

User Manual

ITF Transport Life-cycle Assessment
Tool for India (v1.0)



Case-Specific Policy Analysis

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Assessment Tool for
India (v1.0)



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The International Transport Forum

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Cite this work as: ITF (2023), "User Manual: ITF Transport Life-cycle Assessment Tool for India (v1.0)", *International Transport Forum Policy Papers*, No. 121, OECD Publishing, Paris.

Tool available for download: www.itf-oecd.org/sites/default/files/itf-transport-life-cycle-assessment-tool-india.xlsx

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Abbreviations

2W	two-wheeler
3W	three-wheeler
BEV	battery electric vehicle
EV	electric vehicle
FCEV	fuel cell electric vehicle
GHG	greenhouse gas
GREET Model	Greenhouse gases, Regulated Emissions, and Energy use in Technologies (LCA model created by the Argonne National Laboratory)
HEV	hybrid electric vehicle
ICE	internal combustion engine
kWh	kilowatt-hour
LCA	life-cycle assessment
pkm	passenger-kilometre (pkm)
tkm	tonne-kilometre
vkm	vehicle-kilometres

Glossary

Vehicle-kilometre (vkm)	Unit of travel demand measurement. The movement of a vehicle over one kilometre.
Passenger-kilometre (pkm)	Unit of travel demand measurement. The movement of a passenger over one kilometre. Passenger-kilometre = vehicle-kilometre × average load
Average load	The average number of people in a passenger vehicle over its lifetime or the average weight carried by a freight vehicle over its lifetime. The ratio of passenger-kilometres to vehicle-kilometres.
Energy consumption per vehicle, per vkm, per pkm	Total energy consumed by a vehicle in its entire lifetime, expressed on a per-vehicle, per-vkm, per-pkm basis.
GHG emission per vehicle, per vkm, per pkm	Total greenhouse gases (GHG) emitted by a vehicle in its entire lifetime, expressed on a per-vehicle, per-vkm, per-pkm basis.

Chapter 1. Introduction

Life-cycle assessment (LCA) is a methodology for evaluating the environmental impact of any product or service over its entire lifetime. The “life-cycle” or “cradle-to-grave” impacts include the extraction of raw materials; the processing, manufacturing and fabrication of the product; the transportation or distribution of the product to the consumer; the use of the product by the consumer; the energy required for producing fuels; and the disposal or recovery of the product after its useful life.

A product’s environmental footprint can be evaluated for impacts such as energy use, greenhouse gas (GHG) emissions or emissions of pollutants. The results are usually reported for a comparable service unit. In transport, this may be passenger-kilometre (pkm), tonne-kilometre (tkm), vehicle-kilometre (vkm) or per vehicle.

LCA in transport is beneficial for the following purposes:

- When applied to different transport modes or vehicle types, LCA comprehensively evaluates their environmental performance. For example, it includes the emissions associated with battery manufacturing for electric vehicles (EVs). It can also account for the embedded emissions of rail infrastructure for a planned metro system.
- LCA can be used to assess alternative fuels, evaluate the energy sources of the electricity grid used to charge EVs, or compare alternative production pathways for biofuels.
- LCA can also highlight the environmental impact of mobility services. It can account for the empty running of ride-sourcing vehicles/taxis between passengers. It can also include the operational services required to charge and distribute shared fleets of two- and three-wheelers (2W, 3W).

The remainder of this chapter discusses the ITF Transport LCA Tool for India v1.0 – including its aim and scope, intended user types, and potential applications and limitations. If using a subsequent version of the tool, please ensure you refer to the correct manual.

1.1. Aim and scope

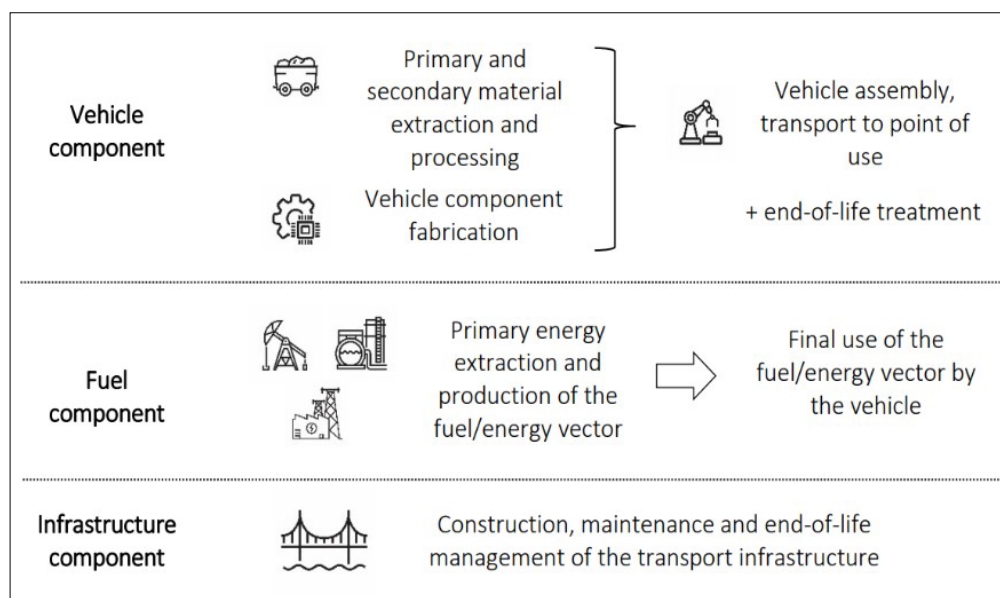
The tool’s objective is to estimate the energy consumption and GHG emissions associated with different modes of transport. The tool considers the characteristics of the vehicles needed to serve them, their manufacturing, their powertrain technologies, the energy vectors used to power them and the infrastructure required to operate them.

More specifically, the tool aims to provide a holistic assessment of different transport options, accounting for energy use and GHG emissions that occur in different phases of the life of the vehicles (Figure 1.1), including:

- manufacturing, including the assembly and disposal of materials associated with the vehicle and battery

- transport of the vehicles to the place of use
- use of the vehicles, including impacts associated with energy production for the use of the vehicle
- operational services needed by specific vehicles and possibly the involvement of other vehicles, where required (this does not typically apply to private vehicles)
- infrastructure construction and maintenance, according to relevant usage profiles (i.e., using an attributional approach, allocating energy and emissions occurring during construction and operation of infrastructures to the transport activity taking place on these same infrastructures).

Figure 1.1. Life-cycle stages considered in the tool



Source: ITF (2020), “Good to Go? Assessing the Environmental Performance of New Mobility”, *International Transport Forum Policy Papers*, No. 86, OECD Publishing, Paris.

The tool relies on the Argonne National Laboratory’s Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model 2018¹ for certain assumptions. Therefore, the system boundaries for the LCA assessment are consistent with those used in the GREET model. The tool’s outputs are GHG emissions and energy consumption at the per-pkm, -vkm, and -vehicle level.

The tool was designed to be flexibly applicable at different administrative levels, including, in particular, local (urban) administrations and central or state governments.

1.2. Types of users

The term *users* will be used to denote the primary audience of the tool, who are assumed to have a solid understanding of transport and emissions but are not LCA experts who would desire further modifications. This manual refers to *heavy users* when describing functionalities that may be of interest to experts willing

¹ The ITF Transport LCA Tool for India is not associated with the GREET Model.

to understand the detailed mechanics of the tool, with an interest in customisation beyond the input fields provided. See Section 4.2 for more.

1.3. Tool highlights

- The tool includes 32 passenger vehicle types. It considers both internal combustion engine (ICE) and battery electric vehicles (BEVs), two- and four-wheelers in private and shared categories, three-wheelers, urban buses and coach buses, and metro/urban trains.
- The tool includes three different energy scenarios for producing electricity and the option for the user to define a fourth.
- Petrol, diesel and CNG options are considered for ICE vehicles where relevant.
- The tool allows users to provide input data for critical variables or choose a default value.
- The tool calculates results for GHG emissions and energy consumption for the vehicle's entire lifetime per pkm, vkm, and vehicle.

1.4. Tool applications and limitations

- The tool does not check the data quality provided by the user. The user is responsible for selecting input parameters (either the default or an alternative value) and reviewing completeness, consistency and accuracy of their data.
- The tool excludes the consideration of equipment manufacturing and capital investments in construction-related production facilities. These are outside the system boundary.
- The tool evaluates only GHG emissions and energy consumption. Other impacts are outside the scope of this tool.

Chapter 2. Using the tool

This chapter describes the tool’s required operating environment, basic setup, methodology, and overall structure. Greater detail is provided in Chapter 3.

2.1. Tool operation specification

The LCA tool was developed for, and tested, in:

- Microsoft® Windows 10 and 11 operating systems
- Microsoft® Excel® for Office 365 (Version 13 and above).

2.2. Setting up the tool

The LCA tool is delivered as an Excel workbook file. The first step is to download the latest version of the file from the ITF website² and copy the file to the chosen location on the user’s computer. The instructions for completing this task are as follows:

- Open File Explorer.
- Create a folder/directory to store the workbook.
- Copy the downloaded file to the folder/directory created.

2.3. Tool structure

An instruction sheet will open when the tool is opened for the first time. Users should read the instructions carefully before carrying out the analysis as well as read Chapters 2 and 3 of this manual

The tool consists of nine primary worksheets, divided into three sections as follows:

1. **INPUTS** – All user inputs are contained in two sheets:
 - a. **Base Inputs** – Users can use this sheet to define input values or select default values that will be used in subsequent calculations.
 - b. **Electricity Mix (EM)** – This sheet allows the user to choose from among three electricity grid evolution scenarios, with the option (under “Scenario 4” towards the bottom of the sheet) of defining their own electricity grid evolution scenario.
2. **PHASES** – Users interested in the details can see the calculations, by phase of life-cycle, in the following five sheets. These cells *should not* be edited. Heavy users may desire to override values

² www.itf-oecd.org/sites/default/files/itf-transport-life-cycle-assessment-tool-india.xlsx

in cells, but this should only be done with a solid understanding of the calculations and downstream impacts.

- a. **Vehicle Manufacturing** – Calculations associated with the vehicle’s manufacturing, including the assembly and disposal of materials related to the vehicle and battery
- b. **Transport** – Calculations associated with the vehicle’s transport from production point to purchase point
- c. **Use** – Calculations associated with the vehicle’s use (including impacts associated with energy production)
- d. **Operational service** – Calculations associated with operational services needed by specific vehicles and possibly requiring the involvement of other vehicles
- e. **Infrastructure** – Calculations associated with the construction and maintenance of infrastructure, according to relevant usage profiles (i.e. using an attributional approach, allocating energy and emissions occurring during construction and operation of infrastructures to the transport activity taking place on these same infrastructures).

3. RESULTS

- a. **Summary** – Tabular summary showing energy consumption and GHG emissions per pkm, vkm and vehicle in each phase
- b. **Graphs** – Graphic representation of results in the Summary sheet.

Following these primary sheets, there are numerous datasheets that may be of interest only to heavy users. The first section, DATA_SHEETS, includes summaries and data from multiple sources. These datasheets feed into the default values used as inputs and within the calculations in the model. They also refer, where needed, to assumptions from the GREET Model. Relevant sheets are included in the section GREET1_2_DATASHEETS. The “DefaultValues” sheet summarises the default values included in the "Base Inputs" sheet, including the results of dedicated data collection to ensure the characterization of the tool for India. The “Default_data_source” sheet lists the sources for the default values.

2.3.1. Vehicles considered

Version 1.0 of the tool includes 32 different passenger vehicle types (grouped by mode, application and technology), as summarised in Table 2.1. Each primary sheet (except for “EM”) has the same structure, with column-wise calculations for each vehicle type. Vehicles are grouped by general vehicle category, indicated by alternating shading. (The shading is of no practical relevance except to separate the categories visually.)

Table 2.1. Vehicle types considered in the tool

Mode	Application	Vehicle technology
Car	Private	Petrol/ EV
	Ride-hailing	Diesel/ EV
2W	Scooter-Private	Petrol/ EV
	Scooter-Shared	Petrol/ EV
	Motorcycle-Private	Petrol/ EV
	Motorcycle-Shared	Petrol/ EV
3W	Commercial	Diesel/ CNG/ EV
Urban Bus	12m AC	Diesel/ CNG/ EV
	12m Non-AC	Diesel/ CNG/ EV
	9m AC	Diesel/ CNG/ EV
	9m Non-AC	Diesel/ CNG/ EV
Intercity Bus	12m AC	Diesel/ CNG/ EV/FCEV
Metro	Metro rail	EV

2.3.2. Colour schemes

The tool uses two colour schemes:

1. a colour scheme for INPUTS and RESULTS sheets
2. a colour scheme for calculations in PHASES sheets.

Colour scheme for INPUTS and RESULTS

The rows in the “Base input” and “Summary” sheets are coloured based on the life-cycle phase where the variable is used in the calculations. The PHASES sheet tabs corresponding to the life-cycle phase also have the same colour (Table 2.2).

Table 2.2. Colour coding for inputs and results

Colour	Meaning
Blue	Vehicle manufacturing
Yellow	Transport
Green	Use
Orange	Operational services
Brown	Infrastructure
Black	Irrelevant input/ User input is not required.

For example, if in the “Base inputs” worksheet a row is coloured blue, the input is being used in the “Vehicle manufacturing” worksheet; or if a row is coloured green, the input is being used in the “Use” worksheet (Figure 2.2). Likewise, if in the “Summary” worksheet a row is coloured yellow, the result is coming from the “Use” worksheet (Figure 2.3). The same colours are used in the bar graphs in the “Graphs” worksheet (Figure 2.4). Black cells in the “Base inputs” worksheet denote inputs that are not relevant for the user’s chosen vehicle type.

The “EM” worksheet denotes user input cells in green, indicating that these values are relevant to the “Use” phase.

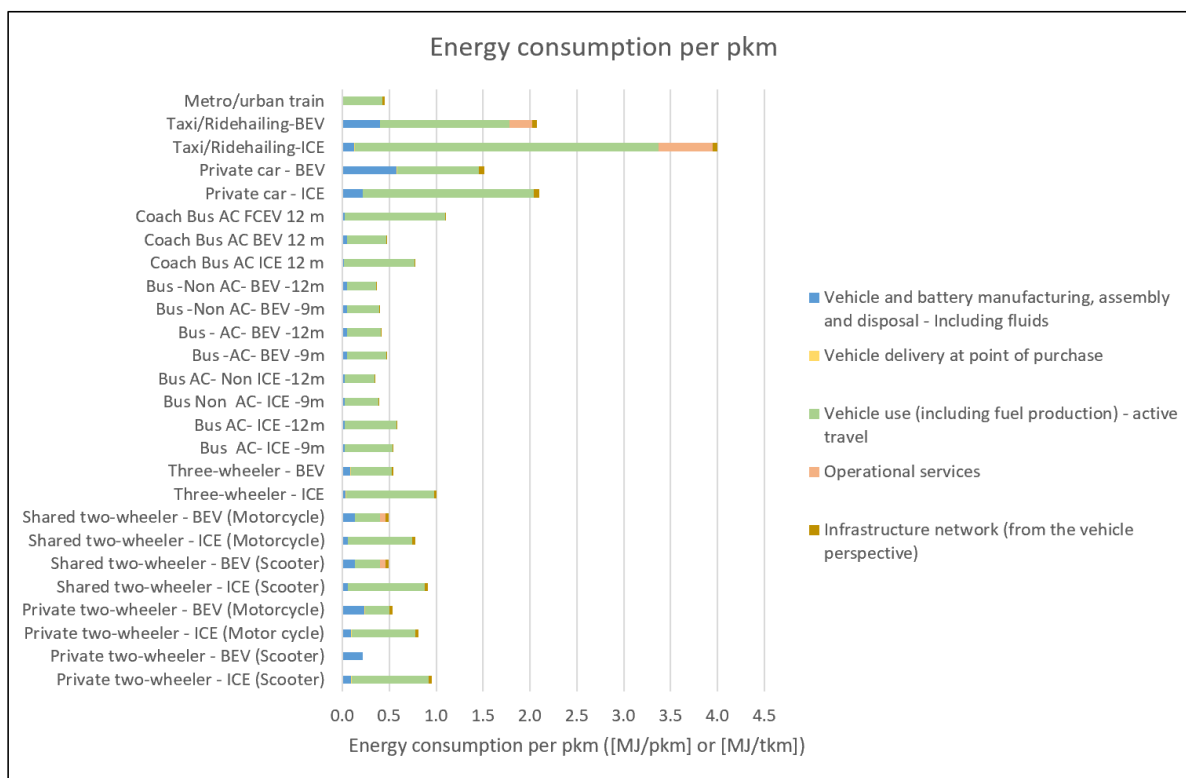
Figure 2.2. Colour coding for the “Base Inputs” sheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
			Private two-wheeler - ICE (Scooter)	Private two-wheeler - BEV (Scooter)	Private two-wheeler - ICE (Motorcycle)	Private two-wheeler - BEV (Motorcycle)	Shared two-wheeler - ICE (Scooter)	Shared two-wheeler - BEV (Scooter)	Shared two-wheeler - ICE (Motorcycle)	Shared two-wheeler - BEV (Motorcycle)	Three-wheeler - ICE	Three-wheeler - BEV	Bus AC-ICE-9m	Bus AC-ICE-12m	Bus Non AC-ICE-9m	Bus Non AC-ICE-12m	Bus AC-BEV-9m
1	Vehicle characteristics																
2	Fluid technology		ICE	BEV	ICE	BEV	ICE	BEV	ICE	BEV	ICE	BEV	ICE	ICE	ICE	ICE	BEV
3	Use of fuel/km																
4	Fuel type		Gasoline (Oil)		Gasoline (Oil)		Gasoline (Oil)		Gasoline (Oil)		Natural Gas (fossil, EU)		Diesel (Oil)	Diesel (Oil)	Diesel (Oil)	Diesel (Oil)	
5	Gasoline (Oil)		50.0		60.0		50.0		60.0				3.4	2.3	4.8	4.0	
6	Diesel (Oil)										29.5						
7	Natural Gas (fossil, EU mix)																
8	Electricity			0.03		0.03		0.03		0.03		0.08					1.10
9	Hydrogen																
10	Share of electric driving			100.00%		100.00%		100.00%		100.00%		100.00%		100.00%		100.00%	
11	Lifetime (vehicle)		10.0	10.0	10.0	10.0	6.0	6.0	6.0	6.0	8.0	8.0	12.0	12.0	12.0	12.0	12.0
12	Annual mileage (active km, including cruising and overhauling)		6500.0	6500.0	6500.0	6500.0	18000.0	18000.0	18000.0	18000.0	35000.0	35000.0	60000.0	70000.0	60000.0	70000.0	60000.0
13	Average load		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	25.0	34.0	25.0	34.0	25.0
14	Vehicle weight		99.0	83.3	104.4	83.0	99.0	83.3	104.4	83.0	350.0	300.0	6805.0	9950.0	6805.0	9950.0	8500.0
15	Weight % by material type (excluding batteries)																
16	Steel		38.2%	45.4%	46.0%	41.4%	38.2%	45.4%	46.0%	41.4%	67.0%	67.7%	53.7%	53.7%	53.7%	53.7%	55.1%
17	Stainless Steel		6.5%	7.7%	4.8%	5.9%	6.5%	7.7%	4.8%	5.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.8%
18	Cast Iron		3.6%	0.0%	3.3%	0.0%	3.6%	0.0%	3.3%	0.0%	3.3%	2.1%	17.2%	17.2%	17.2%	17.2%	14.0%
19	Wrought Aluminum		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	18.9%	18.9%	18.9%	18.9%	19.3%
20	Cast Aluminum		28.9%	24.1%	23.1%	29.3%	28.9%	24.1%	23.1%	29.3%	8.0%	9.9%	1.1%	1.1%	1.1%	1.1%	1.0%
21	Copper/Brass		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
22	Glass		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%
23	Plastics (polycarbonate)		14.8%	15.7%	10.9%	11.4%	14.8%	15.7%	10.9%	11.4%	10.5%	10.1%	2.0%	2.0%	2.0%	2.0%	2.0%
24	Carbon fiber		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
25	Rubber		6.0%	7.1%	10.0%	11.9%	6.0%	7.1%	10.0%	11.9%	7.6%	7.0%	4.2%	4.2%	4.2%	4.2%	4.1%
26	Others		2.0%	0.0%	2.0%	0.0%	2.0%	0.0%	2.0%	0.0%	0.9%	0.5%	0.0%	0.0%	0.0%	0.0%	1.9%
27	Check		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
28	Vehicle (and battery) production		With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal	With AI smelting mostly from coal
29	Battery information (in case of BEVs only)																
30	Number of replacements			1.0		1.0		1.0		1.0		1.0					1.0
31	Battery Capacity			3.70		4.00		3.70		3.70		10.00					180.00
32	Battery chemistry			NMC111		NMC111		NMC111		NMC111		NMC111					LFP; solid state

Figure 2.3. Colour coding for the “Summary” sheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
			Private two-wheeler - ICE (Scooter)	Private two-wheeler - BEV (Scooter)	Private two-wheeler - ICE (Motorcycle)	Private two-wheeler - BEV (Motorcycle)	Shared two-wheeler - ICE (Scooter)	Shared two-wheeler - BEV (Scooter)	Shared two-wheeler - ICE (Motorcycle)	Shared two-wheeler - BEV (Motorcycle)	Three-wheeler - ICE	Three-wheeler - BEV	Bus AC-ICE-9m	Bus AC-ICE-12m	Bus Non AC-ICE-9m	Bus AC-Non ICE-12m
1	Results															
2	Energy consumption per pkm	[MJ/pkm] or [MJ/tkm]	0.951	0.526	0.815	0.538	0.912	0.493	0.775	0.493	1.002	0.545	0.537	0.583	0.392	0.347
3	Vehicle and battery manufacturing, assembly and disposal - including fluids		0.092	0.219	0.091	0.230	0.055	0.132	0.055	0.132	0.037	0.085	0.026	0.024	0.026	0.024
4	Vehicle delivery at point of purchase		0.008	0.008	0.008	0.009	0.0046	0.0051	0.005	0.005	0.004	0.004	0.0003	0.0003	0.0003	0.000
5	Vehicle use (including fuel production) - active travel		0.818	0.266	0.682	0.266	0.818	0.266	0.682	0.266	0.940	0.435	0.504	0.552	0.360	0.318
6	Operational services		0.000	0.000	0.000	0.000	0.000	0.057	0.000	0.057	0.000	0.000	0.001	0.001	0.001	0.001
7	Infrastructure network (from the vehicle perspective)		0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.021	0.021	0.005	0.005	0.005	0.005
8	Energy consumption per vkm	[MJ/vkm]	0.951	0.526	0.815	0.538	0.912	0.493	0.775	0.493	1.704	0.927	13.415	19.814	9.804	11.811
9	Vehicle and battery manufacturing, assembly and disposal - including fluids		0.092	0.219	0.091	0.230	0.055	0.132	0.055	0.132	0.063	0.144	0.655	0.821	0.655	0.821
10	Vehicle delivery at point of purchase		0.008	0.008	0.008	0.009	0.005	0.005	0.005	0.006	0.007	0.008	0.010	0.008	0.008	0.010
11	Vehicle use (including fuel production) - active travel		0.818	0.266	0.682	0.266	0.818	0.266	0.682	0.266	1.599	0.740	12.601	18.784	9.001	10.801
12	Operational services		0.000	0.000	0.000	0.000	0.000	0.057	0.000	0.057	0.000	0.000	0.036	0.046	0.026	0.026
13	Infrastructure network (from the vehicle perspective)		0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.036	0.036	0.115	0.153	0.115	0.153
14	Energy consumption per vehicle	[MJ/vehicle]	61826.29	34184.72	52957.75	34953.99	98448.16	53240.33	83718.27	53235.50	477159.55	259550.95	9658491.63	16643634.38	7058847.55	9921217.06
15	Vehicle and battery manufacturing, assembly and disposal - including fluids		5969.58	14205.47	5934.06	14965.91	5969.78	14205.51	5934.27	14202.58	17541.06	40405.21	471366.74	689269.76	471366.74	689269.76
16	Vehicle delivery at point of purchase		498.38	549.94	525.56	559.02	498.38	549.94	525.56	548.43	1761.94	1863.20	5540.94	8101.74	5540.94	8101.74
17	Vehicle use (including fuel production) - active travel		53186.89	17270.28	44322.41	17270.28	88372.06	28695.24	73643.38	28695.24	447646.94	207243.38	9072804.14	15778783.23	6480571.69	9072800.36
18	Operational services		0.00	0.00	0.00	0.00	0.00	6202.34	0.00	6202.34	0.00	0.00	25940.66	38669.29	18529.03	22234.84
19	Infrastructure network (from the vehicle perspective)	Results not available at the vehicle level	2171.45	2159.02	2175.72	2158.79	3607.94	3587.30	3615.05	3586.91	10209.61	10039.16	82839.15	128810.36	82839.15	128810.36
20	GHG emissions per pkm	[g CO ₂ /pkm] or [g CO ₂ /tkm]	74.40	50.19	65.31	51.23	71.51	47.55	62.38	47.65	75.76	50.20	42.18	45.63	31.43	28.12
21	Vehicle and battery manufacturing, assembly and disposal - including fluids		6.87	15.93	6.97	16.96	4.26	9.62	4.32	9.72	3.28	6.34	2.97	2.86	2.97	2.86
22	Vehicle delivery at point of purchase		0.68	0.75	0.72	0.77	0.41	0.45	0.43	0.45	0.33	0.35	0.04	0.03	0.04	0.03
23	Vehicle use (including fuel production) - active travel		55.43	22.15	46.19	22.15	55.43	22.15	46.19	22.15	64.81	36.30	37.49	41.10	26.78	23.63
24	Operational services		0.00	0.00	0.00	0.00	0.00	3.98	0.00	3.98	0.00	0.00	0.11	0.10	0.08	0.06
25	Infrastructure network (from the vehicle perspective)		11.41	11.35	11.44	11.35	11.41	11.35	11.44	11.35	7.33	7.21	1.57	1.54	1.57	1.54

Figure 2.4. Results presented as bar graphs showing energy consumption per pkm



Colour scheme for calculations in PHASES sheets

The second colour scheme is aimed at heavy users who are interested in better understanding the mechanics of the model and the calculations in each of the PHASES sheets (Table 2.3 and Figure 2.5). While this manual does not provide detailed explanations for each calculation, the following colour scheme should help heavy users navigate and understand how the calculations work in the model. It simplifies the tracing of cell references. The scheme indicates where cells contain a user input or link to a cell value with no further alteration, which cells contain formulas linked to values within the primary sheets, and which cells have formulas that link to DATA_SHEETS.

Table 2.3. Colour scheme for calculations in phases sheets

Colour	Meaning
	Direct reference to user input from input sheet
	Formula within main sheets
	Formula with links to DATA_SHEETS

Figure 2.5. Colour scheme for calculations in phases sheets

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
			Private two-wheeler - ICE (Scooter)	Private two-wheeler - BEV (Scooter)	Private two-wheeler - ICE (Motorcycle)	Private two-wheeler - BEV (Motorcycle)	Shared two-wheeler - ICE (Scooter)	Shared two-wheeler - BEV (Scooter)	Shared two-wheeler - ICE (Motorcycle)	Shared two-wheeler - BEV (Motorcycle)	Three-wheeler - ICE	Three-wheeler - BEV	Bus AC-ICE -9m	Bus AC-ICE -12m	Bus Non AC-ICE -9m
1															
2	Operational services														
3															
4	Vehicle required to provide operational services	[type]	None	None	None	None	Van - ICE	Van - ICE	Van - ICE	Van - ICE	Van - ICE	Van - ICE	Bus AC-ICE -9m	Bus AC-ICE -12m	Bus Non AC-ICE -9m
5															
6	Vehicle travel	[km/day]	17.81	17.81	17.81	17.81	49.32	49.32	49.32	49.32	100.00	100.00	164.38	191.78	164.38
7	Lifetime mileage (use phase, including cruising and overhauling for ride sourcing)	[km/vehicle]	65000.00	65000.00	65000.00	65000.00	108000.00	108000.00	108000.00	108000.00	280000.00	280000.00	720000.00	840000.00	720000.00
8	Travel requirement for vehicle providing operational services	[km of service vehicle trip/day/vehicle]	0.00	0.00	0.00	0.00	11.25	11.25	5.63	11.25	11.25	11.25	0.50	0.50	0.50
9	Average number of vehicles serviced by a single service vehicle every day	[vehicles/service vehicle]	0.00	0.00	0.00	0.00	14.06	14.06	14.06	14.06	11.25	14.06	1.06	1.06	1.06
10															
11	Travel requirement ratio for vehicle providing operational services	[vkm of service vehicle use/vkm of use phase, including cruising and overhauling for ride sourcing]	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.02	0.01	0.01	0.0029	0.002451	0.0029
12															
13	Energy required by the service vehicle	[MJ/km of service vehicle use]	0.00	0.00	0.00	0.00	3.54	3.54	3.54	3.54	3.54	3.54	#N/A	#N/A	#N/A
14	GHG emissions of the service vehicle	[g CO2 eq/km of service vehicle use]	0.00	0.00	0.00	0.00	245.26	245.26	245.26	245.26	245.26	245.26	#N/A	#N/A	#N/A
15															
16	Energy needed for operational services	[MJ/vehicle]	0.00	0.00	0.00	0.00	6202.34	6202.34	3101.17	6202.34	9909.49	7929.94	23118.96	35899.01	16513.54
17															
18	GHG emissions needed for operational services	[g CO2 eq/vehicle]	0.00	0.00	0.00	0.00	429822.48	429822.48	214911.24	429822.48	686727.38	549544.73	1719695.20	2670334.16	1228353.71

Note: The shading in the top row specifying vehicle types is used to separate the different vehicle categories. It has no connection with the colour coding discussed above.

2.4. How to use the tool

Chapter 3 offers a detailed explanation of the sheets and variables found in the tool. Users should review this first to ensure they understand all the variables in the tool and how to use each sheet. Figure 2.6 provides a schematic flow chart of the tool.

2.4.1. Step 1: Fill out “Base Inputs” and “EM” (Electricity Mix) INPUT sheets

Users must fill in the values for each variable (listed in Column A) for each vehicle category of interest (listed in Row 1) of the “Base Inputs sheet”. Default values, which have been adapted to the Indian context where possible, have been provided for each variable. Users are free to provide their own inputs but are responsible for ensuring their accuracy. See Section 3.1 for a detailed description of the “Base inputs” sheet and each variable.

The final results depend on the information provided by the user in the “Base input” spreadsheet. It is important for users to consider how some variables, especially those pertaining to vehicle use, vary across different cities and regions in India. Traffic patterns differ among cities of varying sizes – for example, between Tier 1, 2 and 3 cities (according to the classification of Indian cities used by the Government of India).

Consequently, attributes like fuel efficiency, annual distance travelled, vehicle lifespan, average load, type of vehicle needed for operational service, travel requirements for vehicles providing operational services, and the average number of vehicles handled in a single service trip will vary accordingly.

Users can also fill out the “EM” sheet, if relevant (i.e. if they want to define their own electricity mix scenario). See Section 3.2 for details on the “EM” sheet.

2.4.2. Step 2: Review calculations, if interested, in the PHASES sheets

Each of the PHASES sheets displays the calculations of GHG emissions and energy consumption at each of the vehicle's life-cycle phases. Inputs are taken from the INPUT sheets, and the results are summarised in the RESULTS sheets. Heavy users may wish to adjust interim assumptions/values in the calculations sheets but are strongly advised to do so only with a complete understanding of the implications. See Sections 3.3 to 3.7 for more.

2.4.3. Step 3: Review results

The RESULTS sheets present the results in tabular form ("Summary" sheet) and graphic form ("Graphs" sheet). Sections 3.8 and 3.9 provide more details.

Figure 2.6. Tool structure and calculations



Chapter 3. Tool worksheets and variables

As mentioned in section 2.3, the tool consists of nine worksheets, divided into three sections: inputs, phases, and results. Each worksheet is here discussed in turn.

3.1. Base inputs [Input sheet]

Users can specify values for the most relevant variables required to calculate the life-cycle impact of a vehicle. Where possible, each variable contains a default value based on India-specific data. The tool allows users to provide their own values for the variables. Users can directly type numerical inputs into the cells or choose "+Default_value" to populate the cell with the default. For categorical variables, the user can choose from the dropdown menu or similarly choose "+Default_value".

The variables contained in the "Base input" worksheet refer to the various phases of the life cycle of vehicles. Variables are divided into **vehicular characteristics**, **battery information**, **transport phase**, **operational services** and **electricity generation scenarios**.

3.1.1. Vehicular characteristics

This segment includes details on fuel use, general vehicle characteristics, material composition, and the battery. The variables are relevant to the vehicle manufacturing and use phases.

Engine category

The user here describes the engine category by selecting "ICE", "BEV" or "FCEV" from the dropdown list.

Fuel type

Fuel type describes the type of fuel used by ICE vehicles. The user must select "Gasoline (Oil)", "Diesel (Oil)" or "Natural Gas (fossil, EU mix)" from the dropdown list:

- Gasoline (Oil) specifies the vehicle's gasoline/petrol use in kilometres per litre. It is applicable only when the fuel type is Gasoline (Oil).
- Diesel (Oil) specifies the vehicle's diesel use in kilometres per litre. It is applicable only when the fuel type is Diesel (Oil).
- Natural Gas (fossil, EU mix) specifies the vehicle's natural gas use in kilometres per kg. It is applicable only when the fuel type is Natural Gas (fossil, EU mix).

Electricity

Electricity specifies the amount of electricity used by the vehicle in kilowatt-hours (kWh) per kilometre. It is applicable only when the engine type is BEV.

Hydrogen

Hydrogen specifies hydrogen use by the vehicle in kilometres per kilogram.

Share of electric driving

Share of electric driving is defined as the percentage of kilometres travelled during the vehicle's lifetime powered by electrical energy. It is always zero for ICE vehicles and 100% for BEV. It should only be changed to a value between 0 and 100% in the case of hybrid electric vehicles (HEV), which can be added to the model.

Lifetime (Vehicle)

Lifetime (Vehicle) is defined as the number of years the vehicle is used (i.e. the length of the Use phase), measured as the time from the registration of the vehicle to the end of the vehicle usage period.

Annual mileage (active km, including cruising and deadheading/overheading)

Annual mileage is the total distance travelled by the vehicle, on average, in a year. This includes the active travel time, as well as cruising and deadheading (trips made without a passenger present) in the case of shared vehicles.

Average load

Average load for passenger vehicles is the average number of passengers carried at a given time over the course of the vehicle lifetime. It is defined as lifetime pkm / lifetime vkm.

Vehicle weight

Vehicle weight is the vehicle's total weight (in kilograms) for ICE vehicles, not including fuel weight. In the case of BEVs, it is the total weight (in kilograms) without the battery.

Weight % by material type (excluding batteries)

Weight % indicates the material composition of the vehicle, by weight, excluding the fuel or battery. If the user changes the default composition, they must ensure that the total is 100 percent. See Row 26 of the "Base inputs" sheet labelled "Check" to confirm.

Vehicle and battery production

Users can choose how aluminium is made, which dominates the carbon production of battery manufacturing. The default for India assumes "with aluminium smelting from coal". The alternative option in the dropdown assumes aluminium production with considerable recycling of materials.

3.1.2. Battery information

This segment includes information about the battery. Calculations are relevant for the Vehicle Manufacturing phase of BEVs and FCEVs only.

Number of replacements

Number of replacements is the number of batteries that need to be replaced during the vehicle's lifetime.

Battery capacity

Battery capacity is the amount of electricity (in kilowatt-hours) that can be stored in the battery pack.

Battery chemistry

Battery chemistry defines the type of battery, based more specifically on the cathode material. NMC111 batteries are set as the default for most vehicles – except for buses, where “LFP: Solid State”³ is set as the default for buses as they are most common in India. It is to be noted that the battery technology is progressing quickly. The tool currently utilises the most commonly used battery chemistry technology options; nevertheless, as other technologies continue to advance, the outcomes for BEVs may be subject to change.

3.1.3. Transport phase

This segment includes inputs that affect the Transport phase. The impact of local manufacturing vs. importing vehicles can be modelled by specifying different types of transport modes and distances travelled.

Distance covered by delivery vehicle

Users can specify the distance, in kilometres, travelled by different types of delivery vehicles to transport the vehicle from the manufacturing location to the point of sale.

3.1.4. Operational services

Vehicle required to provide operational services

Users can specify the type of vehicle used for operational services (if any). In the case of taxis/ride-hailing and public transport, operational services include extra travel by the vehicle itself. Because deadheading/overheading is included in the Use phase, no additional vehicle is specified for the operational service phase. In contrast, for shared 2W and 3W vehicles, operational services may be provided by a different vehicle (i.e. a van). Private vehicles do not need operational services.

Travel requirements for the vehicle providing operational services

Users define the average travel required from the service vehicle per trip, per vehicle serviced per day.

Average number of vehicles taken care of by a single service vehicle trip

Users can define the number of vehicles that a single service vehicle trip can serve. The unit is vehicles / service vehicle trip.

3.1.5. Electricity generation scenarios

This segment allows users to specify different electricity generation scenarios.

³ LFP stands for “lithium ferro-phosphate”, also known as “lithium iron phosphate”.

Analysis for electricity mix (use phase): fuel-specific or region-specific?

Users can specify whether they would like to assign a fuel or region-specific definition of the energy mix for the electricity grid. Choosing *fuel-specific* allows users to specify a single source of energy for electricity. Choosing *region-specific* allows users to specify an energy mix scenario allowing evolution over time.

Fuel-specific: choice of primary energy

Users can specify the energy source of electricity that stays constant over the vehicle's lifetime.

Region-specific: electricity mix (use phase): base year

Base year is the year the vehicle is purchased. It is the starting year for the electricity mix analysis, which computes the average energy intensity and grid emission factor over the lifetime of a given vehicle. The default base year is 2022.

Region-specific: electricity mix (use phase): evolution over time

The tool provides three different electricity-mix scenarios plus an option for a user-defined fourth scenario. This input allows the user to choose the scenario, while the scenarios are defined in the "EM" (Electricity Mix) sheet (see Section 3.2). The "Constant" scenario assumes a constant energy mix until 2050 (the 73% coal share of energy continues until 2050). The "Switch to Renewables" scenario reflects the intended policy trajectory in India (the coal share will reduce to 51% by 2030 and 21% by 2050). The third scenario, "High Ambition", is an accelerated policy trajectory (the coal share reduces to 51% by 2030 and 11% by 2050). "User-defined" is entirely up to the user.

Note: The "Constant" scenario represents the environmental effects when the electricity generation mix remains unchanged from the current situation. However, since India has made a commitment to achieve net-zero emissions, the most relevant scenario is the "Switch to renewables" scenario. This scenario reflects the environmental impacts when there is a transition to renewable energy sources.

Region-specific: electricity mix (use phase): Country

This input contains a default value, which is India. It is the region in which the electricity mix will be analysed.

3.2. EM (Electricity Mix) [Input sheet]

The Electricity Mix sheet allows users to define the electricity grid energy mix evolution from 2020 to 2050. Three scenarios are already provided (Constant, Switch to Renewables, and High Ambition, as mentioned in Section 3.1.5).

The fourth user-defined scenario allows the user to create their own. The electricity mix is defined in the green cells by five-year increments. The years in between are linearly interpolated by the model.

3.3. Vehicle Manufacturing [Phase calculation sheet]

The “Vehicle Manufacturing” sheet contains calculations of GHG emissions and energy consumption for the vehicle and battery during their respective manufacturing phases, including assembly and disposal of materials. It takes into account the percentage weight of different materials and the percentage of recycled materials, along with their energy intensity, to compute the environmental impacts. The required input for the worksheet is taken from the “Base inputs” worksheet. Although the calculations are shown, the user should not change any data in this sheet without a full understanding of the implications.

3.4. Transport [Phase calculation sheet]

The “Transport” sheet contains calculations of GHG emissions and energy consumption for the vehicle during transport from the point of manufacture to the point of use/sale. The required data for the delivery distance by the different modes are taken from the “Base input” worksheet. Although the calculations are shown, the user should not change any data in this sheet without a full understanding of the implications.

3.5. Use [Phase calculation sheet]

The “Use” sheet contains calculations of GHG emissions and energy consumption for the vehicle during its operational, or use, phase. The inputs, which depend on the vehicle’s powertrain and fuel use, have been taken from the “Base input” sheet. The use phase also includes the GHG and energy intensity of fuel/electricity production. Although the calculations are shown, the user should not change any data in this sheet without a full understanding of the implications.

3.6. Operational Services [Phase calculation sheet]

The “Operational Services” sheet contains calculations of GHG emissions and energy consumption of service vehicles required during the Use phase. Inputs are taken from the “Base input” sheet. Although the calculations are shown, the user should not change any data in this sheet without fully understanding the implications.

3.7. Infrastructure [Phase calculation sheet]

The “Infrastructure” sheet contains calculations of GHG emissions and energy consumption of the road/rail infrastructure required for the vehicle to run over its lifetime. It includes emissions/energy associated with construction and maintenance, according to relevant usage profiles (i.e. using an attributional approach, allocating energy consumption and emissions occurring during construction and operation of infrastructures to the transport activity taking place on these same infrastructures).

The infrastructure phase does not account for the infrastructure necessary for refuelling, recharging or battery swapping. The information used in this phase is extracted from the “Base input” sheet, and the calculations are presented accordingly. Initially, the tool determines the vehicle type based on the user’s selection. Subsequently, the tool automatically identifies the road infrastructure required for the specific vehicle. Additionally, the tool determines the materials needed to construct the road infrastructure and

evaluates how vehicles utilize this infrastructure. The tool obtains data regarding energy intensity and GHG emission intensity of material production from the “DATA_SHEETS”.

Finally, the tool calculates the energy consumption and GHG emissions associated with the infrastructure network. It is important for users to have a comprehensive understanding of the consequences before making any modifications to the data in this sheet.

3.8. Summary [Results sheet]

The “Summary” sheet summarises all numerical results from the previous PHASES sheets in tabular form – first “Energy consumption” by pkm, vkm, and vehicle; and then “Greenhouse gas emissions” by pkm, vkm, and vehicle. Results are presented as totals and disaggregated by phase. The colours of the rows correspond to the phase.

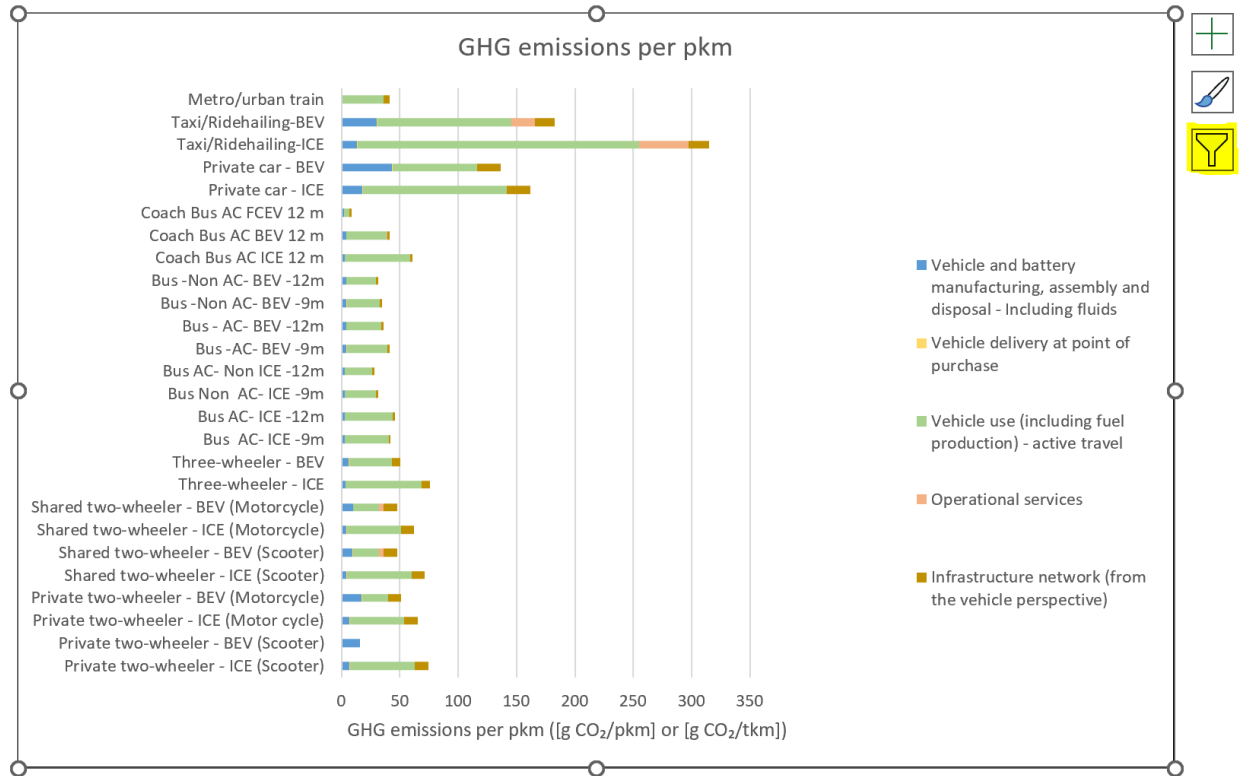
3.9. Graphs [Results sheet]

The “Graphs” sheet provides a graphical representation of the summary sheet. Users can filter the data displayed in the graphs (i.e., choosing only some vehicle types or phases to display) using Excel’s built-in filter option for each graph.

3.9.1. Filtering results in graphs (Excel version 13 or above)

To filter by vehicle type or phase, users must first click on the “Graphs” sheet (which contains bar charts showing vehicle types and their corresponding GHG emissions or energy consumption), then select the applicable bar chart. Three options should appear at the upper right corner of the graph. Users can click on the third option with the filter symbol (see highlight in Figure 2.7) and check/uncheck relevant items to filter results by phase or vehicle type.

Figure 2.7. Filtering results in graphs



Chapter 4. Tool management and extensions

This chapter briefly suggests tips for proper tool management as well as potential ways that heavy users can extend the tool's functionality.

4.1. Tool management

- The user should save a clean backup of the tool's original version before making customisations to the backup worksheet and/or conducting an analysis.
- For every update made to the tool, the user should save a backup and maintain a log of changes made.
- The user should use a unique file for each analysis. For every analysis performed, the user should maintain a log of the version of the tool used to conduct the analysis.

4.2. Extending the functionality of the tool (Heavy users)

Heavy users may want to customise and extend the functionality of the tool. Some ideas are suggested.

4.2.1. Adding vehicle types

If additional vehicle types are desired, heavy users can duplicate the column associated with the closest relevant existing vehicle type and change the input values to align with the new vehicle type. The heavy user will need to ensure that the calculations in the PHASES sheets are performing correctly.

4.2.2. Customising assumptions associated with interim calculations

Heavy users may wish to override internal calculations in favour of their own analysis. For example, if a user has calculated their own electricity grid GHG emission intensity (which is usually calculated internally), they can overwrite the cell which calculates a GHG emission intensity with this value. This can be done to align results with their own assumptions.

Such customisations are the sole responsibility of the user. Heavy users must ensure that the customisation does not result in nonsensical results downstream. In the example presented above, if only the GHG emission intensity of the grid is changed and not the energy consumption (which is a corresponding internal calculation), only the final GHG emission results should be considered.

User Manual

ITF Transport Life-cycle Assessment Tool for India (v1.0)

This manual is a guide to using the ITF Transport Life-cycle Assessment Tool. The tool aims provide a holistic assessment of different modes of transport, accounting for energy use and greenhouse gas emissions that occur in different phases of the life of the vehicles.

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