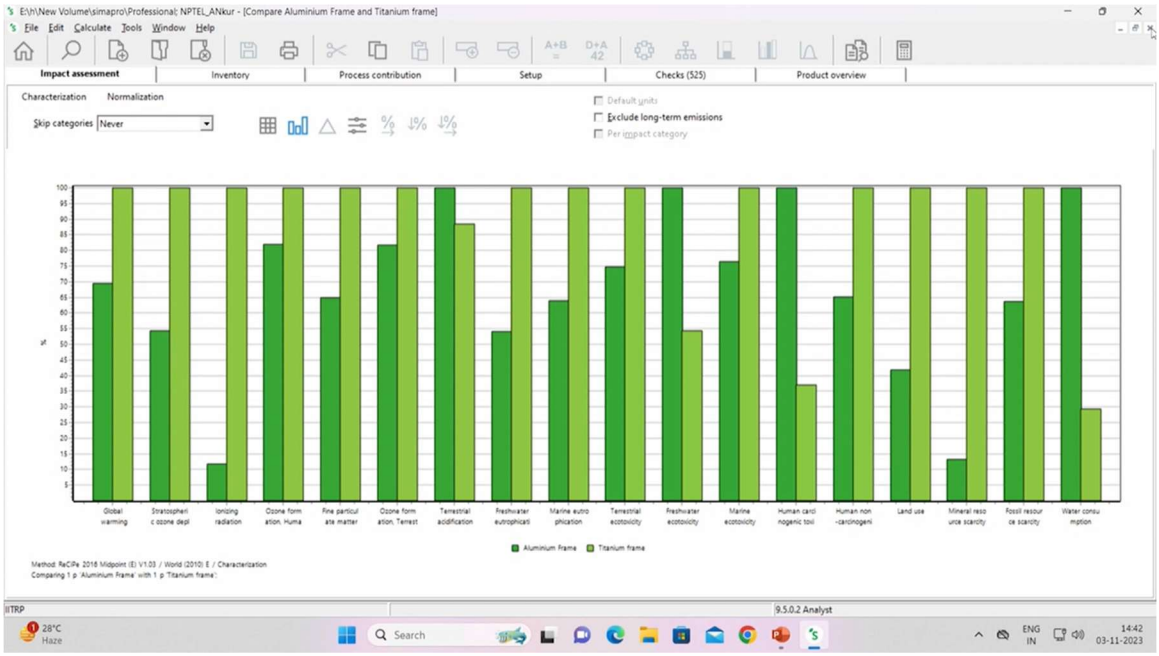
here. The titanium would be somewhere here. Here it is our newly modeled titanium frame. So I will select this one. I want to compare it with aluminum frame.



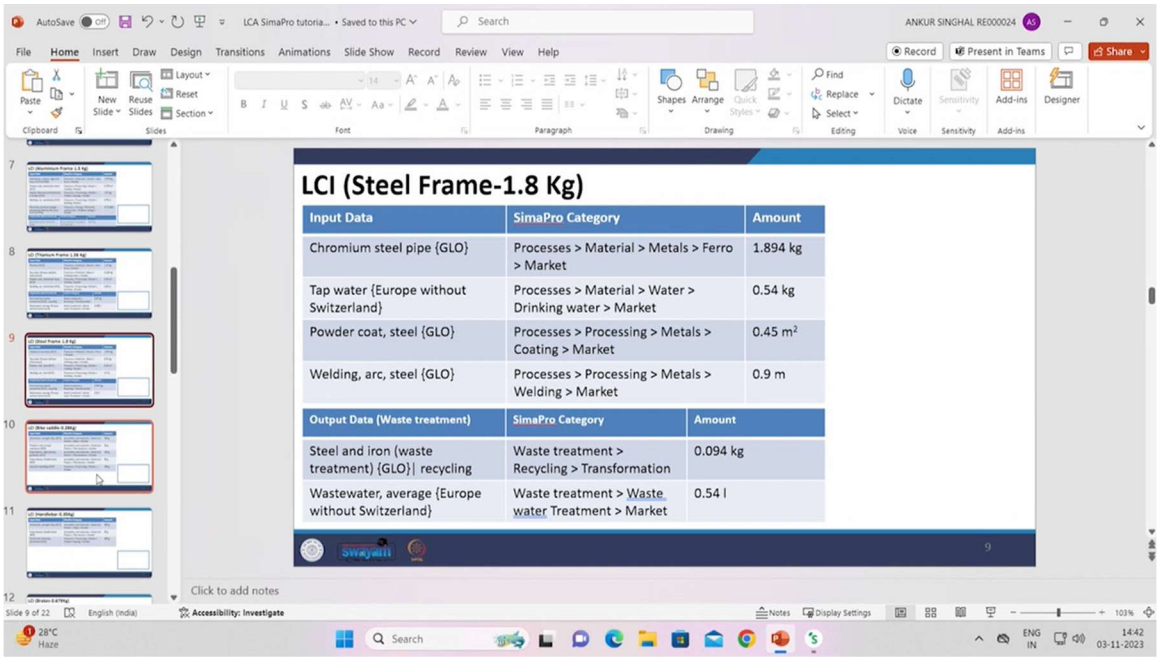
I will press on control and then I will select this one. I will right click on it and then I will click on compare.



So I have selected aluminum frame that I have modeled titanium frame. I will select the impact category. This time let us say we will choose the midpoint one. The recipe 2016 midpoint category and I will click on calculate.



So this will show us a comparison of the two frames if we use the aluminum frame or the titanium frame. Environmentally how does it sound? So as you can see aluminum frame performs better than titanium frame in almost all of the categories. Barring a few like terrestrial acidification the titanium one performs better and in the freshwater ecotoxicity as well. So you can import this graph to excel just by simply by right clicking and copy chart to excel. So this is how we model in SimaPro. I will close this.

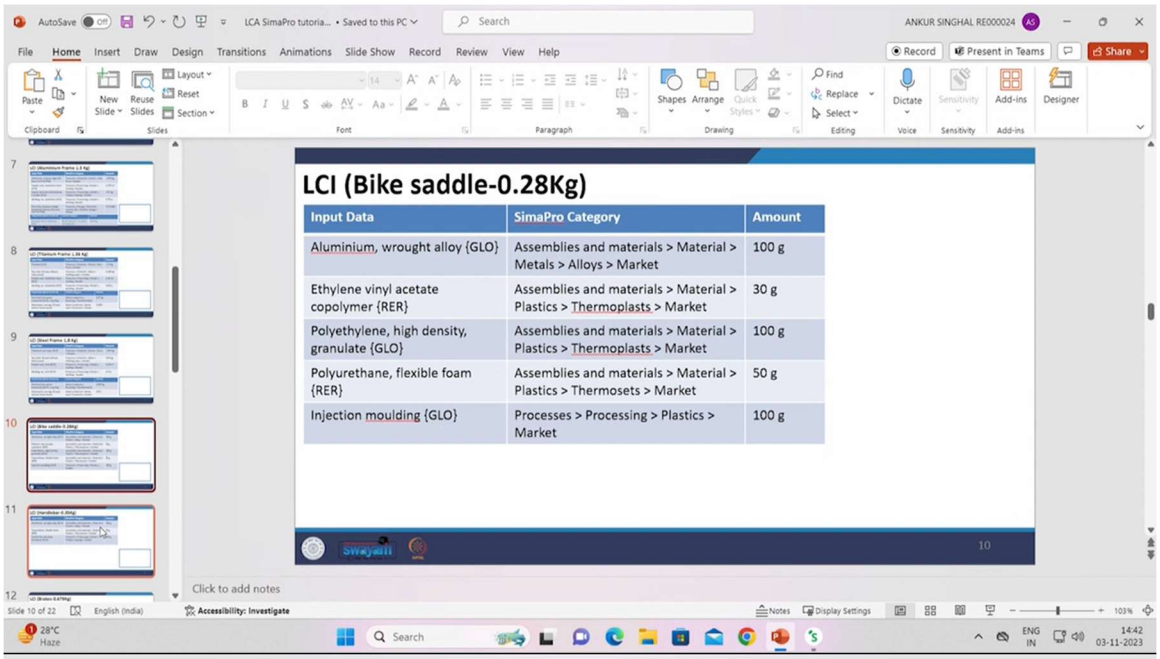


LCI (Steel Frame-1.8 Kg)

Input Data	SimaPro Category	Amount
Chromium steel pipe {GLO}	Processes > Material > Metals > Ferro > Market	1.894 kg
Tap water {Europe without Switzerland}	Processes > Material > Water > Drinking water > Market	0.54 kg
Powder coat, steel {GLO}	Processes > Processing > Metals > Coating > Market	0.45 m^2
Welding, arc, steel {GLO}	Processes > Processing > Metals > Welding > Market	0.9 m

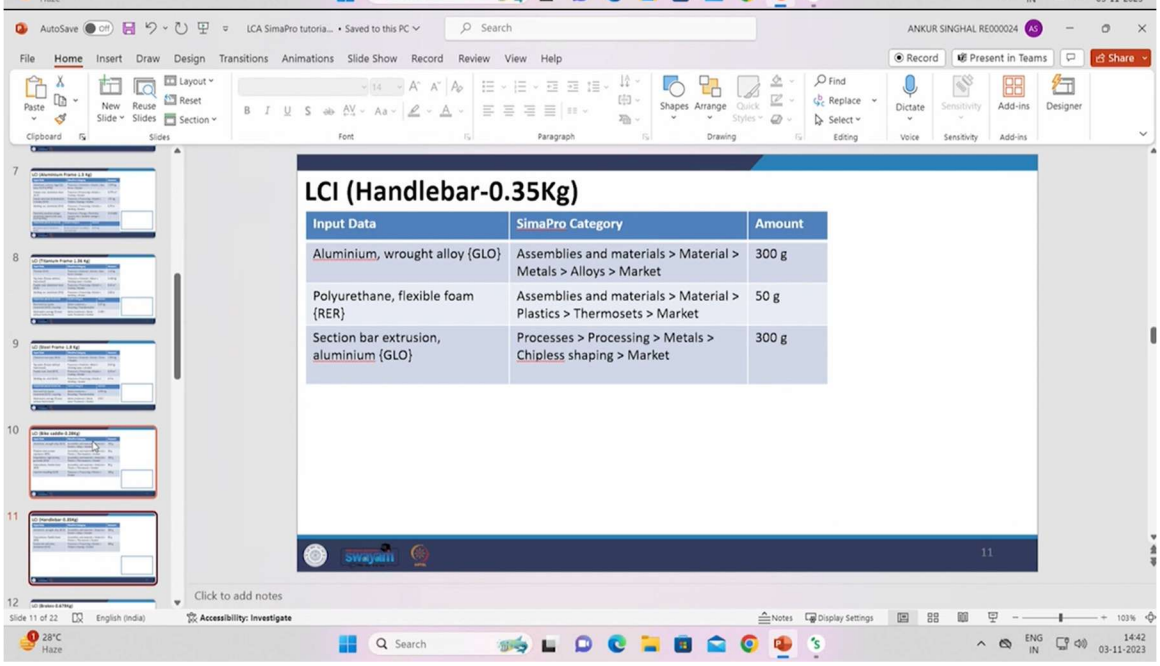
Output Data (Waste treatment)	SimaPro Category	Amount
Steel and iron (waste treatment) {GLO}| recycling	Waste treatment > Recycling > Transformation	0.094 kg
Wastewater, average {Europe without Switzerland}	Waste treatment > Waste water Treatment > Market	0.54 l

I will provide these inventories so that you can model it in SimaPro or other software that are available to you.



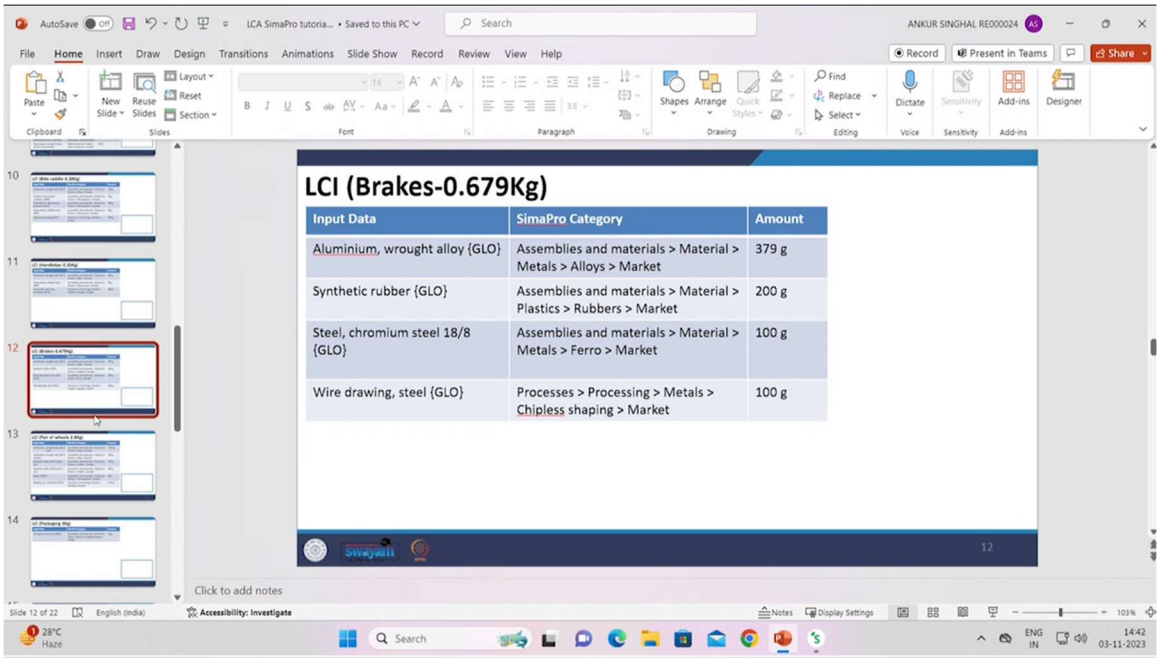
LCI (Bike saddle-0.28Kg)

Input Data	SimaPro Category	Amount
Aluminium, wrought alloy {GLO}	Assemblies and materials > Material > Metals > Alloys > Market	100 g
Ethylene vinyl acetate copolymer {RER}	Assemblies and materials > Material > Plastics > Thermoplasts > Market	30 g
Polyethylene, high density, granulate {GLO}	Assemblies and materials > Material > Plastics > Thermoplasts > Market	100 g
Polyurethane, flexible foam {RER}	Assemblies and materials > Material > Plastics > Thermosets > Market	50 g
Injection moulding {GLO}	Processes > Processing > Plastics > Market	100 g



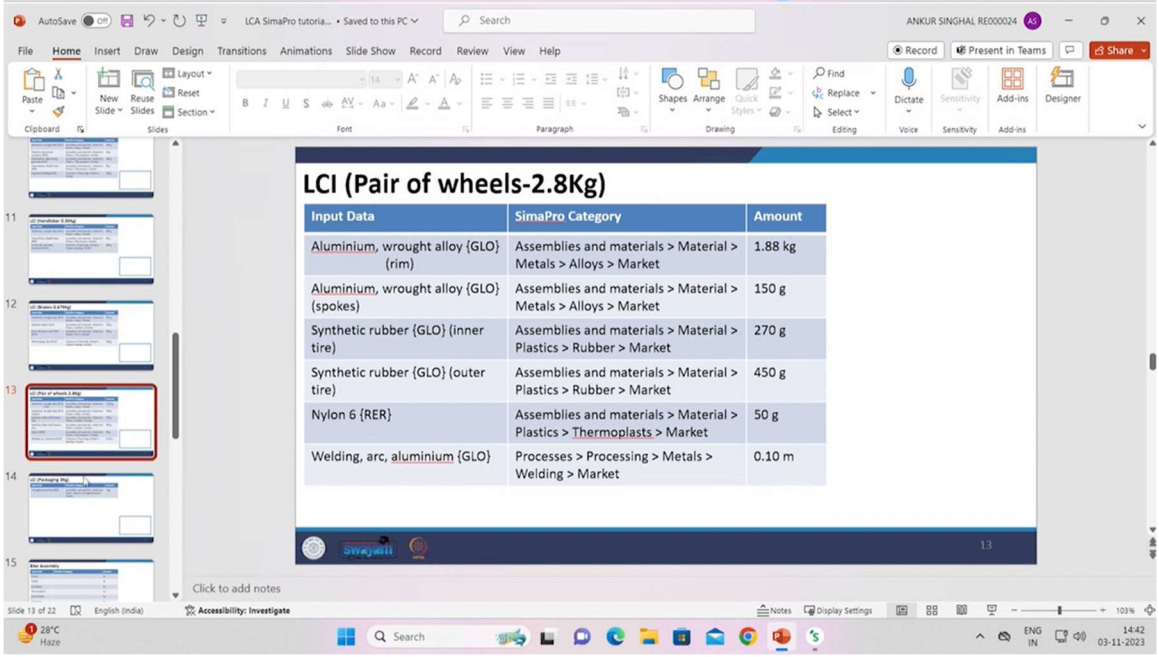
LCI (Handlebar-0.35Kg)

Input Data	SimaPro Category	Amount
Aluminium, wrought alloy {GLO}	Assemblies and materials > Material > Metals > Alloys > Market	300 g
Polyurethane, flexible foam {RER}	Assemblies and materials > Material > Plastics > Thermosets > Market	50 g
Section bar extrusion, aluminium {GLO}	Processes > Processing > Metals > Chipless shaping > Market	300 g



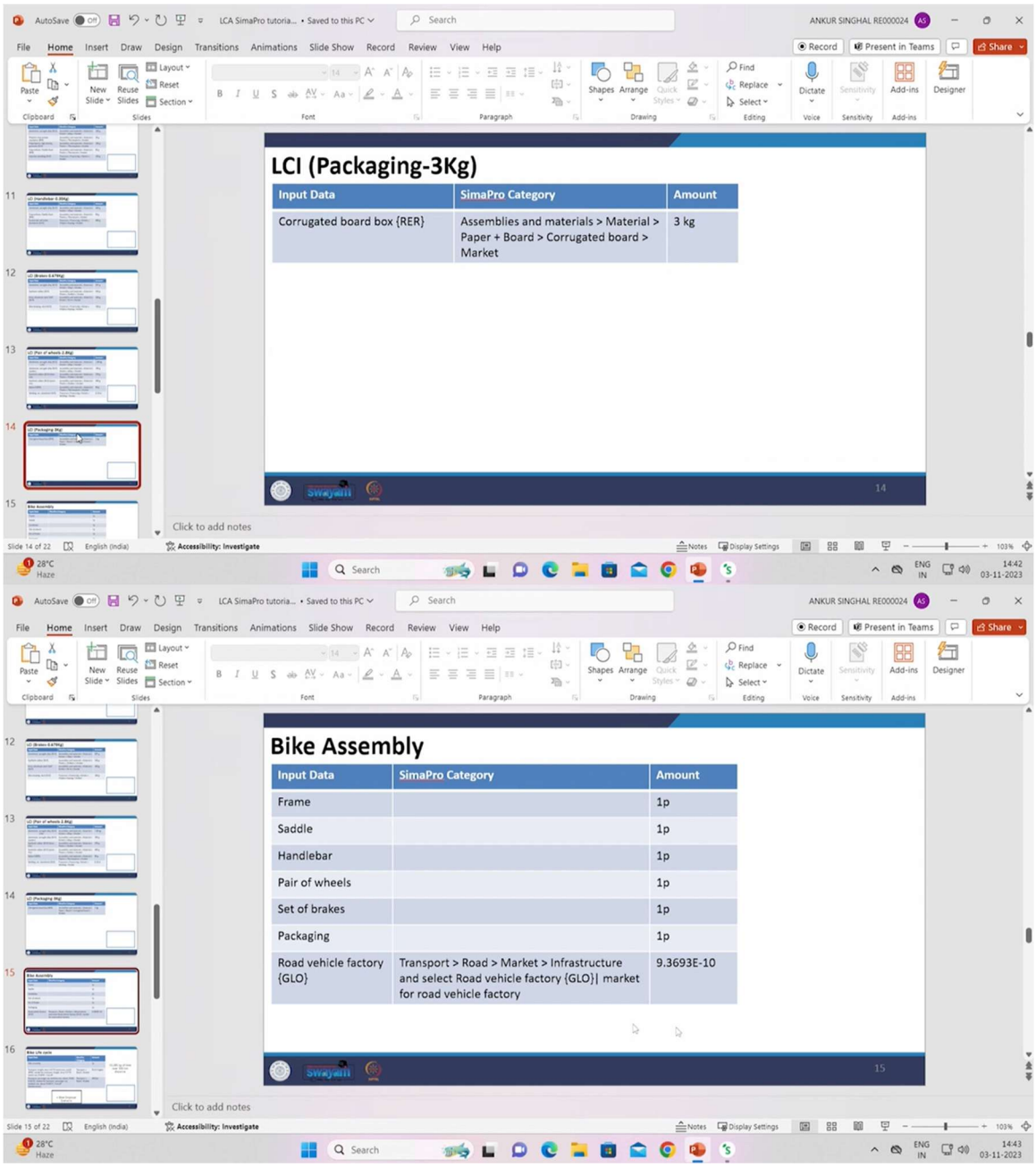
LCI (Brakes-0.679Kg)

Input Data	SimaPro Category	Amount
Aluminium, wrought alloy {GLO}	Assemblies and materials > Material > Metals > Alloys > Market	379 g
Synthetic rubber {GLO}	Assemblies and materials > Material > Plastics > Rubbers > Market	200 g
Steel, chromium steel 18/8 {GLO}	Assemblies and materials > Material > Metals > Ferro > Market	100 g
Wire drawing, steel {GLO}	Processes > Processing > Metals > Chipless shaping > Market	100 g

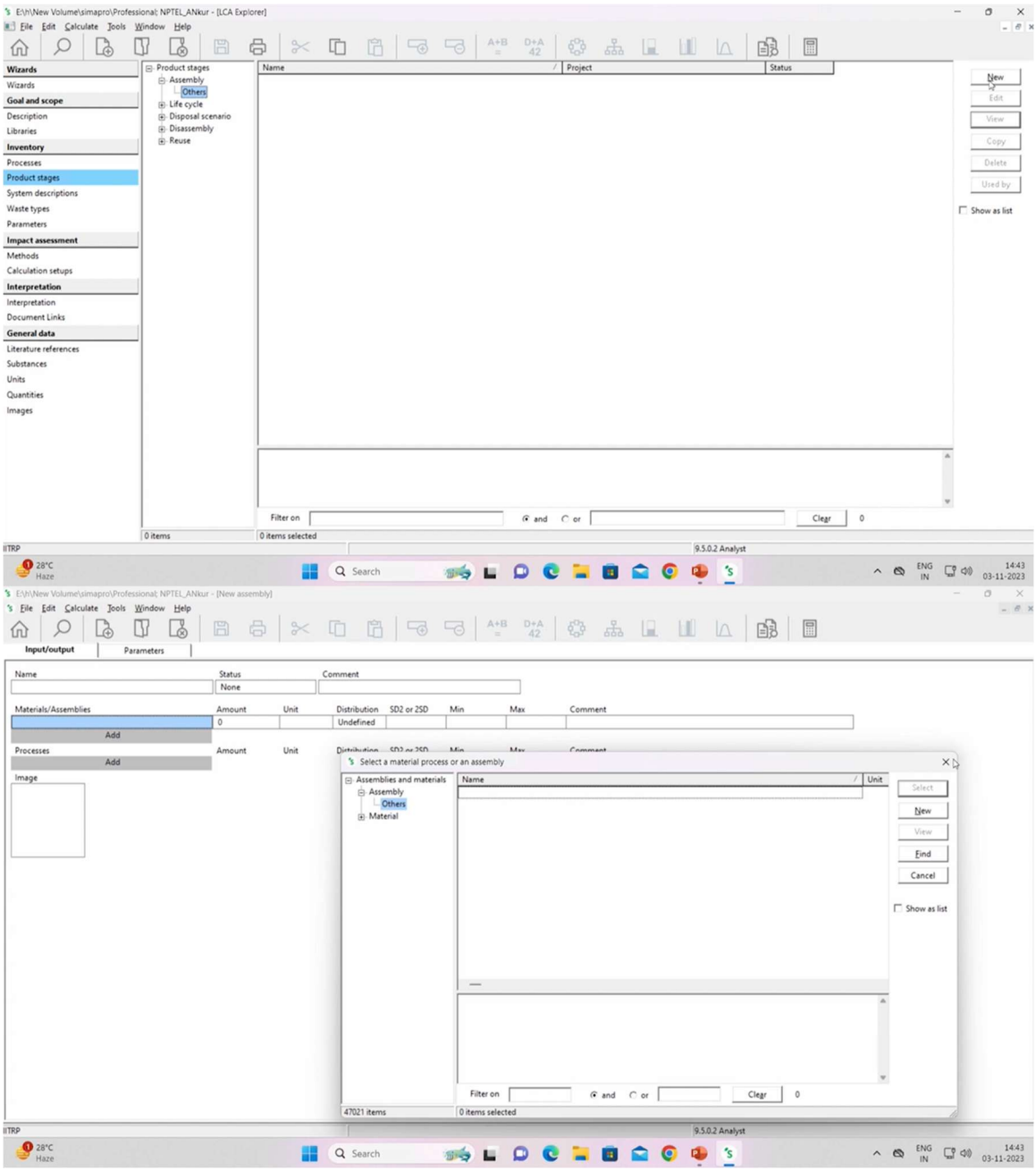


LCI (Pair of wheels-2.8Kg)

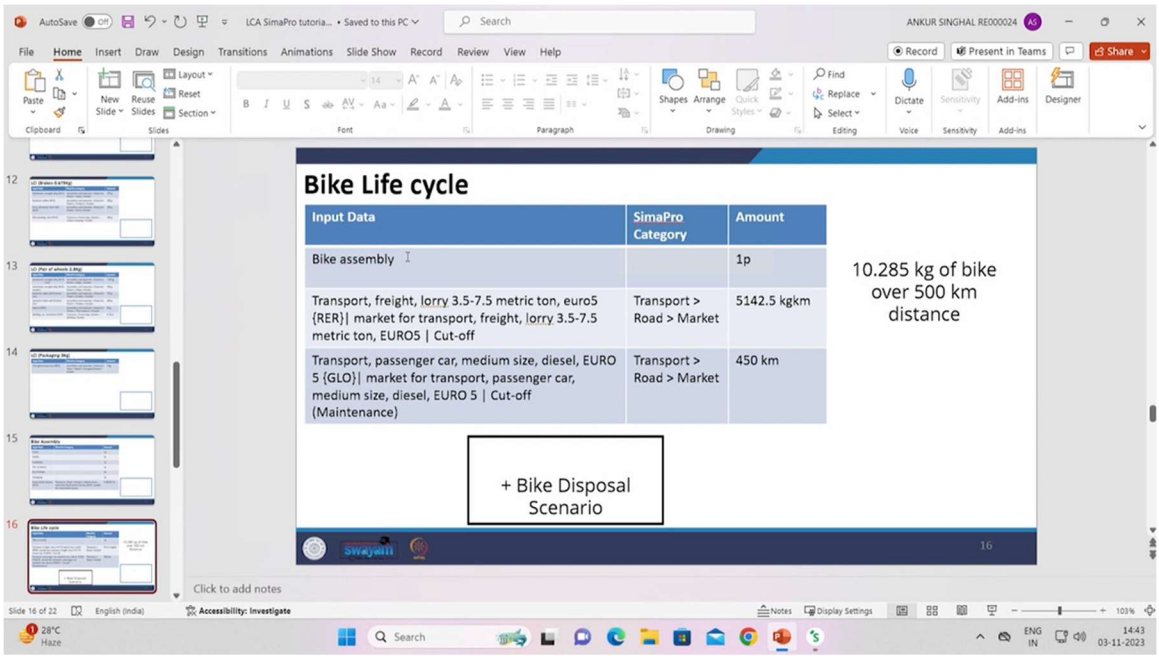
Input Data	SimaPro Category	Amount
Aluminium, wrought alloy {GLO} (rim)	Assemblies and materials > Material > Metals > Alloys > Market	1.88 kg
Aluminium, wrought alloy {GLO} (spokes)	Assemblies and materials > Material > Metals > Alloys > Market	150 g
Synthetic rubber {GLO} (inner tire)	Assemblies and materials > Material > Plastics > Rubber > Market	270 g
Synthetic rubber {GLO} (outer tire)	Assemblies and materials > Material > Plastics > Rubber > Market	450 g
Nylon 6 {RER}	Assemblies and materials > Material > Plastics > Thermoplasts > Market	50 g
Welding, arc, aluminium {GLO}	Processes > Processing > Metals > Welding > Market	0.10 m



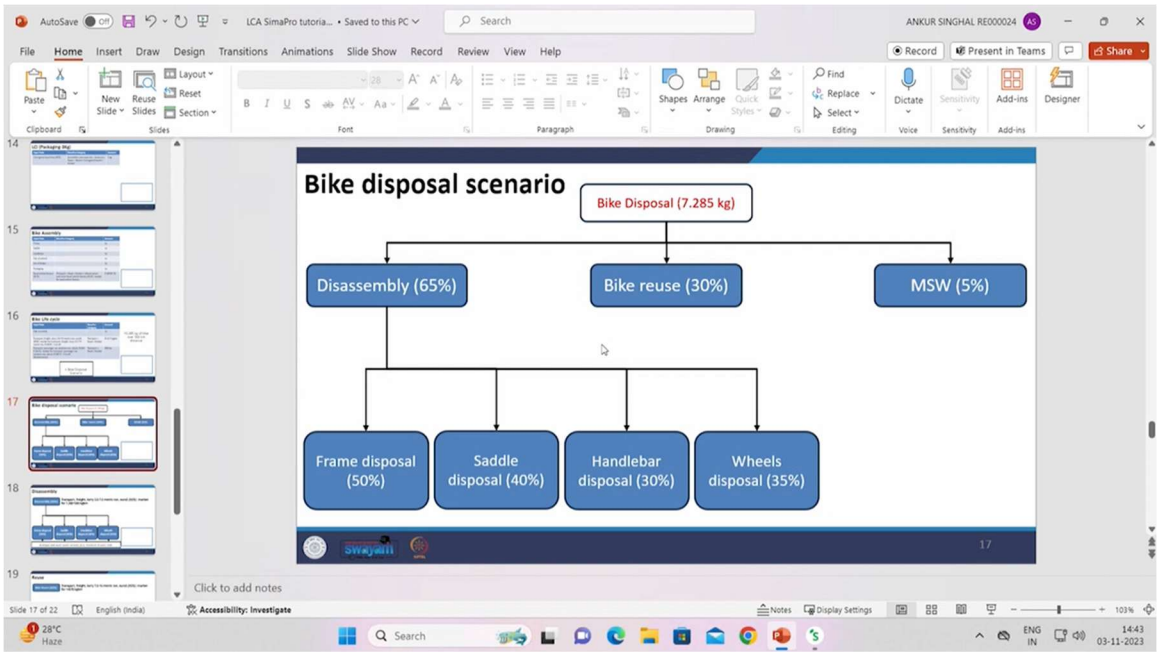
So these are the inventories for brakes, the pair of wheels, the packaging after the production of the bicycle. You can package it as well. The bike assembly.



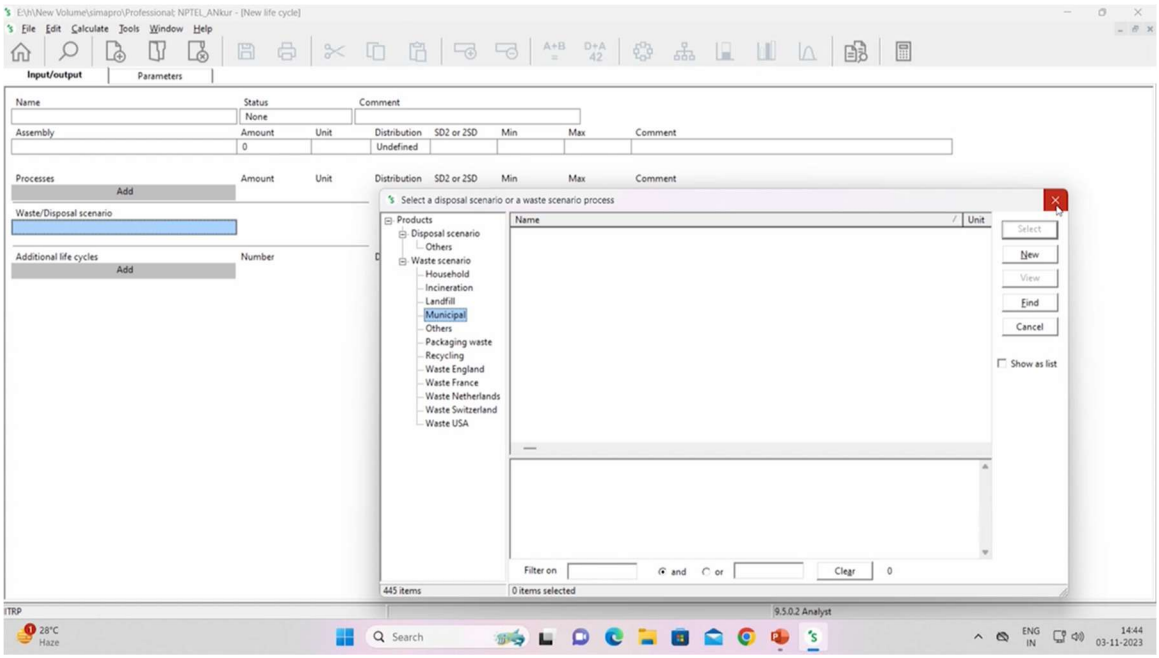
Now coming to the product stages. So in assembly you can create a new one and I will import the bike assembly if I have created all the inventories that I have provided. You can try it on your own.



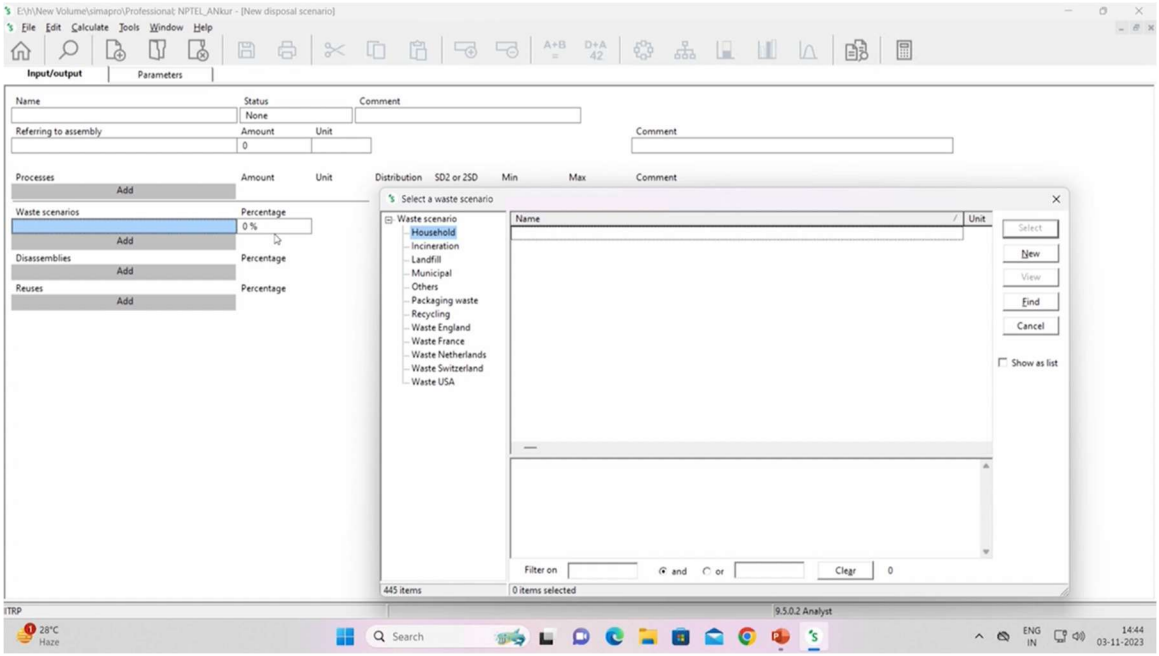
So you need to save it and in the life cycle part I will show you how the life cycle of the bike looks like. So once the bike assembly has been modeled completely then I will import it as input and these are the use phase of the bike.



And I also need to add a bike disposal scenario. So for my case the bike disposal scenario looks something like this. So as you can see 65% of it goes to disassembly and 30% of it goes to bike reuse and 5% of it goes to MSW. So how does it look like in SimaPro? I will show you. The life cycle.

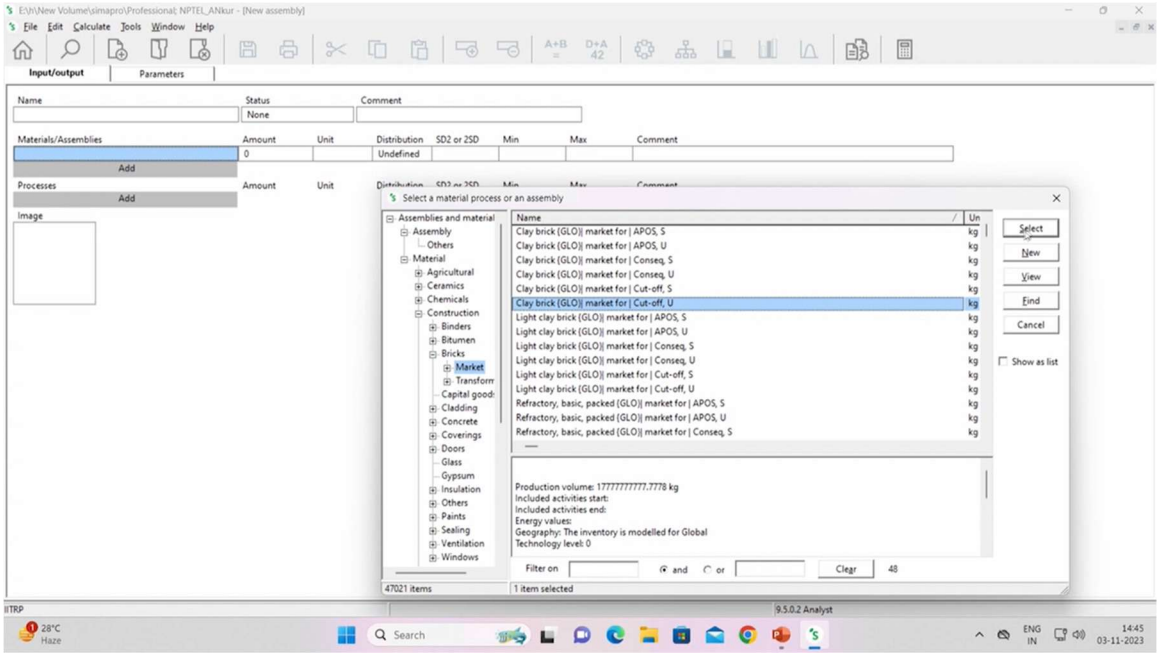


Let's create a new one. Click on others. Let's create a new one. And the waste disposal scenarios are available to you. As you can see household, in simulation, grant, bill, municipal waste all those things are available.

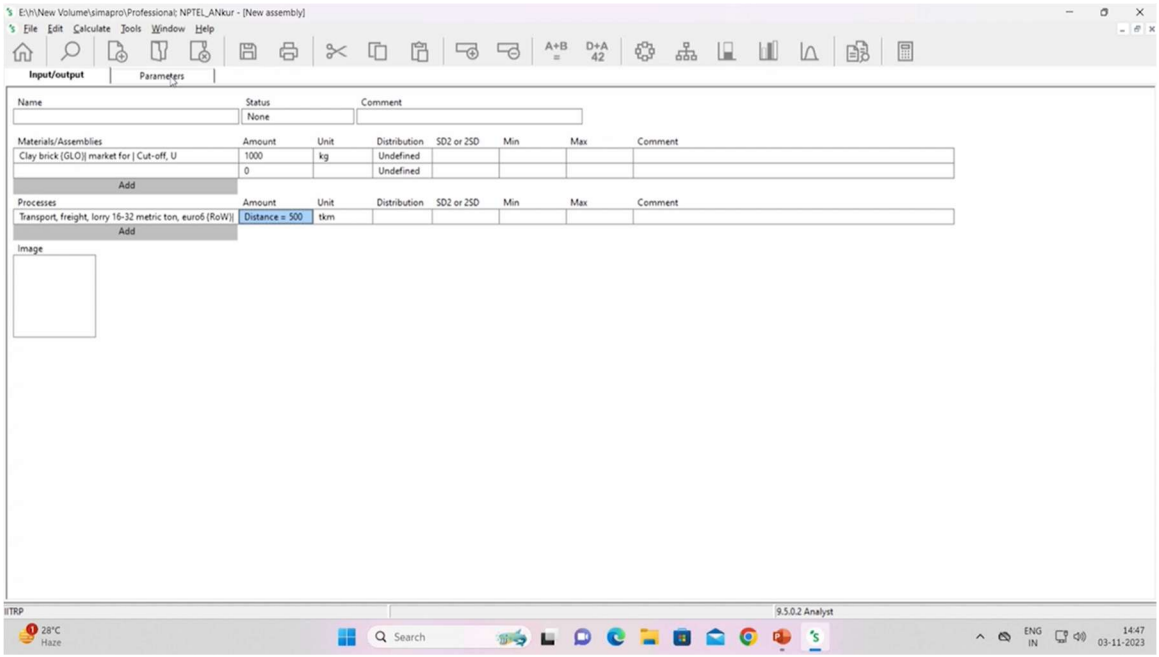


Let's see how the disposal scenario model looks like. I won't be modeling each one of them because it's a lot of inventory and I have showed you the two ones and you can create your assemblies on your own. So waste scenarios I can provide the percentage. So these percentage that I have showed you for bike disposal. So as you can see disassembly contributes to 65% bike reuse 30% MSW 5. So I can add it like this. So municipal solid,

landfill. I can add any one of them to 5% disassemblies. I need to create new ones. So this is how a life cycle from cradle to grave is modeled in SimaPro. Now there is another powerful tool in SimaPro that is known as parameterization.

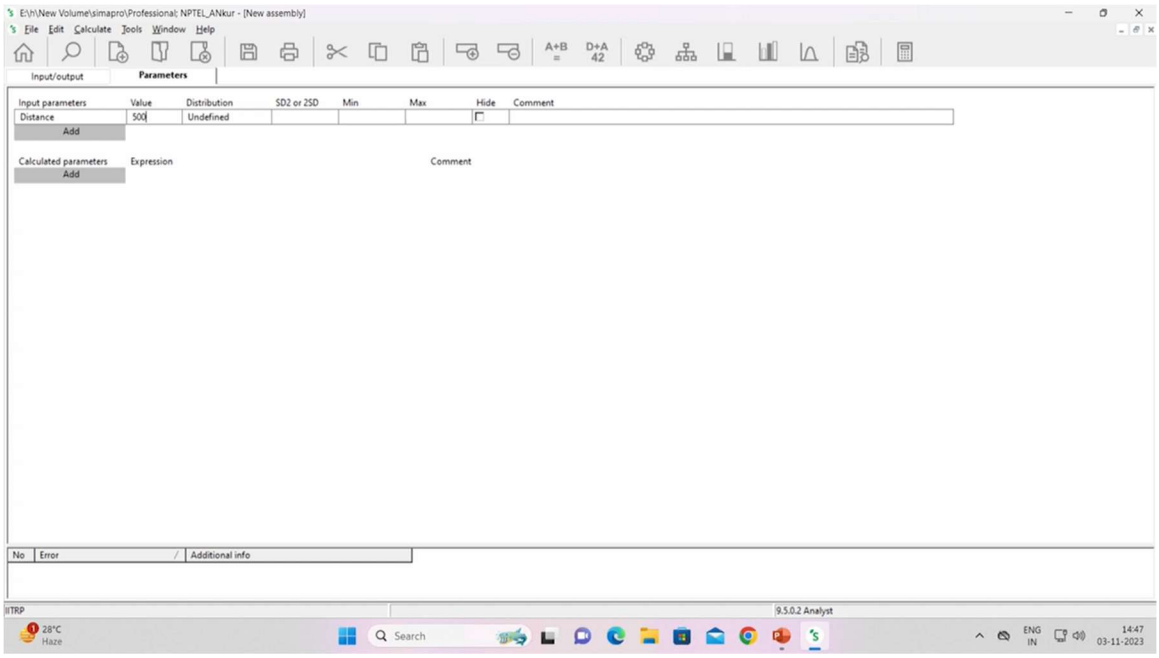


Let us create an assembly first to show how parameters work in SimaPro. So let's say I want to transport some bricks or silo or rather I will go to bricks one, market one.

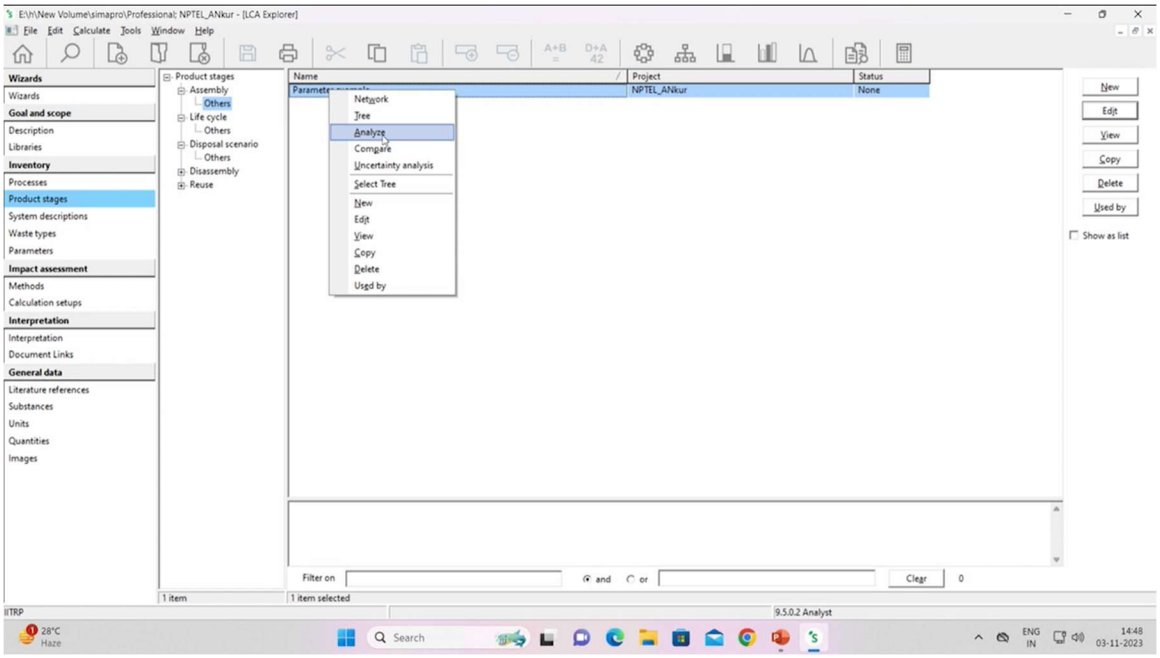


Let's say I want to transport 1000 kg of brakes. And there are three locations or two locations available for me. And those are differentiated by their distances from the

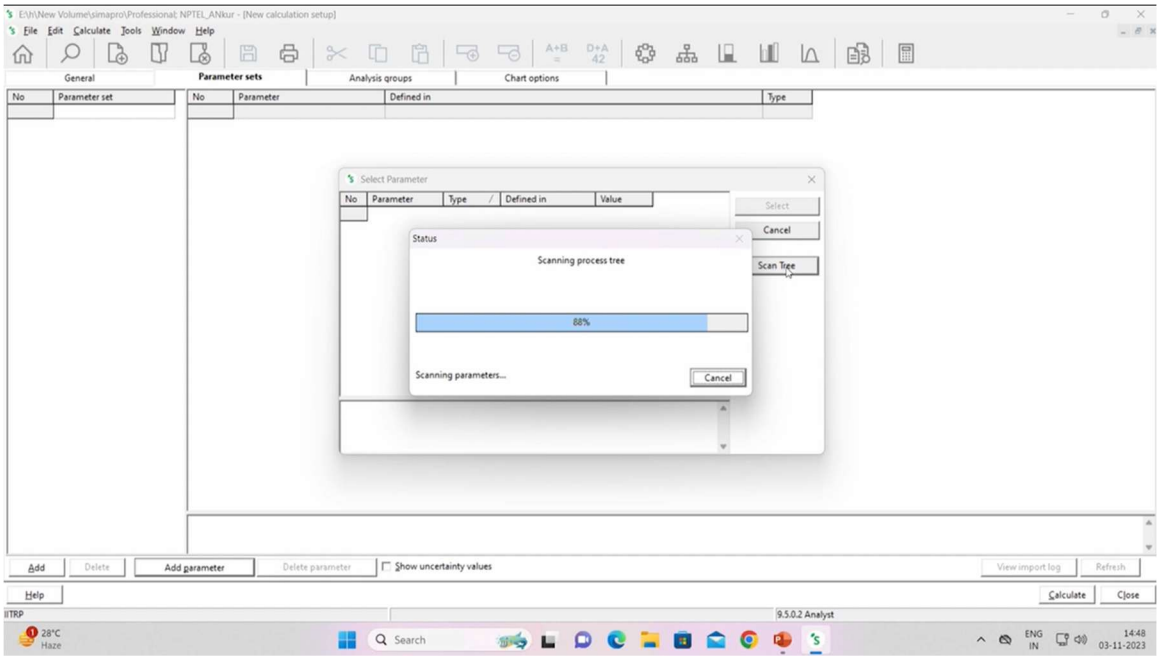
production of labor. So what I will do is I will add a transport process first of all. Let's say I am going by road to market. Let's say I am using a transport freight lorry. So the unit is in terms of tons of km. So transporting 1 ton of mass through 1 km that's the unit ton km. So let's say the first amount is 500 ton km I need to transport it. Now I want to check for the other three locations how the distance if varied would affect the environmental emissions.



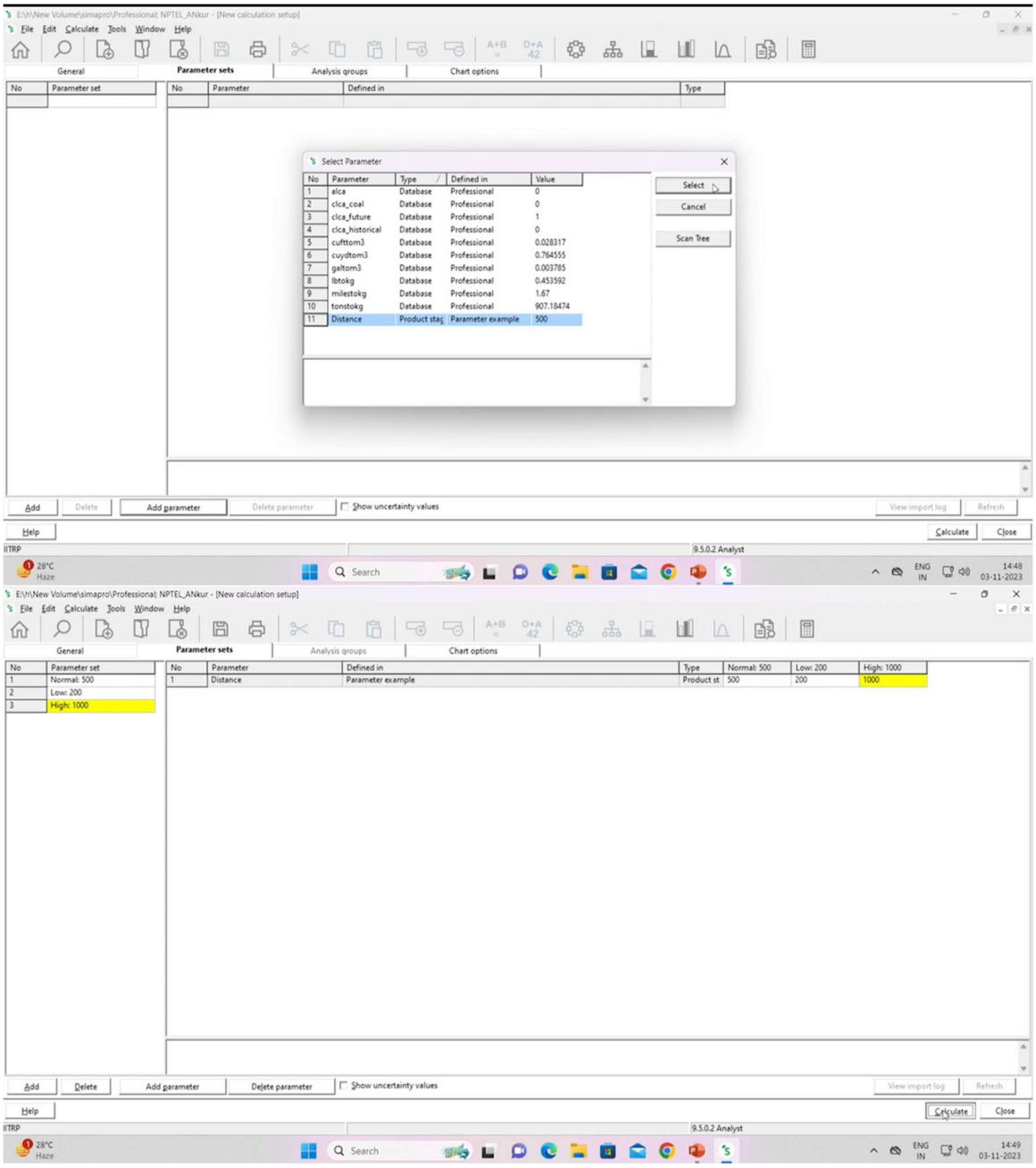
So I need to model it again but no we can add a parameter. As you can see there are two tabs input and output and then in parameters I will add one parameter of my choice. I will name it distance and I will assign the initial value that is the 500. Yeah. And now in place of amount I will simply write the name of the parameter that I have added. So it's distance as you can see is already showing distance equal to 500 km I have just pressed enter. So this is the parameter that I have added. I will click on save. I need to enter a name first. So I will use it as parameter example. Parameters come handy when we don't want to model things again and again. I just want to change this distance. I saved it.



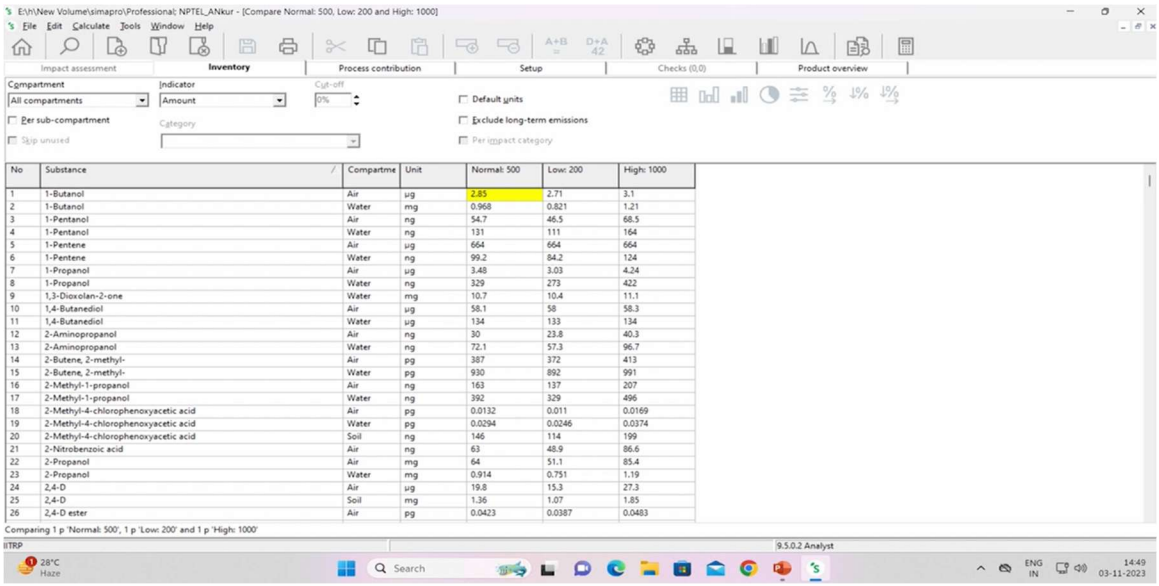
This is the parameter example. I'll right click and I'll click on analyze.



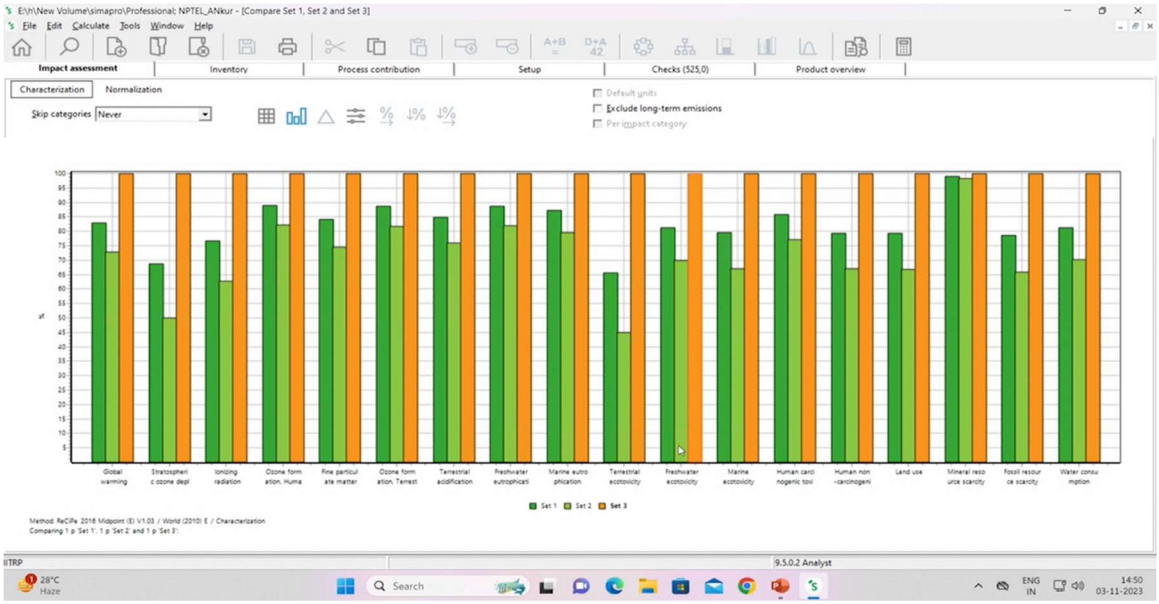
Now as you can see there are various tabs available here as well. So I'll go to parameter sets. I'll click on add parameter. Then this window will pop up. I'll click on scan tree. So in the scan tree it will show all the parameters associated with my assembly.



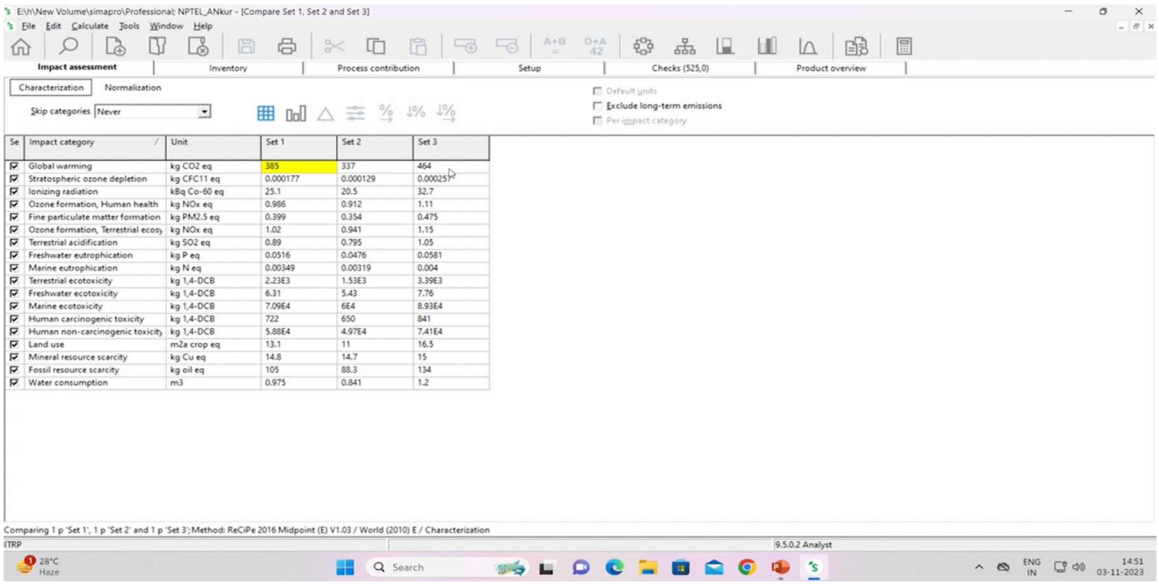
So as you can see this distance parameter was added by us. I'll select this one. I'll add a set. The set one I'll name it as normal. So value is 500. 500 tonne kilometers of distance. I'll add another set and we'll name it low distance or low. So let's say we want to move 200 kilometers. 200 tonne kilometers. So by clicking on add here I've added a set and value. I can just double click it and 200 will be added. Now by clicking on add I'll add a set 3. Which says high distance. So let's say it's 1000 tonne kilometers. I'll click on set 3. Double click on set 3. I'll add the value 1000. So I don't need to model for different distances again and again. I'll just add the parameter and add these values and click on calculate.



So it will show me the environmental impact comparison of these three distances that I've added. So as you can see I haven't selected the method yet. So on the inventory side the normal, the low and the high portions you can see 2.85, 2.71, 3.1. I'll do this again to show the impact assessment. I'll select the method first. Let's say midpoint. I'll go to parameter sets then again add parameter. Already scanned distance. I've already showed you this. Set 1, set 2. You can name it on your own. Our set 3 was the highest one. I'll set the value at 1000 tonne kilometers. I'll click on calculate.

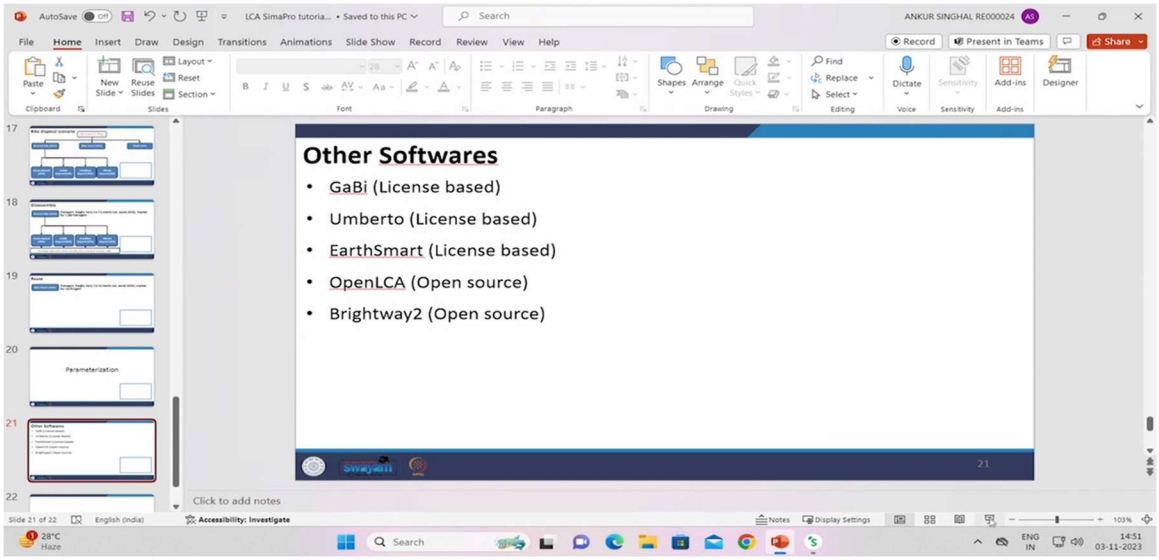


Let's see what the impact assessment shows us. So as expected the set 3 was the highest distance. It shows the red colour. It shows the highest impacts in all of the category. The middle one was the lowest one, the 200 tonne kmh. And the first one was 500, the base case. And as expected the impacts have been shown.



Se	Impact category	Unit	Set 1	Set 2	Set 3
☑	Global warming	kg CO2 eq	385	337	464
☑	Stratospheric ozone depletion	kg CFC11 eq	0.000177	0.000129	0.000257
☑	Ionizing radiation	kBq Co-60 eq	25.1	20.5	32.7
☑	Ozone formation, Human health	kg NOx eq	0.986	0.912	1.11
☑	Fine particulate matter formation	kg PM2.5 eq	0.399	0.354	0.475
☑	Ozone formation, Terrestrial ecos	kg NOx eq	1.02	0.941	1.15
☑	Terrestrial acidification	kg SO2 eq	0.89	0.795	1.05
☑	Freshwater eutrophication	kg P eq	0.0516	0.0476	0.0581
☑	Marine eutrophication	kg N eq	0.00349	0.00319	0.004
☑	Terrestrial ecotoxicity	kg 1,4-DCB	2.23E3	1.53E3	3.39E3
☑	Freshwater ecotoxicity	kg 1,4-DCB	6.31	5.43	7.76
☑	Marine ecotoxicity	kg 1,4-DCB	7.09E4	6E4	8.93E4
☑	Human carcinogenic toxicity	kg 1,4-DCB	722	650	841
☑	Human non-carcinogenic toxicity	kg 1,4-DCB	5.88E4	4.97E4	7.41E4
☑	Land use	m2a crop eq	13.1	11	16.5
☑	Mineral resource scarcity	kg Cu eq	14.8	14.7	15
☑	Fossil resource scarcity	kg oil eq	105	88.3	134
☑	Water consumption	m3	0.975	0.841	1.2

You can click on table to get the exact values as well. Set 3 has the highest global warming, 464. So you don't need to model again for just changing the distance. You can simply add the parameter distance and add the parameter set values and we can simply get to it. So this is the modelling that we have done today in SimaPro. I hope you find it useful. So in today's lecture we saw how to do LCA modelling in SimaPro software. There are a variety of software available for doing LCA modelling as well.



So on your screens you can see there are a variety of software like Gabi, Umberto and Earthsmart. These all 3 are license based. And OpenLCA and Brightway2 are the open source LCA software. The interfaces of these software might be different from SimaPro. But the basics of life cycle assessment would remain the same. So that's it from my side for this lecture. Thank you.