Zoom or Room?

Is Attending a Conference Virtually Better for the Environment?

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Abstract

Scope 3 Emissions Program of Stanford University has identified that the ‘Travel’ category, with emission intensity of 0.36 kg CO_2e/USD, is the fourth most emissions overarching spend category at Stanford. The purpose of this project is to quantify the emissions of attending a conference and to identify the most sustainable way to attend an academic conference by a faculty or a student so as to reduce the scope 3 emissions of the university from travelling. For this project only one purpose - presenting research work - is considered, while other purposes such as networking, learning from other speakers, and local sight-seeing are ignored. The functional unit of our study is one Stanford graduate student attending one conference over 5 days, where we consider only the carbon dioxide emissions associated with transportation and the use of electronic products during the meeting. The scope of our analysis includes everything from raw material acquisition to the meeting itself. In our study, we explored various scenarios for attending virtual and in-person conferences and performed numerous sensitivity analyses on data parameters of uncertainty. Our results show that attending the conference over Zoom has a significantly lower monetary and environmental impact. Specifically, the total emissions over Zoom is 0.5 kg CO_{2e}, while for in-person scenarios, the emissions range from 94 kg to 240 kg CO_{2e}. However, it is important to note that there are additional values and benefits to attending in-person conferences that our LCA cannot quantify, such as networking, workshops and sightseeing. We recommend students discuss with their advisor about potential conferences they would like to attend and decide together which ones would be most worthwhile to attend in-person.

1. Introduction

The Scope 3 Emissions Program of Stanford University, launched in 2021 with an objective to cut down the indirect emissions of the university to the maximum extent, has identified that the 'Travel' category, with emission intensity of 0.36 kg CO_2e/USD, is the fourth most emissions overarching spend category at Stanford. The majority of these emissions are attributed to air travel undertaken by faculty members or students attending conferences to present their research works or ideas.

Generally speaking, academic conferences are held in a specific location. Experts and scholars from all over the world come to the same place through different means of transportation. In the same place, they can discuss academic views face to face. In recent years, with the development of network technology and online video technology, online conferences have gradually become popular. However, face-to-face meetings are still the main way to hold large academic conferences.

Unquestionably, the COVID-19 pandemic has completely changed the way of holding major academic conferences. Almost all conferences in the first part of this year had been moved online, typically via Zoom. To be more specific, a person attends a conference in-person for various purposes like presenting an idea, networking, learning from other speakers and presenters, travelling and local sight-seeing, and so on, but unfortunately virtual conferences cannot fulfill all the purposes, even though they are thought to be economical and eco-friendly.

Considering the current scenario, this project estimates the life cycle emissions associated with the online conference and compares with the emissions released due to attending the conference in-person in different settings. Three different scenarios of travelling are considered for attending an in-person conference - travelling with a battery electric vehicle (BEV), an internal combustion engine vehicle (ICEV), and a passenger plane. Additionally, three different conference destinations are considered for comparing emissions of BEVs and ICEVs to figure out the best way to attend a conference if travelling with a car to a nearby conference destination.

2. Goal and Scope

2.1 Goal of Study

The purpose of this study is to find the most sustainable way to attend an academic conference by a faculty or a student to present the research work or ideas so as to reduce the scope 3 emissions of the university from travelling. To accomplish our goal, we assess the life cycle impacts in terms of carbon emissions and energy resources of attending a virtual and an in-person conference. In the end, we hope our findings will better inform professors and students at Stanford on the varying degrees of impacts of travelling to conferences and to help them decide whether it is worthwhile traveling to the conference or simply attending virtually.

2.2 Functional Unit

In order to compare the impact of virtual attendance to in-person attendance, we define our functional unit as one Stanford graduate student attending one conference over 5 days, and specifically 4 hours per day for virtual attendance.

We only quantify the impacts from transportation and the use of electronic products during the meeting. We neglect the impacts from food, accommodation, commuting between the airport and the meeting place, and personal events during the meeting. The reason we neglect impacts from food and accommodation is because food and accommodation is required regardless of whether we are attending in-person or virtually. Moreover, we chose to neglect commuting between transit because we already expect virtual attendance to have extremely low environmental impacts relative to travelling for an in-person conference. To highlight this gap, we look at the “best case scenario” for the in-person case and the “worst case scenario” for the virtual conference case.

3. Life Cycle Inventory Analysis

3.1 Process Flow Diagrams

For the video conference meeting scenario, we considered the case where the student is at home in the Bay Area, attending the conference virtually from their laptop. In order to accommodate for the hybrid setup, the conference must install a screen display and other video conference peripherals, such as a sound system, a camera and a microphone. Both at home and at the conference would require a separate internet infrastructure setup. This setup is reflected in our process flow diagram for the video conference meeting, Figure 3-1.

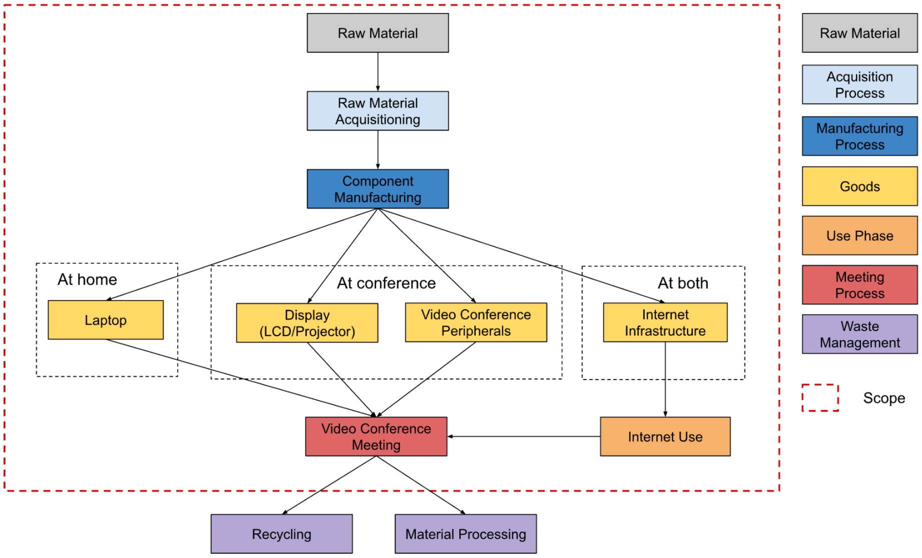


Figure 3-1. Process flow diagram for the video conferencing scenario.

For the in-person conference meeting scenario, we explored three different modes of transportation to the conference: plane, internal combustion engine vehicle (ICEV), and battery electric vehicle (BEV). The process flow diagram for the in-person conference meeting is shown in Figure 3-2. For the in-person scenario, we also consider the fuel manufacturing and fuel consumption impacts of each transport method. We chose not to consider end-of-life in our analysis for simplicity purposes and because it typically is a small fraction of equipment life-cycle impact (Ong et al., 2014).

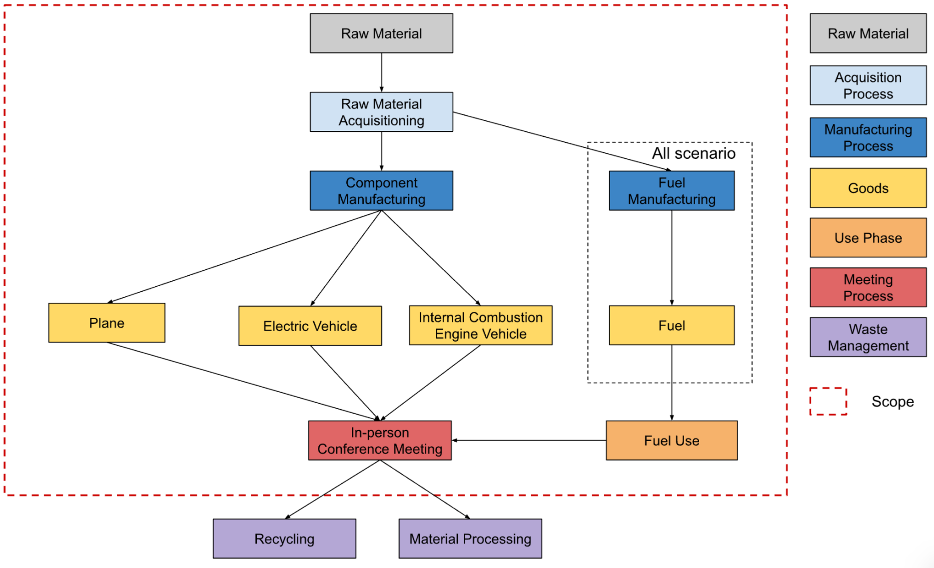


Figure 3-2. Process flow diagram for the in-person conference scenario.

The scope of our analysis includes everything from raw material acquisition to the conference meeting itself. We assume impacts of in-person attendance to the meeting are negligible since the graduate student will not need to use any technology to participate. Similarly to attending the conference in-person, end-of-life material processing and recycling are not considered in our virtual conference analysis. This is emphasized in the process flow diagram in Figures 3-1 and 3-2 as the red dashed box.

3.2 Virtual Conference

In the virtual conference scenario, we identified seven types of equipment needed to support the student, including: laptop, LED 65” display, projector, sound system, microphone, camera, and LAN. We only require one of each equipment type except in the case of the LAN equipment where we would need two, one at the student’s remote location and another at the conference. For these equipment, we obtained the data on the production and use phase emissions from SimaPro and Ong et al.

Out of all the AV equipment we identified would be needed for a virtual conference, SimaPro only had impact data and process flow diagrams for a laptop computer (Table A-1, Figure A-1 and A-2). Ong et al. contained emissions impact data for the full life cycle of each of the other necessary AV equipment. This data is shown in Table A-2 of the Appendix. Given that we are only considering the impacts from raw material to the meeting, neglecting end-of-life, we assumed that 20% of the emissions reported for the AV equipment in Ong et al. are from the production phase and 80% are from the use phase of the equipment for our emissions impact calculations. This assumption was made considering that each of the AV equipment requires energy input for operations in the use phase. From Cisco’s *Environment Technical Review* (Cisco, 2020), the percent of total emissions of their equipment from the use phase ranges from 80% to 90%, with the remaining 10% to 20% being allocated to production and distribution.

Further sensitivity analyses were also performed on the production and use phase emissions allocation in Section 4.1.3.

3.3 In-person Conference

For the in-person conference scenario, our inventory analysis focused on the transport vehicles exclusively. We obtained the input energy and impacts required to produce an ICEV, BEV, and plane from SimaPro (Appendix B). We then used data prepared for us by our sponsor, the Stanford University Office of Sustainability, to estimate the emissions impacts of the use-phase of planes. Data provided from Franklin Associates Ltd. and the Environmental Protection Agency (EPA) is used to estimate use-phase emissions of an ICEV, and data provided from the Environmental Protection Agency (EPA) is used to estimate use-phase emissions of a BEV. It should be noted that for the BEV vehicle, we looked at the car body and the lithium-ion battery production phase emissions separately as they have different emissions impacts in SimaPro. Furthermore, BEVs often have mileage ranges with large variation depending on the manufacturer and model. Thus, it follows that the sizes of the batteries will largely vary as well.

In the case of ICEV, a long range car was considered for the analysis. Production phase emissions depend on the mass of the car and can vary with cars having different weight. Also, the emission per mass of the car was taken from SimaPro which would also vary with different materials of the car. For calculation of use phase emission, combined fuel economy of the car was taken into consideration, which will vary with different cars having different weight and materials.

In the case of the plane, CO_2e emissions mainly come from the use phase. We assume the plane is a Boeing 737, which is the most frequently used airplane. For the use phase, the passenger-miles and the emission factor are of vital importance. We collect this data from Stanford's Office of Sustainability (Stanford University, 2019).

4. Impact Assessment

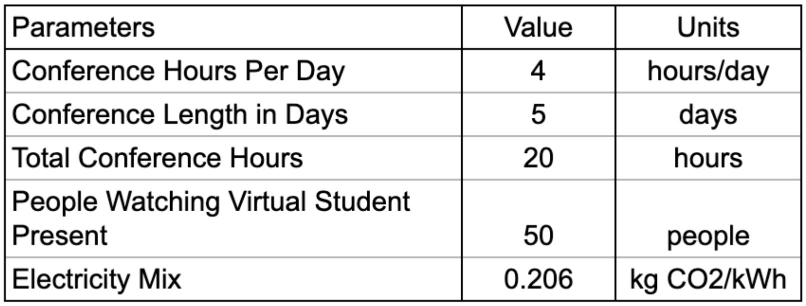
Our impact assessment primarily focused on greenhouse impacts of attending a conference virtually or attending it in-person. Our group decided upon this strategy so that we could look at multiple transportation options for attending a conference in-person. Also, CO_2e emission data was more accessible to our group than other impact categories, such as eutrophication, acidification, etc., and searching for data in these other impact categories would have taken away time for thorough data analysis.

4.1 Virtual Conference

4.1.1 Methods and Assumptions

Our primary assumptions used to calculate GHG emissions are shown in Table 4-1. We assume those who attend the conference virtually will be on zoom for 4 hours per day for each of the 5 days of the conference for a total of 20 hours. We also make an assumption that 50 people will be attending the conference virtually.

Table 4-1. Parameters for impact assessment for video conferencing.



Parameters	Value	Units
Conference Hours Per Day	4	hours/day
Conference Length in Days	5	days
Total Conference Hours	20	hours
People Watching Virtual Student Present	50	people
Electricity Mix	0.206	kg CO2/kWh

To determine the amount of GHG emissions to allocate to the Stanford graduate student for using the AV equipment at home and at the conference, we needed to also make assumptions, based on our knowledge, of the total lifetime of the AV equipment. These assumptions are shown in Table 4-2.

To calculate equipment production GHG emissions to allocate to the graduate student we use Formula 1:

Formula - 1

Production Phase Emission Allocation from AV Equipment (Kg CO_2e***)***

= [AV Equipment Conference Use (hrs) / Lifetime of AV Equipment (hrs)] * [1 graduate student / total people using AV equipment] * [Production Phase Emission of Equipment (Kg CO_2e***)]***

In the Formula 1 allocation, we consider that this conference will only be a small portion of the useful life of the AV equipment and that multiple people attending virtually will be using the AV equipment at the same time.

To calculate equipment use-phase GHG emissions to allocate to the graduate student we use Formula 2:

Formula - 2

Use Phase Emission Allocation from AV Equipment (Kg CO_2e)

= [1 graduate student / total people using AV equipment] * [CA Electricity Mix CO_2e (kg CO_2e/kWh)] * [AV Equipment Power Input (kW)] * [Conference Length (hrs)]

In the Formula 2 allocation, we consider that multiple people attending virtually will be using the AV equipment at the same time. We also consider the power requirements to use the AV equipment and the length of time the equipment will be used for the conference. Power input requirements for the equipment are obtained from Ong et al and shown in Table 4-2.

Apart from the laptop, which is allocated solely to the student, other AV equipment allocations are distributed across the number of virtual participants.

4.1.2 Results

Table 4-2 shows the breakdown of the CO_2e emissions from the production and use phase of each AV equipment. Following our assumptions on allocation, we also assessed the emissions allocated specifically to the individual attending the conference virtually.

Table 4-2. Breakdown of the CO_2 emissions from the production and use phase of each AV equipment, including total emissions allocated to the individual attending the conference virtually.

		At home	**At conference**						**Units**
		Laptop	**Display**		**Video-conf. Peripherals**				
			LED 65"	**Projector**	**Sound System**	**Microphone**	**Camera**	**LAN**	
Equipment Lifetime and Operation Assumptions	Equipment Quantity Needed	1	1	1	1	1	1	2	
	Equipment Lifetime	5	6	6	12	10	5	5	yrs
	Daily Hours of Operation	5	3	3	3	3	3	24	hrs/day
	Lifetime Hours of Operations	9125	6570	6570	13140	10950	5475	43800	hrs
	Power Consumption	40.0	220.6	135.0	4.1	2.5	9.5	20.0	W
Allocation for Individual at Virtual Conference	Conference Hours of Operations	20	20	20	20	20	20	20	hrs
	Production Phase Allocated to Conference	0.22%	0.30%	0.30%	0.15%	0.18%	0.37%	0.05%	%
	Use Phase Allocated to Individual at Conference	100.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	%
Production Phase Emissions	Total Production Phase Emissions	117	74.46	45.57	2.77	1.41	2.67	45.01	kg CO2e
	Production Phase Emission Allocated to Conference	**0.2564**	**0.0045**	**0.0028**	**0.0001**	**0.0001**	**0.0002**	**0.0008**	**kg CO2e**
Use Phase Emissions	Conference Energy Consumption	0.800	4.411	2.700	0.082	0.050	0.190	0.400	kWh
	Use Phase Emissions Allocated to Conference	0.164	0.907	0.555	0.017	0.010	0.039	0.082	kg CO2e
	Use Phase Emission Allocated to Individual at Virtual Conference	**0.16443**	**0.01813**	**0.011099**	**0.000337**	**0.000206**	**0.000781**	**0.001644**	**kg CO2e**
	Total CO2e for conference (CA)	**0.421**	**0.023**	**0.014**	**0.000**	**0.000**	**0.001**	**0.002**	**kg CO2e**

Figure 4-1 summarizes the emissions of each equipment by use and production phases, as well as demonstrating the breakdown total emissions in a stacked bar chart.

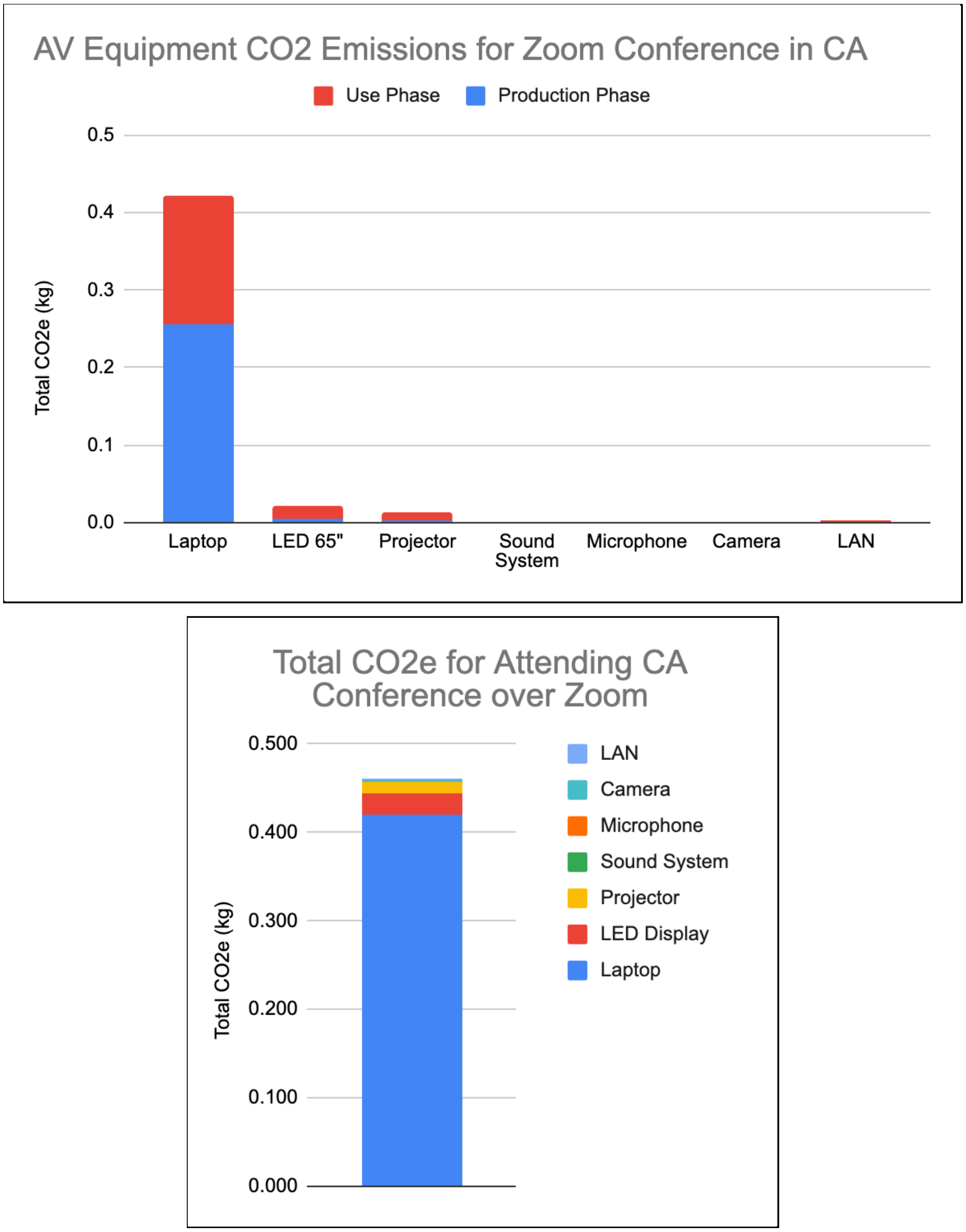


Figure 4-1. CO_2e emissions impact by equipment for attending a conference in LA virtually. Breakdown by use and production phase (top). Stacked bar chart of total emissions (bottom).

4.1.3 Sensitivity Analysis

Due to the uncertainty aspects of our equipment parameters we have used in our impact assessment, we performed several cases of sensitivity analysis on our assumptions and parameters.

Conference Location

Depending on the location of the conference, the electricity mix at that location can vary. In our base case, we examined a conference held in California, which has a high renewable energy portfolio and thus a low carbon emissions impact per kwh. Other locations may rely more heavily on coal for electricity. For our sensitivity analysis, we explored three alternative locations: New Orleans, Louisiana; New York City, New York; and London, UK. The breakdown of the electricity mix is summarized in Table 4-3 (“Power Profiler | US EPA”). Figure 4-2 shows how the electricity mixes impact the total CO_2e emissions from the AV equipment.

Table 4-3. Electricity mix of different locations for sensitivity analysis.

Location	Electricity Mix (kg CO_2e/kWh)
CA	0.206
LA	0.366
NY	0.251
UK	0.266

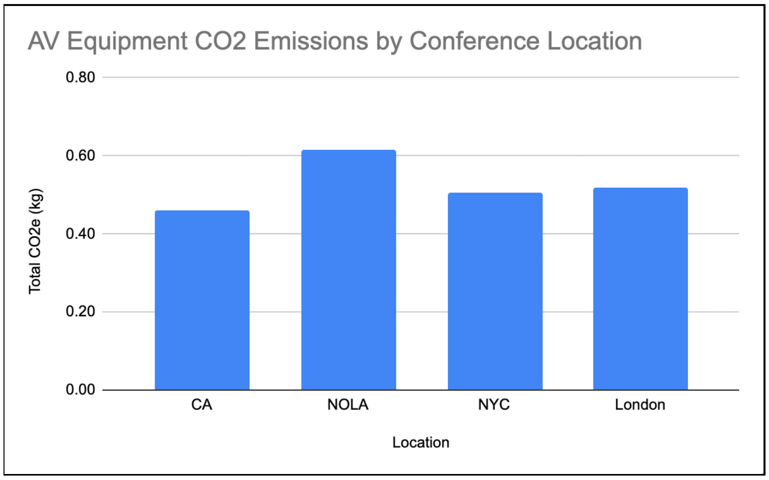


Figure 4-2. Variations in the total CO_2 emissions for virtual attendance by electricity mix.

Length of Conference

The length of the conference may also impact the emissions in both how much electricity is consumed by the equipment from operation and also how much electricity is needed to operate Zoom. Our base case was a student on Zoom for 20 total hours. We explored two scenarios for the sensitivity analysis: 5 total hours, and 40 total hours.

AV Equipment Lifespan

Equipment lifespan affects the percentage of production phase emissions to the conference itself. The longer the equipment lifespan, the smaller that allocation is to the conference itself. Our base case equipment lifespan can be found in Table 4-2. In the sensitivity analysis, we looked at a 50% longer lifetime and a 50% shorter lifetime from the base case.

Number of People Utilizing the Conference Room

The number of people sharing the AV equipment at the conference impacts the allocation of the production and use phase emissions. In our analysis, the AV equipment - excluding laptop - are installed at the conference for when the virtual student presents to an in-person audience. This implies that the larger the number of virtual presenters utilizing this equipment, the smaller the allocation is per person. In the sensitivity analysis, we examined a 50% increase and a 50% decrease in users from the base case in Table 4-2.

Production Versus Use Phase Emissions Allocation

We also performed sensitivity analysis on the percent allocation from the total emissions to use and production phase. The data we obtained from Ong et al. contained emissions impact data for the full life cycle of each of the other necessary AV equipment and since we are only considering the impacts from raw material to the meeting, we assumed that 20% of the emissions reported for the AV equipment are from the production phase and 80% are from the use phase of the equipment for our base case emissions impact calculations. For our sensitivity analysis, we considered a case where 5% of CO_2e emissions is from production rather than 20%, and another case where 50% of CO_2e emissions is from the production phase of equipment.

Figure 4-3 demonstrates how sensitive the results are to each case we explore. As shown, the total conference hours is the most sensitive parameter.

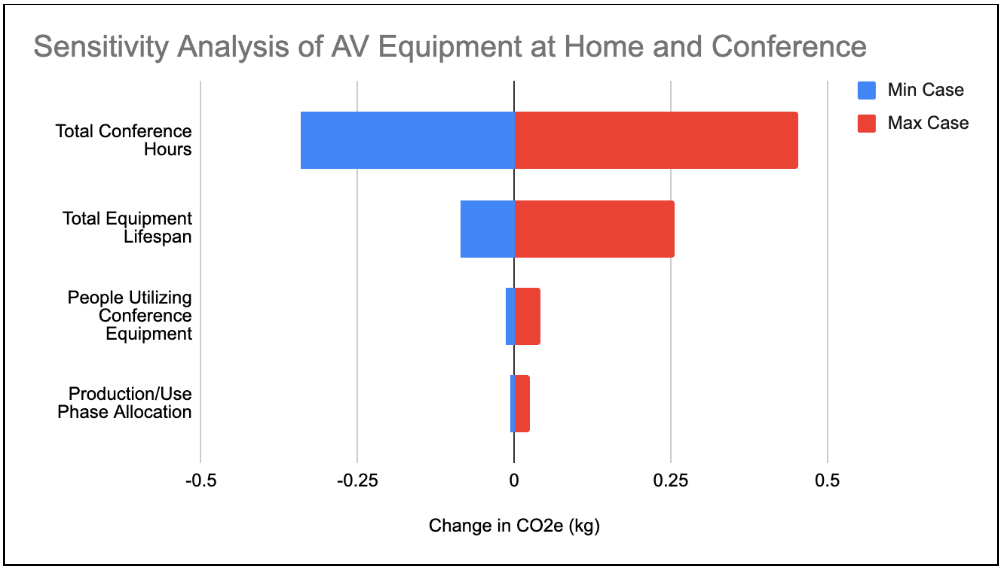


Figure 4-3. Tornado diagram of the CO_2e impact from the sensitivity analysis for attending a virtual conference in CA.

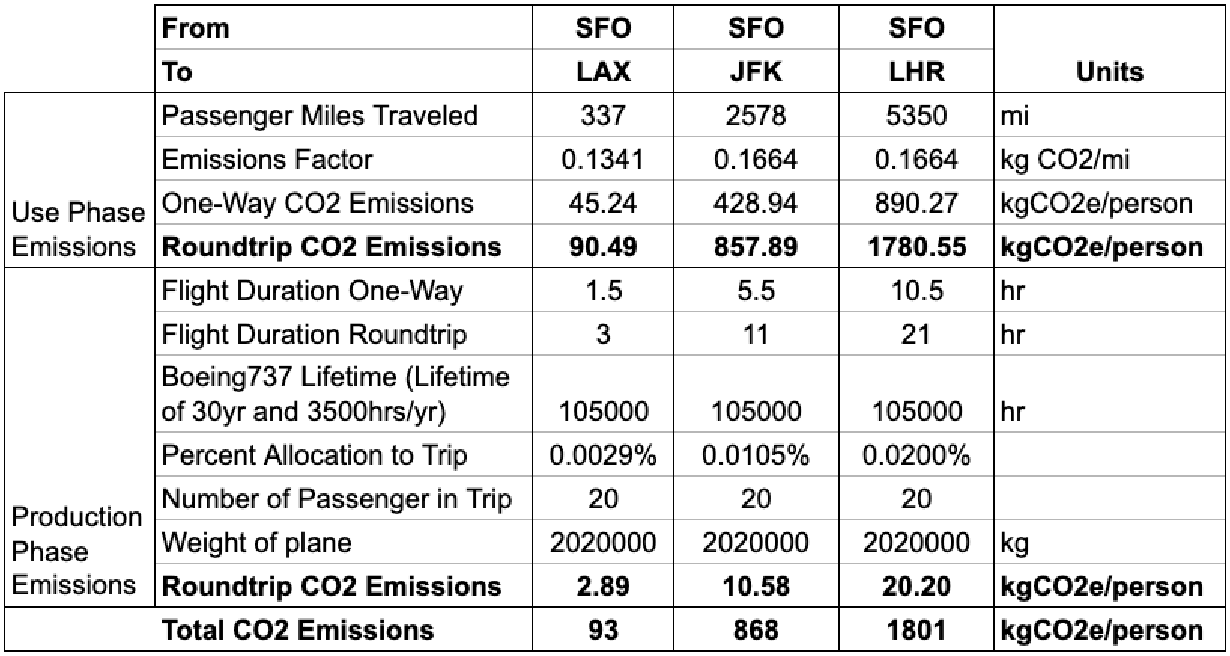
4.2 In-Person Conference

4.2.1 Plane

Our lifetime of airplane data comes from (USAToday). Our emission factor comes from both the website (FlyGreen) and Stanford's Office of Sustainability (Stanford University, 2019). To clarify, we assume that for the production phase, a plane carries 20 people. The reason for our assumption is that the carbon dioxide emissions in the production phase account for only a small proportion. Changing the number of people has little effect on total carbon dioxide emissions (less than 5%). Also, we choose London as our base case (LHR airport) since it is the most frequently visited destination (Stanford University, 2019).

For our project scope, the emission of carbon dioxide is only considered from the use phase and the production phase of the airplane. For the use phase, we multiply the passenger-miles by the corresponding emission factor to get the carbon dioxide emitted from SFO to the destination. For the production phase, we need to allocate all the carbon dioxide produced by the production of an aircraft to each passenger for every flight. Specifically, first, we calculated the proportion of the flight to the life of the aircraft. Next, we multiplied all the carbon dioxide produced by the production phase of an aircraft by the ratio of the flight to the lifetime of the plane to obtain the carbon dioxide in the production phase allocated for every flight. Finally, we allocate the carbon dioxide generated by the flight to each passenger according to the number of passengers. It is worth noting that we assume that each trip is a two flight round-trip.

Table 4-4. CO_2e emissions from the production and use phase of each destination allocated to the individual attending the conference in-person via plane.



	From	**SFO**	**SFO**	**SFO**	
	To	**LAX**	**JFK**	**LHR**	**Units**
Use Phase Emissions	Passenger Miles Traveled	337	2578	5350	mi
	Emissions Factor	0.1341	0.1664	0.1664	kg CO2/mi
	One-Way CO2 Emissions	45.24	428.94	890.27	kgCO2e/person
	Roundtrip CO2 Emissions	**90.49**	**857.89**	**1780.55**	**kgCO2e/person**
Production Phase Emissions	Flight Duration One-Way	1.5	5.5	10.5	hr
	Flight Duration Roundtrip	3	11	21	hr
	Boeing737 Lifetime (Lifetime of 30yr and 3500hrs/yr)	105000	105000	105000	hr
	Percent Allocation to Trip	0.0029%	0.0105%	0.0200%	
	Number of Passenger in Trip	20	20	20	
	Weight of plane	2020000	2020000	2020000	kg
	Roundtrip CO2 Emissions	**2.89**	**10.58**	**20.20**	**kgCO2e/person**
	Total CO2 Emissions	**93**	**868**	**1801**	**kgCO2e/person**

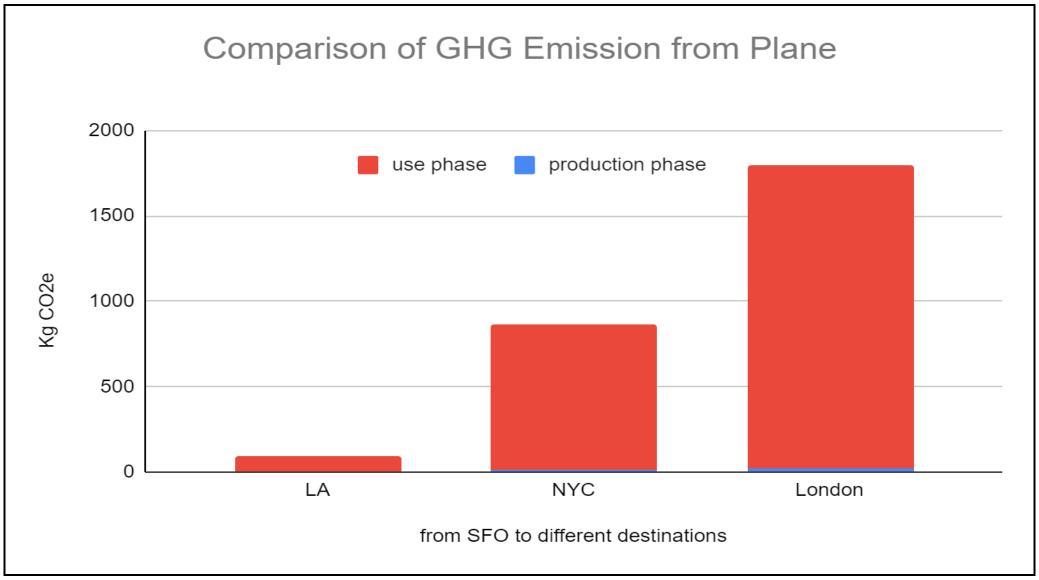


Figure 4-4. CO_2e emission from flying to different destinations of the conference.

4.2.2 Internal Combustion Engine Vehicle (ICEV)

A 2020 Toyota Corolla Sedan Compact Car was considered for the analysis to figure out the greenhouse gas emissions due to travelling to three different destinations (San Francisco, Sacramento, and Los Angeles) of academic conferences from Stanford. Firstly, production phase emissions of the car were calculated using CO_2e emission rate (Kg CO_2e / Kg of car) and mass of car, as per Formula 1. Emissions were allocated to the conference as per the distance travelled by the car for the purpose of conference, as per Formula 2. Use phase emissions attributed due to tailpipe emission from the burning of gasoline while travelling to conferences were calculated using the Formula 3. Pre-combustion emissions of fuel consumed were also included in this phase to get the life cycle emission of fuel. Table 4-5 depicts the detailed calculation of GHG emissions associated with travelling to an academic conference.

Formula - 1

Production Phase Emission of Car (Kg CO_2e)
= [CO_2 emission rate (Kg CO_2e/Kg of car)] * [Mass of Car (Kg)]

Formula - 2

Production Phase Emission Allocation to Conference (Kg CO_2e)
= [Distance Travelled (Km) / Lifetime of car (Km)] * [Production Phase Emission of car (Kg CO_2e)]

Formula - 3

Use Phase Emission (Kg CO_2e)
= [Fuel Energy Content (mBTU/gal)] * [Fuel GHG Emission Rate (kg CO2e/mBTU)] *
[Combined Fuel Economy (gal/Km)] * [Distance Travelled by car (Km)]

Table 4-5. GHG emissions from the production and use phase of three destinations allocated to the individual attending the conference in-person via ICE car.

	Destination 1	**Destination 2**	**Destination 3**
From	Stanford	Stanford	Stanford
To	San Francisco	Sacramento	Los Angeles
Total Round Trip Distance (Km)	114	388	1160
Production Phase Emission Allocation			
CO_2e emission rate (Kg CO_2e / Kg of car)	6.831	6.831	6.831
Mass of Car (Kg)	1315	1315	1315
CO_2e Emission (Kg CO_2e)	8982.765	8982.765	8982.765
Lifetime of Vehicle (Km)	482803	482803	482803
% Allocation to Conference Travel	0.0002361	0.0008036	0.0024026
Production Phase Emission (Kg CO_2e)	**2.121**	**7.219**	**21.582**
Use Phase Emission Allocation			
Gasoline Energy Content (million BTU/1000 gal)	142	142	142
Gasoline GHG Emission Rate (Pounds CO_2e/million BTU)	155.77	155.77	155.77
Combined Fuel Economy (L/100Km)	7.1	7.1	7.1
CO_2e Emission (Kg CO_2e/Km)	0.188	0.188	0.188
Use Phase Emission (Kg CO_2e)	**21.427**	**72.928**	**218.032**
Total Emission (Kg CO_2e)	**23.548**	**80.147**	**239.615**

4.2.3 Battery Electric Vehicle (BEV)

For the BEV analysis, a 2021 Tesla Model 3 Longe Range with no further upgrades was utilized. Specifications were pulled from the owner's manual (Tesla). Additionally, the electricity mix used to charge the car was assumed to be that of California as all three of our destinations are located within California. The lifetime of the vehicle was kept the same as the ICEV, although the BEV can likely support more mileage due to the nature of battery longevity (Els). As seen in Formula 4, the total production phase emissions of the car sums the emissions from the car body and the emissions from the lithium-ion battery pack due to different emission values from SimaPro for these values, as seen in Table 4-6. Production phase emissions for the BEV were allocated like those of the ICEV. Use phase emissions, as seen in Formula 6, rely on the energy consumption per km in addition to the distance travelled and carbon intensity of California's electricity mix. It is important to note that energy consumption is determined by battery size [kWh] and range [km] specifications under the assumption that DC power is used and kWh into the battery is equal to kWh out of the battery, since the vehicle also utilizes regenerative braking. Additionally, battery degradation (resulting in higher energy consumption) is not accounted for.

Formula - 4

Production Phase Emissions of BEV (Kg CO_2e)
= [CO_2 emission rate (Kg CO_2e/Kg of battery)] * [Mass of battery (Kg)] + [CO_2 emission rate (Kg CO_2e/Kg of car body)] * [Mass of car body (Kg)]

Formula - 5

Production Phase Emission Allocation to Conference for BEV (Kg CO_2e)
= [Distance Travelled (Km) / Lifetime of car (Km)] * [Production Phase Emission of car (Kg CO_2e)]

Formula - 6

Use Phase Emissions for BEV (Kg CO_2e)
= [Energy Consumption (kWh/km)] * [CA Electricity Mix CO_2e (kg CO_2e/kWh)] * [Distance Travelled by car (Km)]

Table 4-6. GHG emissions from the production and use phase of three destinations allocated to the individual attending the conference in-person via BEV car.

	Destination 1	**Destination 2**	**Destination 3**
From	Stanford	Stanford	Stanford
To	San Francisco	Sacramento	Los Angeles
Total Round Trip Distance (Km)	114	388	1160
Production Phase Emission Allocation			
Mass of car without battery (Kg)	1367	1367	1367
Mass of battery (Kg)	480	480	480
CO_2e Emission Car without battery per kg (Kg CO_2e)	7.739	7.739	7.739
CO_2e Emission battery per kg (Kg CO_2e)	6.049	6.049	6.049
CO_2e Emissions per car (Kg CO_2e)	13483.74	13483.74	13483.74
Lifetime of Vehicle (Km)	482803	482803	482803
% Allocation to Conference Travel	0.0002361	0.0008036	0.0024026
Production Phase Emission (Kg CO_2e)	**3.18**	**10.84**	**32.39**
Use Phase Emission			
CA Electricity Mix CO_2e [kg CO_2e/kWh]	0.289	0.289	0.289
Battery Size [kWh]	82	82	82
Km per charge	576.14	576.14	576.14
Energy Consumption [kWh/km]	0.142	0.142	0.142
[kg CO_2e/km]	0.041	0.041	0.041
Use Phase Emission (Kg CO_2e)	**4.68**	**15.95**	**47.71**
Total Emission (Kg CO_2e)	**7.87**	**26.79**	**80.11**

4.2.4 Comparison of ICEV and BEV

Figure 4-5 shows the resulting GHG emissions for the three different conference locations travelled for the ICEV and BEV. We notice that for all locations, driving the BEV round trip to the conference results in about 33% of the emissions that the ICEV produces. The production phase emissions for the Tesla Model 3 long range (BEV) allocated for each trip are about double that of the Toyota Corolla (ICEV). However, the BEV makes up for this with low use phase emissions, such that overall, the BEV's total emissions are about ~33% of the ICEV total emissions.

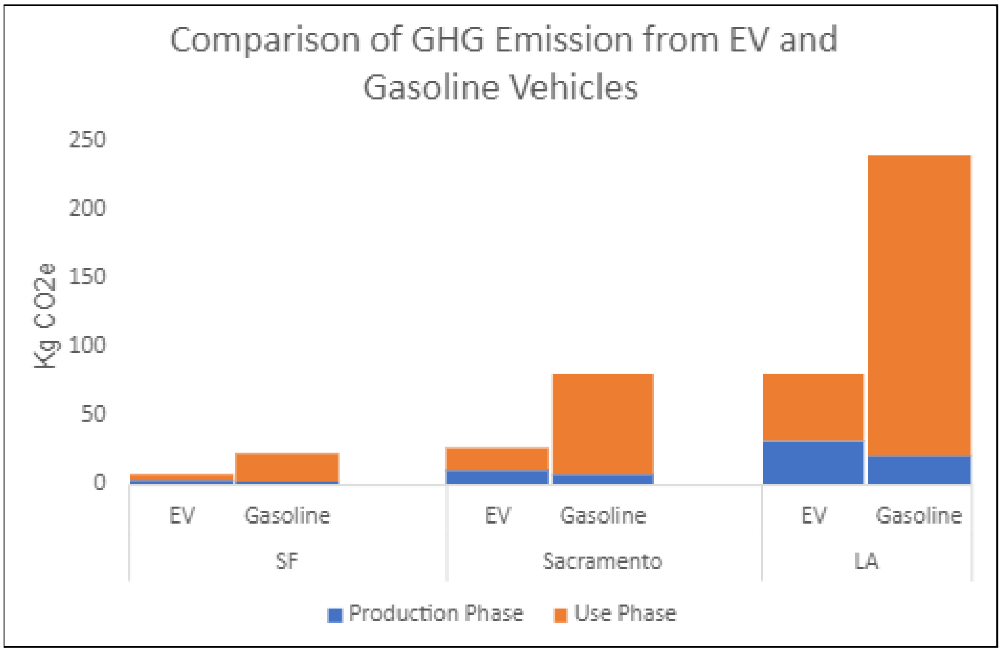


Figure 4-5. Comparison of emissions in kg CO_2e from travelling to three destinations of conference via EV and ICE cars.

4.3 Final Impact Comparison

When comparing all attending in-person scenarios for attending a conference in Los Angeles, as seen in Figure 4-6, and attending virtually, we notice that zoom is the most emissions friendly option. In comparison to all of the in-person scenarios, the emissions from attending via zoom are virtually negligible.

Looking at the modes of transportation to attend in-person, it is clear that driving an ICEV by yourself to a conference is by far the worst option as it emits more than double that of the plane and BEV. Meanwhile, driving a BEV will produce fewer emissions than flying.

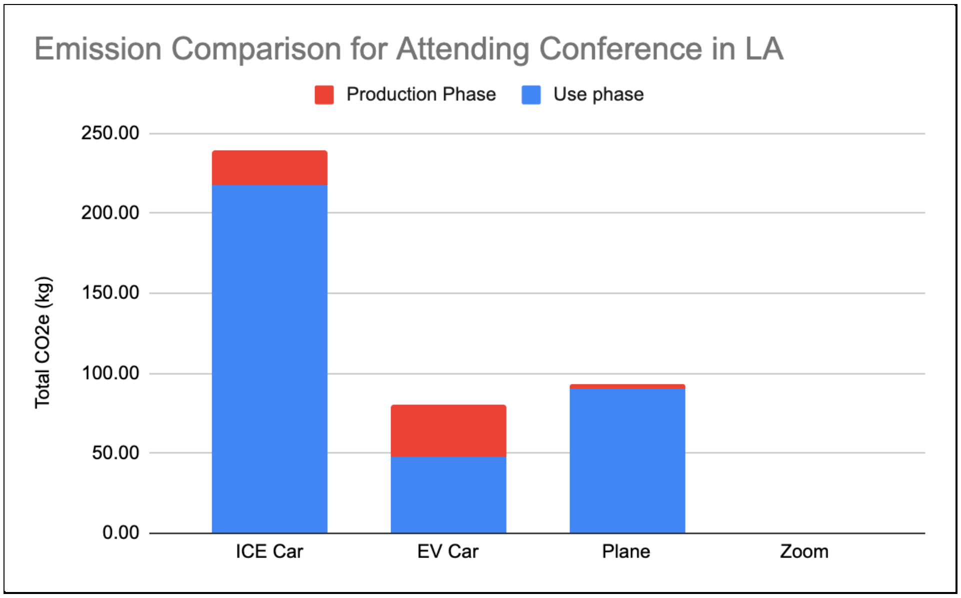


Figure 4-6. Comparison of the CO_2e emissions from attending a conference in LA via different modes of transportation and virtually.

5. Cost Assessment

A cost assessment of all four options to attend a conference in LA are compared in Figure 5-1. The registration fees and hotel fees are pulled from the 2021 AGU conference ("Registration Rates"), as these should be similar from year to year regardless of location. It is assumed that the electricity necessary to power a 2021 MacBook Pro 16-inch laptop (MSRP \$2499) ("Buy 16-inch MacBook Pro") at home will cost 26 ¢/kWh through PG&E under the standard E-1 (Tier 1) rate plan ("Understand the PG&E Tiered Rate Plan (E-1)"). However, the BEV will necessitate a different rate plan for at-home charging, namely the EV-2A rate plan through PG&E, where off-peak charging from 12am-3pm is 19 ¢/kWh ("Making sense of the rates"). The ICEV is assumed to be fueled with regular gas at 4.551 \$/gal, as reported by the EIA for California gas prices on November 22, 2021 ("California Gasoline and Diesel Retail Prices"). Finally, the MSRP for the 2021 Tesla Model 3 long range (base model) is assumed to be \$50,990 ("Design Your Model 3") and the MSRP for the 2020 Toyota Corolla (automatic base model) is assumed to be \$20,790 ("2020 Toyota Corolla L (auto) Specifications - The Car Guide"). Material allocation costs are allocated similarly to their emissions counterparts for all scenarios except for by plane. For the plane scenario, this cost is the full cost of the plane ticket (Google).

We notice that across all scenarios, the virtual option is the most cost effective with the bulk of the cost coming from the registration fee. For the in-person options, the plane is the most expensive, while the ICEV and the BEV options are similar. An interesting point to note is that although there is more than a \$30,000 difference between the two vehicles, the difference in trip costs is quite small (around \$4.00). This is largely due to the cheap electricity vs expensive fuel costs.

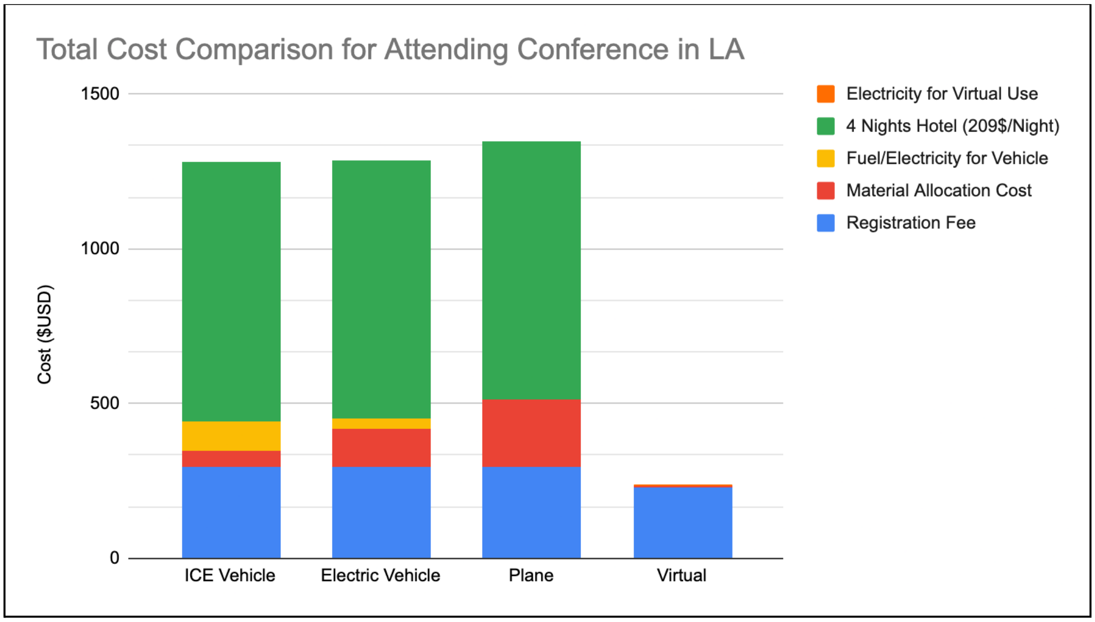


Figure 5-1. Comparison of the total cost for attending a conference in LA via different modes of transportation and virtually.

6. Conclusions and Recommendations

Our results demonstrate that attending a conference virtually has a significantly lower monetary and environmental impact. Specifically, the total emissions of a virtual attendance is 0.5 kg CO_{2e}, while for in-person scenarios, thet emission ranges from 94 kg to 240 kg CO_{2e}. In terms of total cost, the difference between attending virtually and in-person is almost six times higher.

While attending conferences virtually has a significantly reduced monetary and environmental impact, these are not the only considerations. When deciding between attending a conference in-person or online, the professor and student will also want to consider the audience at the conference and the potential networking opportunities that would be more valuable if the student attends the conference in-person. Attending the conference in-person will likely lead to stronger connections with others in the same field of study which can be invaluable to finding career opportunities into the future. In addition, it is important to consider that students work exceptionally hard and having the opportunity to travel and have some time to take their mind off of their studies and explore a new place can enable them to study more effectively during working hours. These are all benefits to attending in-person conferences that are difficult, if not impossible, to quantify.

We recommend students talk with their research advisor about potential conferences they would like to attend and decide together which ones would be most worthwhile to attend in-person. We recommend students to travel to at least one conference in-person to have a better chance of meeting new people in their field of studying.

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Appendix A: Impact Assessment of AV Equipment and Video Conferencing

A1. Laptop

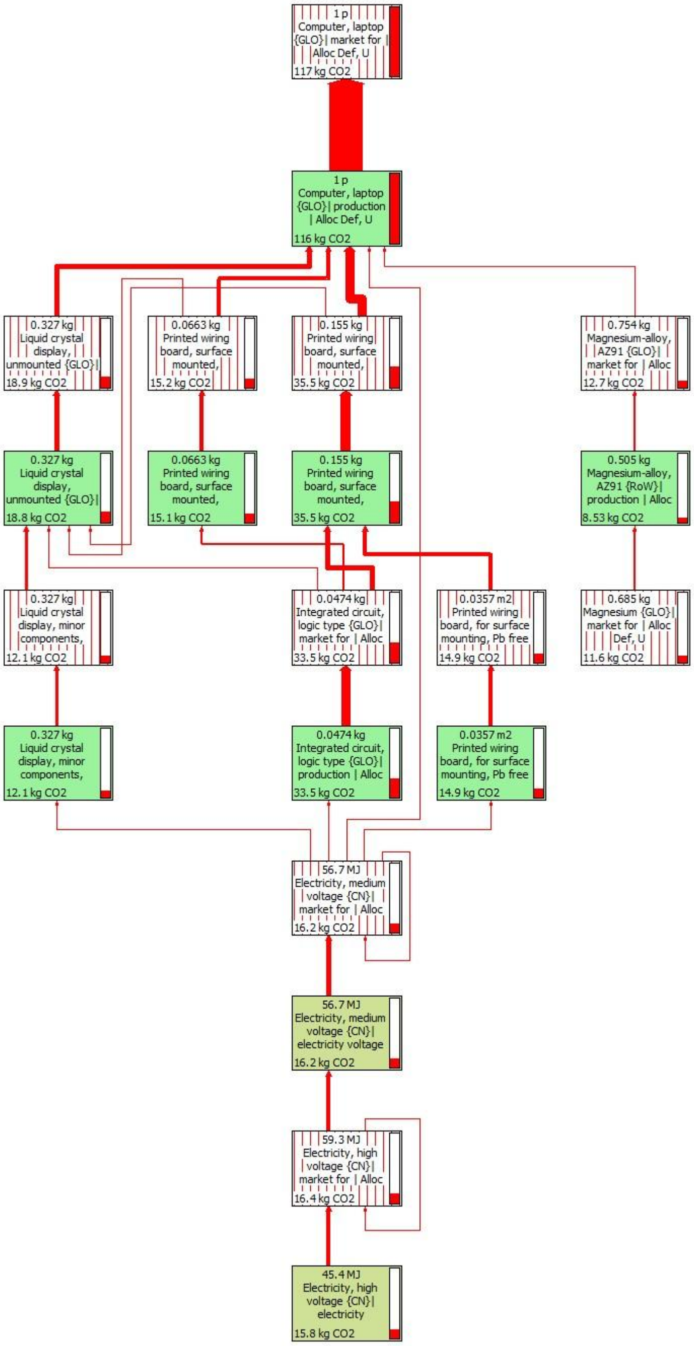


Figure A-1: Impact assessment of laptop production in CO2 emissions. (SimaPro)

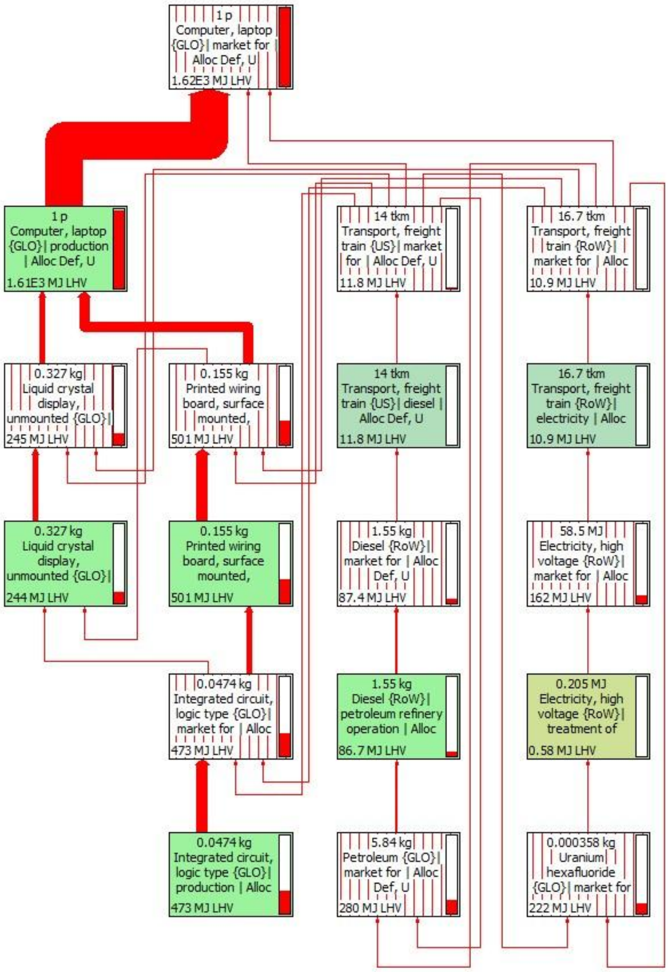


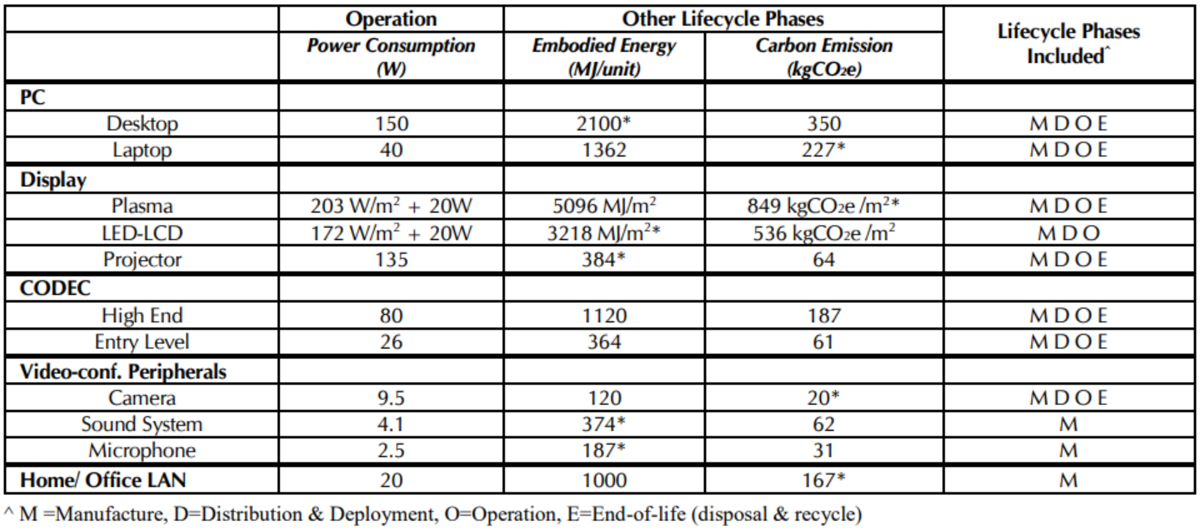
Figure A-2: Impact assessment of laptop production in energy basis. (SimaPro)

Table A-1: Summary of impact for each category of laptop production. (SimaPro)

Impact category	Unit	Total
Greenhouse	kg CO2	1.17E+02
Ozone layer	kg CFC11	8.49E-06
Acidification	kg SO2	1.06E+00
Eutrophication	kg PO4	9.77E-01
Heavy metals	kg Pb	5.93E-02
Carcinogens	kg B(a)P	3.86E-05
Pesticides	kg act.subst	0.00E+00
Summer smog	kg C2H4	4.09E-02
Winter smog	kg SPM	7.53E-01
Energy resources	MJ LHV	1.62E+03
Solid waste	kg	0.00E+00

A2. AV Equipment

Table A-2: AV equipment life cycle CO_2 impacts. (Ong et al., 2014)



	Operation	Other Lifecycle Phases		Lifecycle Phases Included^
	Power Consumption (W)	***Embodied Energy (MJ/unit)***	***Carbon Emission (kgCO$_2$e)***	
PC				
Desktop	150	2100*	350	M D O E
Laptop	40	1362	227*	M D O E
Display				
Plasma	203 W/m^2 + 20W	5096 MJ/m^2	849 kgCO$_2$e /m^2*	M D O E
LED-LCD	172 W/m^2 + 20W	3218 MJ/m^2*	536 kgCO$_2$e /m^2	M D O
Projector	135	384*	64	M D O E
CODEC				
High End	80	1120	187	M D O E
Entry Level	26	364	61	M D O E
Video-conf. Peripherals				
Camera	9.5	120	20*	M D O E
Sound System	4.1	374*	62	M
Microphone	2.5	187*	31	M
Home/ Office LAN	20	1000	167*	M

^ M =Manufacture, D=Distribution & Deployment, O=Operation, E=End-of-life (disposal & recycle)

Appendix B: Impact Assessment of Different Modes of Transportation

B1. Plane

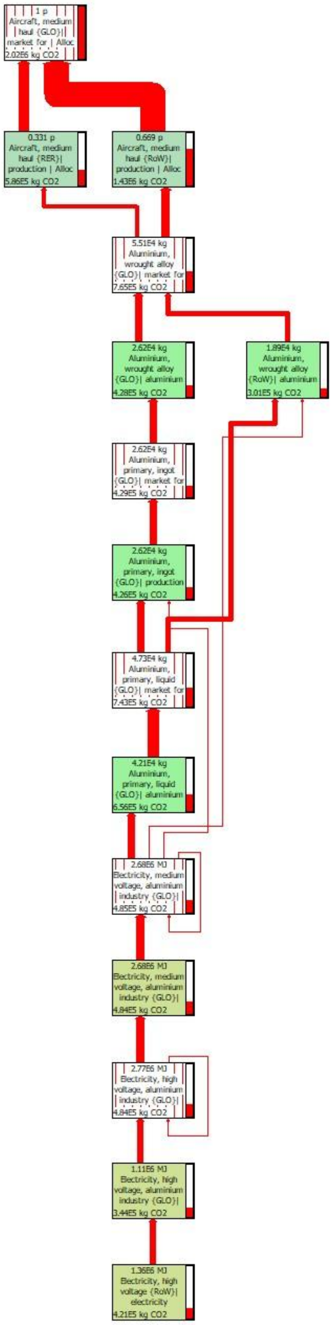


Figure B-1: Impact assessment of plane production, medium haul, in CO2 emissions. (SimaPro)

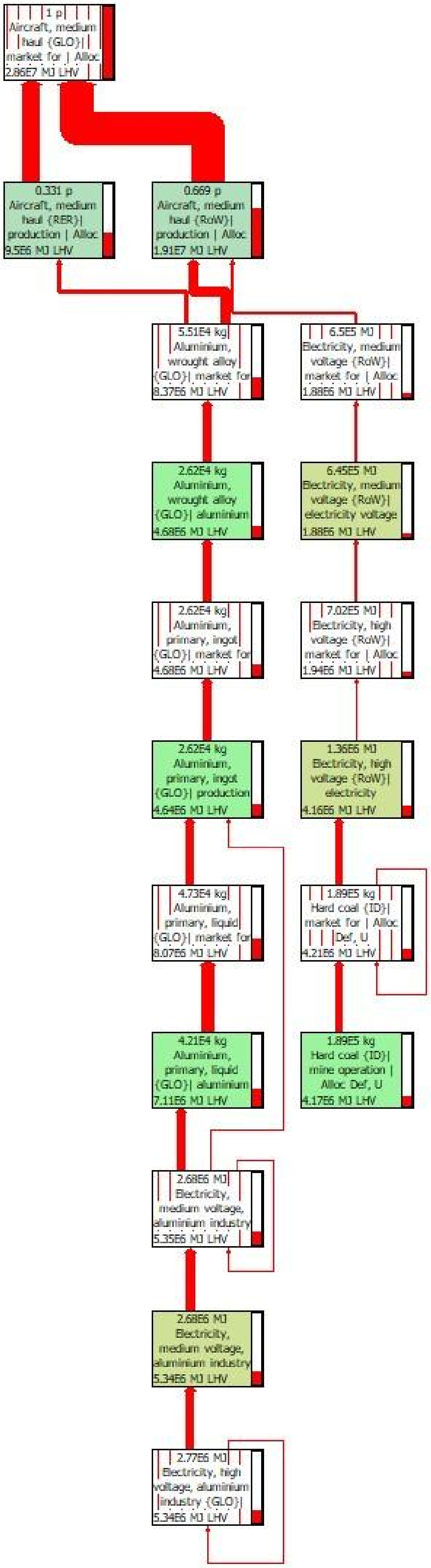


Figure B-2: Impact assessment of plane production, medium haul, in energy basis. (SimaPro)

Table B-1: Summary of impact for each category of plane production. (SimaPro)

Impact category	**Unit**	**Total**
Greenhouse	kg CO2	2016220
Ozone layer	kg CFC11	0.09
Acidification	kg SO2	13467
Eutrophication	kg PO4	3611
Heavy metals	kg Pb	76.81
Carcinogens	kg B(a)P	1.69
Pesticides	kg act.subst	0.00
Summer smog	kg C2H4	2892
Winter smog	kg SPM	11519
Energy resources	MJ LHV	28557494
Solid waste	kg	0.00

B2. Internal Combustion Engine Vehicle

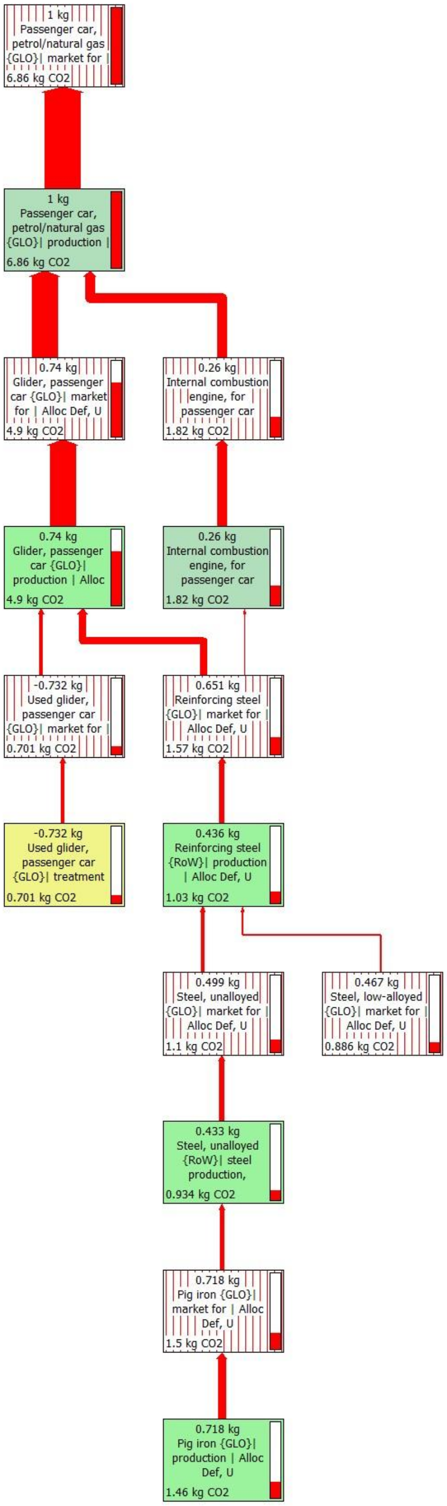


Figure B-3: Impact assessment of 1 kg passenger car, petrol/natural gas, production in CO2 emissions. (SimaPro)

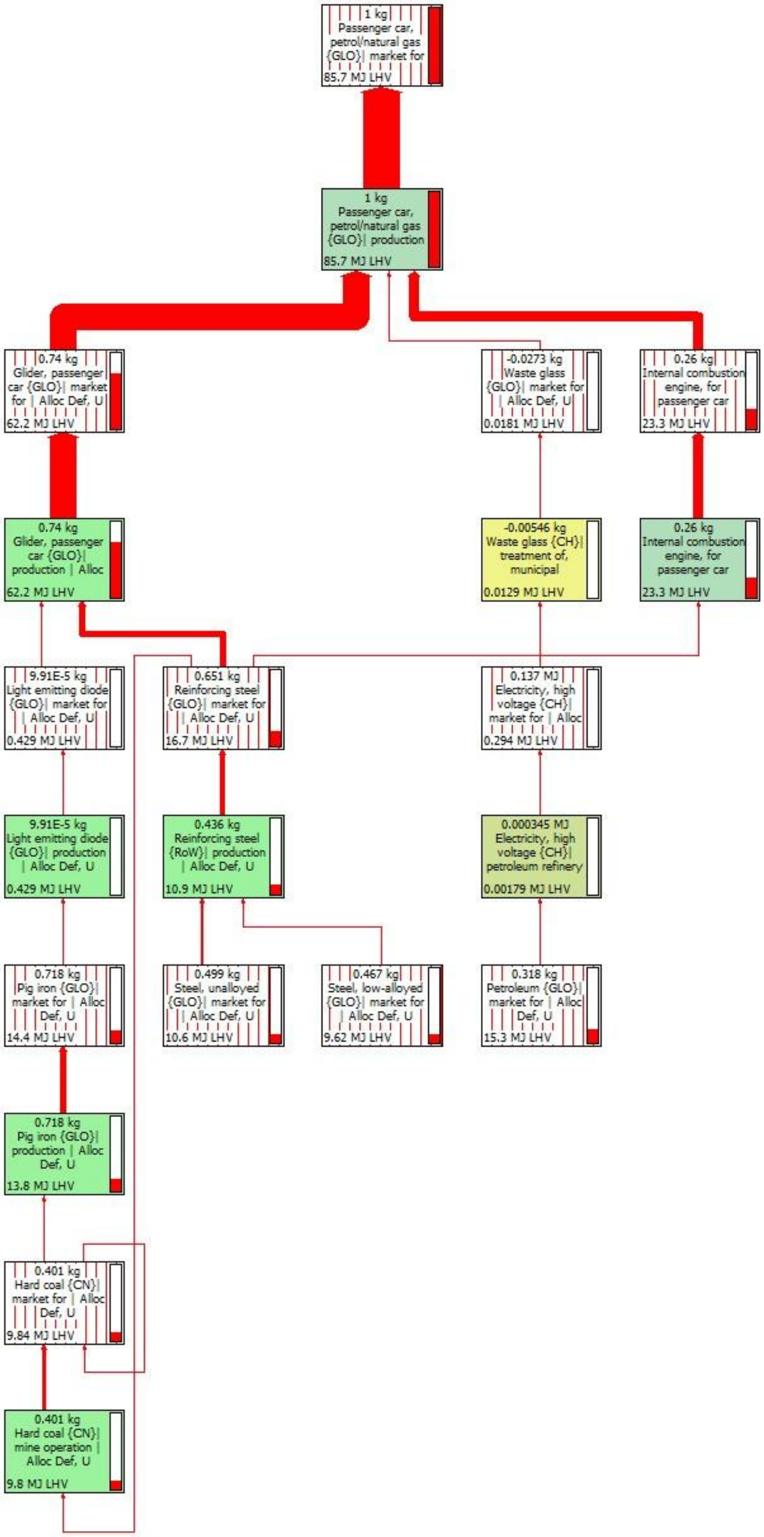


Figure B-4: Impact assessment of 1 kg passenger car, petrol/natural gas, production in energy basis. (SimaPro)

Table B-2: Summary of impact for each category of 1 kg passenger car, petrol/natural gas, production. (SimaPro)

Impact category	**Unit**	**Total**
Greenhouse	kg CO2	6.86E+00
Ozone layer	kg CFC11	6.68E-07
Acidification	kg SO2	4.48E-02
Eutrophication	kg PO4	1.80E-02
Heavy metals	kg Pb	2.63E-03
Carcinogens	kg B(a)P	4.40E-06
Pesticides	kg act.subst	0.00E+00
Summer smog	kg C2H4	4.80E-03
Winter smog	kg SPM	3.92E-02
Energy resources	MJ LHV	8.57E+01
Solid waste	kg	0.00E+00

B3. Electric Vehicle

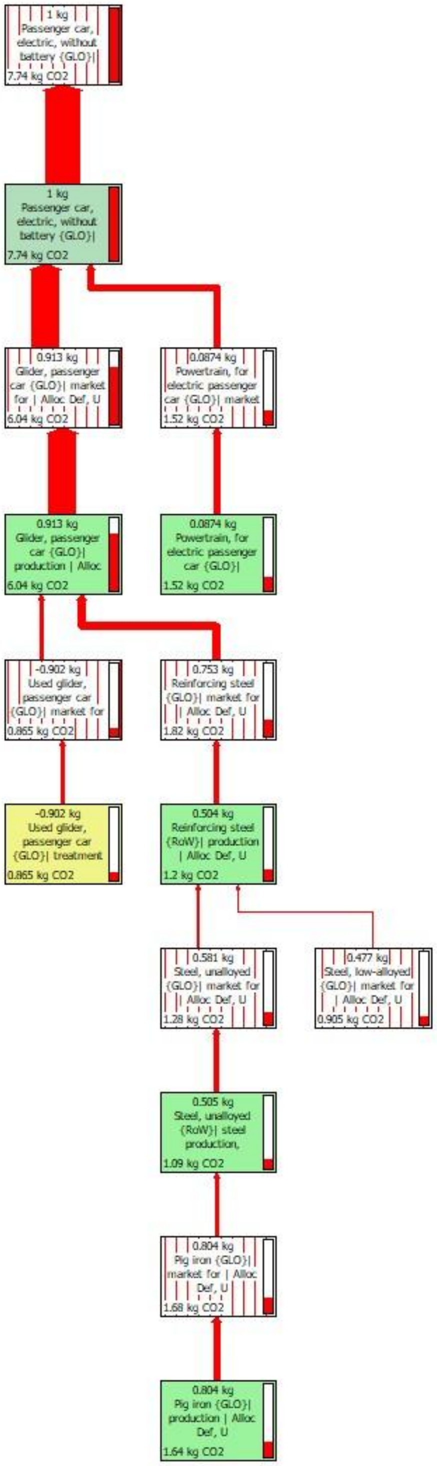


Figure B-5: Impact assessment of 1 kg passenger car, electric, without battery in CO2 emissions. (SimaPro)

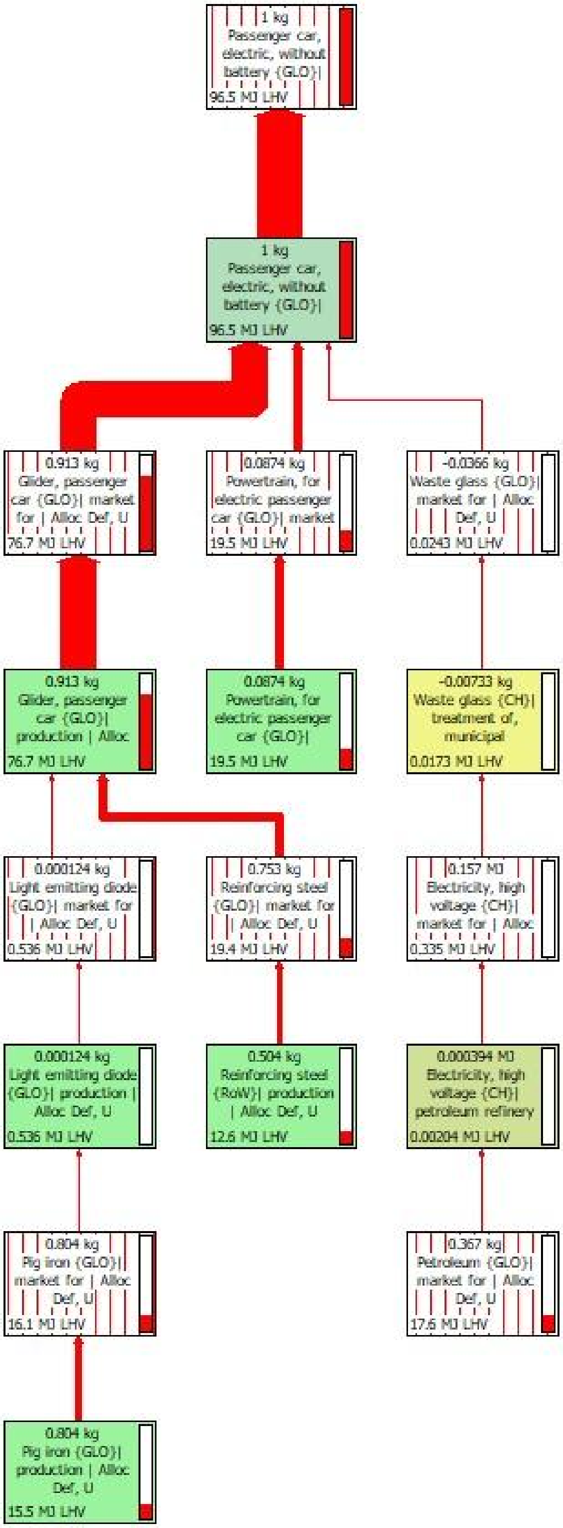


Figure B-6: Impact assessment of 1 kg passenger car, electric, without battery in energy basis. (SimaPro)

Table B-3: Summary of impact for each category of 1 kg passenger car, electric, production. (SimaPro)

Impact category	**Unit**	**Total**
Greenhouse	kg CO2	7.74E+00
Ozone layer	kg CFC11	4.03E-07
Acidification	kg SO2	5.38E-02
Eutrophication	kg PO4	2.85E-02
Heavy metals	kg Pb	3.20E-03
Carcinogens	kg B(a)P	5.21E-06
Pesticides	kg act.subst	0.00E+00
Summer smog	kg C2H4	5.02E-03
Winter smog	kg SPM	4.54E-02
Energy resources	MJ LHV	9.65E+01
Solid waste	kg	0.00E+00

Table B-4: Summary of impact for each category of 1 kg lithium-ion battery, rechargeable, prismatic, production. (SimaPro)

Impact category	**Unit**	**Total**
Greenhouse	kg CO2	6.05E+00
Ozone layer	kg CFC11	7.91E-07
Acidification	kg SO2	1.00E-01
Eutrophication	kg PO4	5.86E-02
Heavy metals	kg Pb	4.34E-03
Carcinogens	kg B(a)P	8.53E-06
Pesticides	kg act.subst	0.00E+00
Summer smog	kg C2H4	2.89E-03
Winter smog	kg SPM	7.73E-02
Energy resources	MJ LHV	8.73E+01
Solid waste	kg	0.00E+00