ASSESSING THE ENVIRONMENTAL IMPACT OF SHARED MICROMOBILTY SERVICES

A Guide for Cities

New Urban Mobility alliance

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GLOSSARY

Bill of material: A list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts, and the quantities of each needed to manufacture a product.

Carbon dioxide equivalent (CO_2e): A term for describing different greenhouse gases in a common unit. For any amount and type of greenhouse gas, CO_2e signifies the amount of carbon dioxide (CO_2) that would have the equivalent global warming impact (Brander n.d.).

Life cycle emissions assessment (LCA): A method of analysis to estimate the total greenhouse gas emissions and consumption impacts associated with a product or service. LCAs for micromobility vehicles include emissions and consumption-related impacts from the entire lifespan of the vehicle ("cradle-to-grave"), in contrast to emissions assessments for transportation modes that only include tailpipe emissions ("tank-to-wheel") or tailpipe emissions plus upstream emissions from fuel or energy production ("well-to-wheel").

Micromobility vehicle: For the purposes of this guide, any vehicle offered by a shared micromobility company or service. A commonly cited definition is "vehicles with a mass of less than 350 kilograms (kg) and a design speed of 45 kilometers per hour (km/h) or less" (International Transport Forum 2020). The most common micromobility vehicles in the United States and Europe are e-scooters, bicycles, e-bikes, and e-mopeds. The term includes both electric and people-powered vehicles and includes vehicles that are owned or operated by a private company, public entity, or both.

Operational model: The practices that a micromobility company uses to manage its fleet and run its business (e.g., types of auxiliary vehicles, how routes are created for those auxiliary vehicles, where charging facilities are sited, or how electricity is sourced for charging facilities).

Passenger-mile (or -kilometer): One mile (or kilometer) traveled by one passenger. A passenger-mile is different from a vehicle-mile (or -kilometer), which is one mile (or kilometer) traveled by one vehicle. For example, a car with five passengers that travels one mile generates five passenger-miles and one vehicle-mile.

Product category rule (PCR): A document of rules, requirements, and guidelines for how an LCA should be conducted for a specific product category, consistent with international standards ISO 14025 and ISO 14044. PCRs ensure that functionally similar products are assessed in the same way. PCRs are usually developed through active engagement with a group of stakeholders, like an industry association or group of manufacturers (EPD International n.d.).

Transportation network company (TNC): "Transportation network companies (TNCs) provide prearranged transportation services for compensation using an online-enabled application or platform (such as smart phone apps) to connect drivers using their personal vehicles with passengers" (California Public Utilities Commission n.d.).

EXECUTIVE **SUMMARY**

Highlights

- A growing number of cities and micromobility operators want to better understand the environmental impacts of shared micromobility services and to compare operators, but there is no standard way to collect or analyze the data to do so.

- This guide is intended to help city departments of transportation navigate the process of understanding the greenhouse gas emissions of shared micromobility services. Cities can use this guide to clarify their use cases for data about the environmental impacts of micromobility and to learn how to request, interpret, and act on that data.

- A focus of the guide is life cycle emissions assessments (LCAs). The guide builds on existing LCA standards and presents best practices that are specific to micromobility, including how to select input data, delineate the life cycle stages of a micromobility vehicle, and estimate environmental impacts from the vehicle's end-of-life. This guidance can also be used by micromobility operators undertaking LCAs.

- The guide was developed by the Working Group on Micromobility Life Cycle Emissions Assessments, a collaborative body of over 30 members representing city governments, micromobility operators, and subject matter experts from the United States and Europe.

As micromobility modes like shared electric scooters and bikes become more widespread, formalized parts of urban mobility, more cities are seeking to understand the environmental impact of micromobility and the differences among operators. However, there is little alignment in the emissions information that cities request from micromobility operators, or the methods or assumptions that micromobility operators use to create that information. This leads to a situation that is challenging for both parties: cities receive data that are not comparable among operators and, therefore, have limited usefulness in informing decisions. Meanwhile, operators spend resources to share data that do not end up answering the questions cities pose, and operators also risk being penalized for taking a more transparent or rigorous approach that may lead to them reporting higher emissions than other operators.

This guide is intended to help standardize cities' and micromobility operators' approach to estimating greenhouse gas (GHG) emissions from micromobility and to help city departments of transportation and other agencies navigate the process of understanding the environmental impacts of micromobility. A standard approach would provide cities with more comparable, actionable information to inform their selection of operations and the design of policies and programs. It would also enable micromobility operators to generate data in a more efficient, widely trusted way and to share information that more clearly indicates the differences between their companies.

The guide is primarily intended for cities in the United States, Europe, and other high-income countries. Middle- or low-income country contexts may require different approaches, given possible differences like a larger percentage of shared micromobility vehicles that are fossil-fuel powered, higher rates of individual ownership of motorized micromobility vehicles (e.g., gas-powered motorcycles), different micromobility vehicle types (e.g., tuk-tuks, pedi-cabs), different permitting practices, and data gaps. However, many aspects of this guide remain applicable.

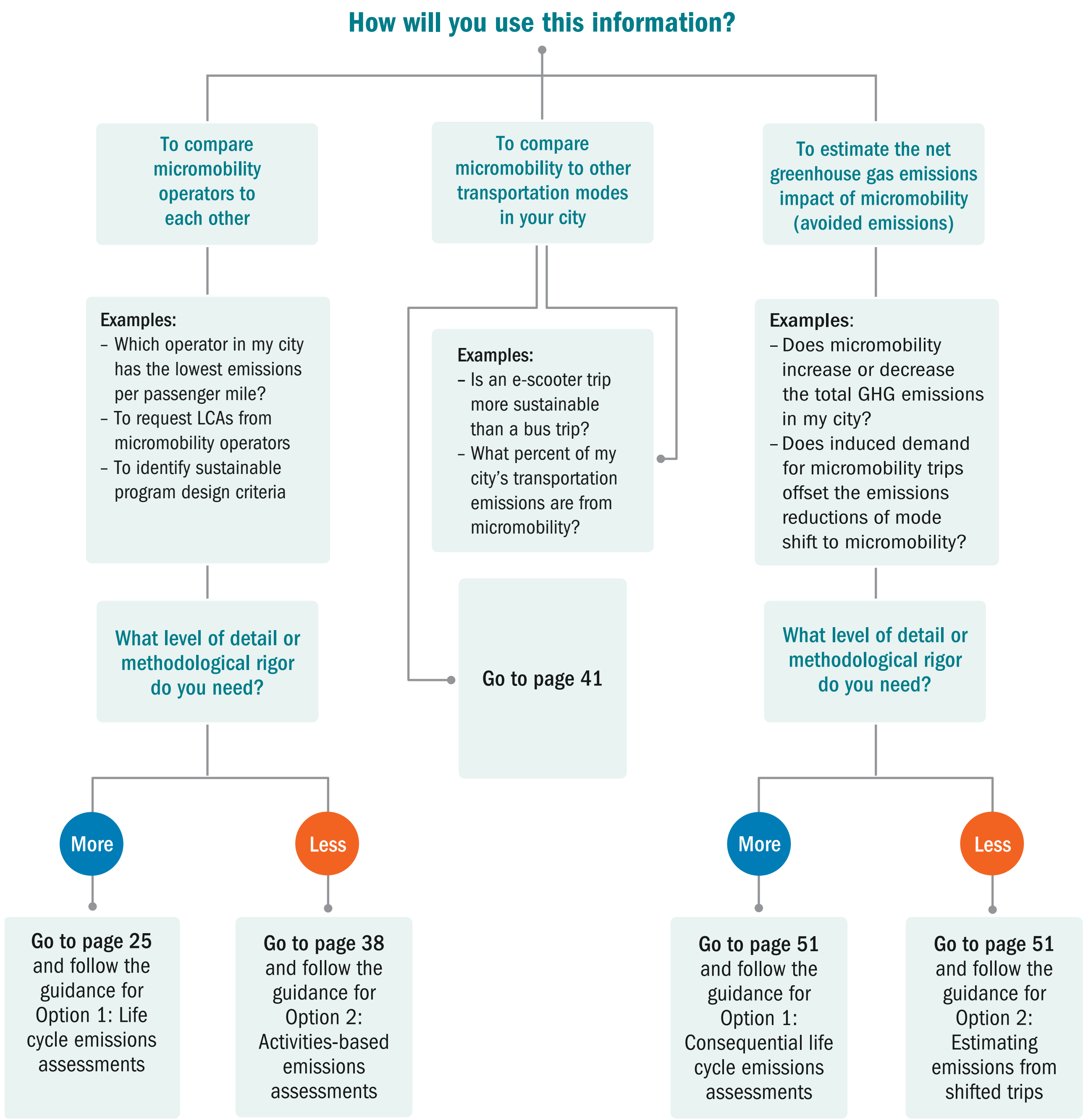
The guide was developed based on the work of the Working Group on Micromobility Life Cycle Emissions Assessments, which the New Urban Mobility alliance (NUMO) convened in 2022. The working group consisted of over 30 members representing city governments, micromobility operators, and third-party topic experts from around the United States and Europe.

The guide's starting point is that cities' different use cases for emissions information require distinct types of information. It is structured around the three most common use cases:

- **Use Case 1:** Compare Micromobility Operators to Each Other
- **Use Case 2:** Compare Micromobility to Other Transportation Modes
- **Use Case 3:** Estimate the Net GHG Emissions Impact of Micromobility

Figure ES1 helps cities clarify their use case for micromobility emissions information, and the corresponding sections provide guidance on how to collect, interpret, and act on the data needed for that use case.

Figure ES1: Flowchart: Identifying Your Use Case



Source: Authors.

Use Case 1: Compare Micromobility Operators to Each Other

Example: Preparing an RFP
A city department of transportation is drafting a request for proposals (RFP) for prospective micromobility companies to operate in the city. The city wants to use sustainability as a criterion for comparing operators' proposals. The department wants to request sustainability information in a way that will yield reliable data that allow for direct comparison among operators.

Example: Evaluating operators that participated in a pilot or permitting cycle
A city department of transportation is nearing the end of a micromobility pilot program or permitting cycle. The department wants to compare the environmental performance of the operators that participated, which will inform the design of future programs or the selection of an operator with which to continue working. At the beginning of the program or permitting cycle, micromobility operators signed a permit that enables the city to request as-yet-unspecified operational or sustainability data. The city is now determining what specific request will yield reliable information that allows for direct comparison among operators.

To compare micromobility operators, cities can use life cycle emissions assessments (LCAs) or activities-based emissions assessments. An LCA is a well-established method of analysis to estimate the total emissions associated with a product—in this case, a micromobility vehicle. LCAs describe emissions from the vehicle's entire lifespan, from extracting raw materials to disposing of the used vehicle. They include emissions from processes that facilitate the vehicle's usage, like the electricity to charge it and the vehicles used transport it for maintenance or rebalancing. LCAs methods are codified in standards ISO 14040 and 14044. This guide is supplementary to those standards, focusing on aspects specific to micromobility. Figure 2. Checklist For Micromobility Life Cycle Emissions Assessments outlines best practices for LCAs for micromobility vehicles.

Figure ES2: Checklist for Micromobility Life Cycle Emissions Assessments

Standards, Scope, and Boundaries

- ✓ Prepared in accordance with ISO 14040:2006 and ISO 14044:2006
- ✓ Uses the system boundary of "cradle-to-grave"
- ✓ Uses the functional unit of "one passenger-mile/-kilometer of riding a [vehicle model] operated by [operator name] in [location] in [year]." For example, "one passenger-mile of riding a model Bird Three e-scooter operated by Bird in Los Angeles, California, USA, in 2022."
- ✓ The LCA may be prepared by the operator or by a third-party consultant or academic
- ✓ Cities may prefer LCAs that have been critically reviewed by a third party for compliance with ISO standards

Inputs and Assumptions

- ✓ Contains input data that conform to ISO 14044 data quality requirements and the guidance in Table 2. Best Practices for Determining LCA Inputs
  - Includes a list of assumptions used and their rationales, such as the conditions under which those assumptions were met during real-world operations
- ✓ Uses data with quality scores of one or two, according to Table 1. Best Practices for Determining LCA Inputs, for input data related to manufacturing and materials, lifespan, types of auxiliary vehicles, and distance traveled by auxiliary vehicles, and scores of three or better for all other input data
- ✓ Uses a high-quality database for background data and is transparent about which database was used
- ✓ Uses high-quality databases and tools for impact assessment

Outputs

- ✓ Includes a breakdown of emissions by use stage (life cycle phase), as defined in Figure 3. Life Cycle Stages for Life Cycle Emissions Assessments for Shared Micromobility Services
- ✓ Includes information about the type and amount of uncertainty in the LCA

Source: Authors.

To improve comparability, we recommend that LCAs for micromobility vehicles use a standard set of life cycle phases. Figure 7 lists the life cycle phases relevant to a micromobility vehicle. These are structured to enable readers to distinguish the emissions associated with the different processes involved in operating a shared micromobility service.

Figure ES3: Life Cycle Stages for Life Cycle Emissions Assessments for Shared Micromobility Services

Production				Use					End-of-Life				Benefits and Loads Beyond the System Boundaries		
Raw material extraction	Transport of raw materials and intermediate manufactured goods	Manufacturing	Transport of manufactured micromobility vehicle, dock, and other infrastructure	Micromobility vehicle use	Micromobility vehicle maintenance and repair	Servicing	Infrastructure use	Infrastructure maintenance and repair	Dismantling and deconstruction	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	B1	B2	B3	B4	B5	C1	C2	C3	C4	D1	D2	D3

Notes:

A4: Includes transport of manufactured components as well as final products, including the micromobility vehicle, dock (if applicable), and other infrastructure. A4 can be further divided into four sub-stages: 1) transport of manufactured intermediate components, and transport of the final manufactured vehicle 2) from manufacturing site to port, 3) port to port, and 4) port to market. This can help operators to understand their logistics-related emissions and conduct sensitivity analyses on the impacts of shipping via air, overland freight, ocean freight, etc.

B2: Includes emissions associated with the life cycle of replacement components used during maintenance.

B3: Includes transporting micromobility vehicles for rebalancing, charging, maintenance or repair, and any activities associated with the auxiliary vehicles used for servicing.

B4 and B5: Infrastructure includes docking stations and the energy consumption associated with their use, maintenance, and repair (including spare parts). Emissions from manufacturing and transporting docking stations and other infrastructure are included in A1–A4. B4 and B5 can optionally include roadway-based infrastructure like bicycle lanes and parking areas for dockless vehicles. An example of a method for a micromobility LCA that includes roadway infrastructure can be found in de Bortoli (2021).

Sources: Adapted from European Standards (2019); International Standards Organization (2017); and de Bortoli (2021).

All micromobility LCAs require input data that are not specific to any operator or even to micromobility, but rather describe the emissions from general industrial or logistical activity, like the GHG emissions (kg CO_2e) from producing one kilogram (kg) of aluminum. These background data can be sourced from numerous LCA databases (see Appendix A). It is vital to ensure alignment in how to select inputs that will vary among micromobility operators, as differences in these inputs can result in significant differences among operators' LCAs. Table 2 provides guidance for selecting operator-specific inputs.

In the working group meetings, three topics emerged for which micromobility-specific guidance was especially needed for LCAs: how to account for vehicle end-of-life and second life; how to account for differences among docked, dockless, and hybrid systems and micromobility vehicles with different battery designs (swappable and embedded batteries); and how to account for renewable energy certificates (RECs) in electricity emissions factors. Guidance on these areas can be found on page 32.

Cities highlighted a need for guidance on understanding and comparing the methodological rigor of the LCAs they receive. A key factor is the quality of the input data. We recommend that cities request that, along with the LCA results, operators submit an assessment of data quality. Table 2. Data Quality Pedigree Matrix provides a framework for doing so. We recommend cities look for LCAs with data quality scores of one or two in the areas that generate the largest share of emissions: manufacturing and materials, lifespan, types of auxiliary vehicles, and distance traveled by auxiliary vehicles. A score of three is acceptable for other data. If an LCA meets those criteria, it can be considered to have high quality data and can be directly compared to other LCAs with high data quality, regardless of their specific scores.

For many cities, the most important output of an LCA is grams of CO_2e per passenger-mile (or -kilometer). This is the simplest way to compare operators based on climate impacts. However, operators' LCA results may fall within a narrow range (see Table 6. Compiled Results of LCAs of Micromobility Vehicles), and simply ranking similar values may not reflect meaningful differences among operators, especially given the uncertainty in these analyses. In other words, there is not a very strong environmental case for selecting an operator that reports 85 g CO_2e per passenger-kilometer over one that reports 90 g CO_2e of per passenger-kilometer.

To account for this, one approach is to designate a "passing score," then differentiate among operators that pass using other criteria like cost, safety, or equity. Another approach is to estimate what each operators' per-mile emissions would add up to over a year and set a threshold for the difference in operators' annual emissions that they consider relevant to their decision-making. Cities may only be interested in differences that equal, for example, the annual emissions of 10 passenger cars, or some other threshold.

An LCA is the most thorough way to estimate micromobility emissions, but this method does have drawbacks. The process is time- and resource-intensive for micromobility operators and cannot be completed in the time between when a city issues a RFP and when proposals are due. Requiring an LCA effectively limits the applicant pool to operators that have already conducted an LCA, possibly excluding smaller, more regional operators or new entrants. LCA results also require technical expertise to interpret.

If cities decide that their use case does not require an LCA, they can instead conduct an "activities-based emissions comparison" to compare operators based on key activities as a proxy for comparing GHG emissions. This approach is reliable because often fewer than 10 activities or inputs relating to operators' operations and equipment (including vehicle lifespan, electricity source, and auxiliary vehicle fleet) explain a large share of the differences among LCA results. Operators can compile this data more expediently than conducting an LCA. Activities-based emissions comparisons, however, do not result in a specific estimate of GHG emissions (i.e., grams of CO_2e/passenger-mile); this process can only compare micromobility operators with each other, not with other modes. Another downside is that verifying operators' self-reported data is more challenging. Table 4. Template Scorecard for Activity-Based Emissions Assessment summarizes information needed for an activities-based emissions comparison and how to the evaluate the results.

Use Case 2: Compare Micromobility to Other Transportation Modes

Example: A city plans to allocate funds to subsidize the use of low-emissions modes for low-income residents. The city is deciding how to allocate the funds among various programs and transportation modes, such as shared e-scooters, an e-bike subsidy program, and free bus passes. The city wants to use GHG emissions as a criterion for making that decision, alongside criteria related to equity and accessibility. First, though, the city needs to know how GHG emissions from e-scooter trips compare to emissions from trips using other modes.

Cities may want to compare emissions from micromobility to emissions from other transportation modes to inform the design of policies, regulations, or infrastructure investments, or to build support for micromobility programs. For this use case, cities need to know the grams of CO_2e per passenger-mile (or -kilometer) for micromobility modes and for other modes used in the city. It is essential to compare emissions using the same scope for all modes, ideally all on a life cycle basis, but otherwise all on a "well-to-wheel" basis (see Figure 1. Different Scopes of Transportation Emissions Assessments), since comparing micromobility life cycle emissions with private car tailpipe emissions would overestimate micromobility emissions relative to other modes. Table 6 compiles published findings on CO_2e emissions per passenger-kilometer for various micromobility modes. Examples of analyses comparing life cycle emissions by mode are in Figure 5, Figure 6, and Figure 7. International Transport Forum published an Excel-based interactive tool to compare life cycle GHG emissions from several kinds of micromobility vehicles and other modes (Cazzola and Crist 2020).

Use Case 3: Estimate the Net GHG Emissions Impact of Micromobility

Example: A city is deciding whether to allow e-scooters to operate on its streets and wants to know whether micromobility is likely to cause net GHG emissions to increase or decrease.

Example: A city is considering whether or how much to prioritize micromobility in their policymaking, transportation planning, and allocation of incentives for transportation modes. The city wants to use the net GHG emission impact of micromobility as one factor in determining prioritization, alongside other considerations like accessibility and air quality.

To understand the impact of micromobility on a city's GHG emissions, cities need to understand how micromobility interacts with their wider transportation landscape. This guide offers two methods to estimate the net GHG emissions impact of micromobility: a consequential LCA and a simpler approach that most city governments could undertake themselves. The LCA described in Use Case 1 is specifically an "attributional" LCA, which estimates the environmental impacts of material flows to and from a product over its life cycle. By contrast, a consequential LCA determines the environmental impact of a product as *compared* to a scenario in which that product does not exist. This includes the environmental impacts of economic or behavioral changes that the product causes, such as mode shift induced by the availability of micromobility vehicles.

Overall, the guidance for a consequential LCA is the same as an attributional LCA, but additional input is needed regarding mode shift patterns and emissions from other modes.

Many cities might prefer an estimate that staff can calculate without extensive technical expertise. Such analyses are based around "shifted miles," the concept that miles that were traveled using micromobility would otherwise have been traveled using other modes (or not traveled at all). If a mile was shifted to micromobility from a low-emitting mode like walking, it represents an increase in emissions; conversely, if micromobility replaced high-emitting mode like a private car, it represents a decrease in emissions. By adding up those increases and decreases for all micromobility trips during the study period, a city can compare its total transportation-related emissions to an alternative scenario of what its transportation-related emissions would have been if micromobility were not available.

Table 9 shows how staff at the Portland, Oregon, Bureau of Transportation estimated the net GHG impact of the city's e-scooter pilot. This is an illustrative example, as results would vary among cities based on rates of car ownership, availability of transit, and other factors. This method requires the following inputs:

1. **Total number of miles (or kilometers) traveled by micromobility during the study period**
2. **Emissions per mile (or kilometer) for every mode of interest, in CO_2e per mile or kilometer**
3. **Data from user surveys about what modes micromobility replaced (i.e., 8 percent of micromobility trips replace bus trips, etc.). Table 8. Modes Replaced by Shared E-Scooter and Shared E-Bike Trips compiles survey results from over 30 cities.**

Table ES1: E-Scooter Shifted Trips and Associated Emissions in Portland, Oregon, USA, in 2019

MODE	LIFE CYCLE EMISSIONS PER MILE (g CO_2e/mi)	PERCENTAGE OF MICRO-MOBILITY TRIPS SHIFT-ED FROM THAT MODE	SHIFTED MILES	BASELINE EMISSIONS (g CO_2e)	SHIFTED EMISSIONS (g CO_2e)	NET CHANGE IN GHG EMISSIONS RESULTING FROM SHIFTING TO E-SCOOTERS (g CO_2e)
Walk	0	38%	392,992	0	67,594,659	67,594,659
Bike	8	7%	69,319	554,556	11,922,947	11,368,391
E-scooter (new trips)	172	6%	56,766	0	9,763,673	9,763,673
Private for-hire vehicle	655	27%	275,640	180,628,513	47,410,143	-133,218,370
Personal vehicle	449	14%	143,005	64,228,168	24,596,945	-39,631,222
Transit	253	9%	90,607	22,930,173	15,584,324	-7,345,848
TOTAL		100%	1,028,330	268,341,409	176,872,692	-91,468,717

SUMMARY	GHG EMISSIONS (G CO_2E)	PERCENT CHANGE
GHG Emissions Avoided by E-Scooter Trips	-180,195,441	
GHG Emissions Added by E-Scooter Trips	88,726,723	
Net Change in GHG Emissions Resulting from Shifting to E-Scooters	-91,468,717	-34%

Note: These data include only miles traveled during the eight-month 2019 pilot period (April 26–December 31, 2019) and do not necessarily reflect the miles typically traveled during a full year.

Source: Adapted from Portland Bureau of Transportation (2020).

However, this framing only focuses on a per-trip basis. More broadly, micromobility can provide a first- and last-mile connection to public transit. If the availability of micromobility makes public transit more accessible or convenient, then residents may feel less compelled to use or buy private cars. The environmental impact of that change in attitude would not be captured in a survey focused on single trip replacements in which a first- or last-mile trip might be shown as replacing walking and thus increasing emissions. This dynamic would be better captured in surveys and studies focused on longer-term mode shift and travel decision-making.

What's Next?

The contents of this guide are relevant beyond the three use cases it contains. As a new mode that is almost exclusively electric or people-powered, shared micromobility is compelling to city departments of transportation to grapple with how they will assess GHG emissions from modes for which nearly all emissions occur *outside* the city (i.e., in a foreign factory or electricity plant in another state), even though those emissions can be directly attributed to activities or demand *inside* the city. Similarly, shifting away from private cars will require a range of other mode options and a greater share of journeys that combine multiple modes. There is significant room for development and dissemination of approaches to track, analyze, and promote multimodal trips. The thinking, capacity building, and reporting systems that cities develop now for estimating emissions from shared micromobility can lay the foundation for understanding transportation-related emissions in an increasingly electric, shared, and multimodal future.

INTRODUCTION

The Problem: Micromobility Emissions Information Is Not Useful Because It Is Not Standardized

As shared micromobility services become a more common, formal part of urban transportation, many cities seek to understand how the environmental impacts of shared micromobility fit into municipal sustainability goals. Cities are also looking to license or contract with micromobility operators that will advance city climate action, accessibility, equity, and other goals. For these reasons, many cities' micromobility permitting or reporting processes in the last few years have included requests for information on greenhouse gas (GHG) emissions and other environmental impacts.

However, in many cases, micromobility operators respond to these requests with information that cannot be compared directly with the information other operators submit. Different operators may provide information that is based on different assumptions, uses different methods (e.g., different system boundaries or impact categories), or refers to different geographic areas. For example, if a large U.S. city receives emissions information based on one company's operations in a large European city in 2021 and information from another company based on a U.S.-wide 2019 average, and if both analyses used different methods or assumptions to collect that data, the city would not be able to tell which company produced fewer emissions. This lack of standardization and comparability often means that the environmental impact information cannot be incorporated into cities' decisions.

This lack of standardization is also a problem for micromobility operators. Some operators are reducing their emissions by incorporating recycled materials, sourcing renewable electricity, using electric vehicles in their operations and maintenance fleets, and through other practices. Without a standard way to report emissions, micromobility operators have less assurance that these efforts will benefit them in the selective permitting and contracting processes some cities are adopting. Likewise, without standard methods, micromobility operators are disincentivized to conduct transparent, rigorous analyses since their competition might not do so.

More broadly, micromobility vehicles emit far less GHG per passenger-mile (or -kilometer) than modes like private cars, taxis, or ride-hailing (see Figures 1–4), and shared micromobility accounts for a small share of trips and miles in most cities. The environmental impact reporting requirements for micromobility are often more extensive than for predominant, high-emitting modes. Micromobility operators might question the usefulness of conducting resource-intensive emissions assessments, especially when these are not required for higher-emitting modes and often do not directly inform action. This reporting burden is especially salient given micromobility's often highly regulated operating environment and still-evolving business model.

The Solution: Standardizing Micromobility Emissions Assessments

Standardizing the approach to assessing emissions from micromobility is a win for cities, micromobility operators, and climate action. Cities would benefit from having more reliable, comparable information to inform their decisions. Micromobility operators would be compared fairly to their peers based on the actual differences between them, and not inadvertently penalized for providing transparent information while other operators report less rigorously or not at all. This would incentivize micromobility operators to continue or scale up sustainable practices by giving a competitive advantage to operators that do so. Standardizing the approach to emissions reporting would also enable companies to generate and share information more efficiently. Additionally, a more rigorous approach would better equip operators to identify and reduce emissions "hotspots" in their supply chain and operations, increasing both environmental benefits and competitiveness.

How to Use This Guide

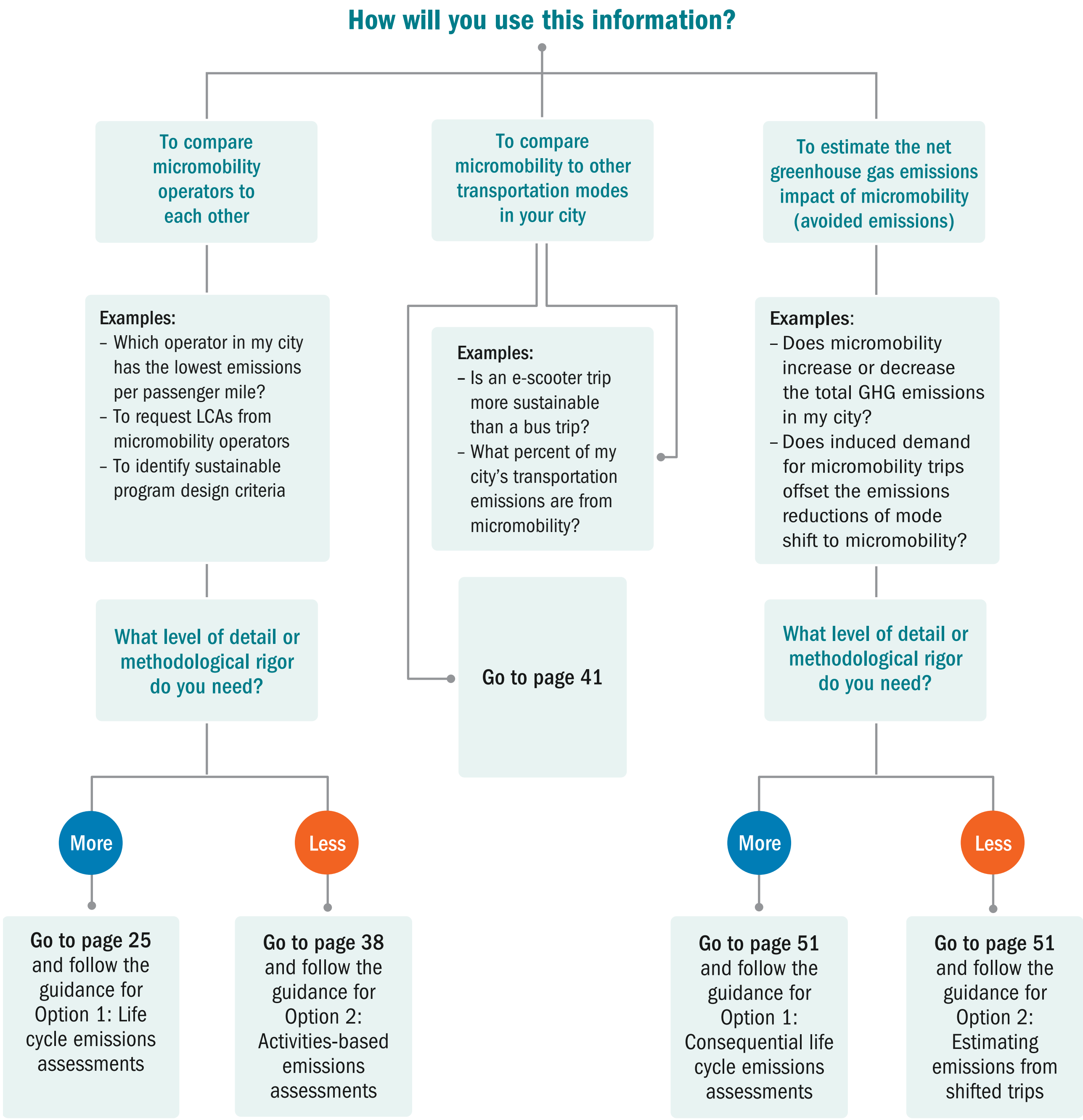
This guide is designed to support city- or municipality-level departments and agencies that are responsible for transportation and micromobility. Cities may have different reasons for assessing the environmental impact of micromobility, and each use case calls for different information. This makes it essential for cities to have their goals and use cases in mind before collecting information from micromobility operators or other sources.

This guide is structured around three main use cases cities may have for micromobility emissions information. The use cases were identified based on working group meetings, published requests for proposals (RFPs), and reports.

1. **Compare micromobility operators to each other**
2. **Compare micromobility to other transportation modes**
3. **Estimate the net GHG emissions and wider environmental impact of micromobility (including mode shift, avoided emissions, and/or induced trips)**

This guide helps cities clarify their use cases for micromobility emissions information and offers approaches and best practices for obtaining and analyzing that data. Figure ES4. Flowchart: Identifying Your Use Case guides readers to sections relevant to their use case.

Figure ES4: Flowchart: Identifying Your Use Case



Source: Authors.

The guidance for each use case builds on established methods for emissions assessment. While those methods can be applied to micromobility vehicles, there is some ambiguity in how to do so because of the relative novelty of micromobility and room for interpretation within existing methods. For example, what assumptions or inputs should be used when real-world data, such as the lifespan of a new e-scooter model, is not available? Is it better to use factory tests or real-world data from a similar model? This guide aims to reduce such ambiguity and facilitate the development of directly comparable emissions assessments by suggesting what inputs and methods cities should use and request from micromobility operators.

The guide is primarily intended for cities in the United States, Europe, and other high-income countries. Middle- or low-income country contexts may call for somewhat different approaches, given possible differences like more fossil-fuel powered shared micromobility vehicles (e.g., gas-powered motorcycles like Mottu in Brazil (“Mottu” n.d.)), different micromobility vehicle types (e.g., tuk-tuks), different permitting practices, higher rates of individually owned motorized micromobility vehicles used for personal or commercial purposes, and data gaps. However, many aspects of this guide remain applicable.

While primarily for city officials and agencies, this guide can also support micromobility operators in developing emissions assessments for internal use, interpreting ambiguous requests from cities, and proactively building systems to enable efficient, high-quality emissions reporting.

How This Guide Was Developed

The guide was developed based on the work of the Working Group on Micromobility Emissions Assessments. At the suggestion of partners in the micromobility field, the New Urban Mobility alliance (NUMO) convened the working group in 2022 to build consensus around the most appropriate approach to emissions assessments for micromobility. The working group consisted of over 30 members representing city governments, micromobility operators, and subject matter experts from the United States and Europe. The group met approximately six times in 2022 and reviewed multiple drafts of the guide.

This guide was drafted by Leah Lazer, Research Associate at NUMO, and is based closely on extensive input from the working group. However, the guide contains the author’s synthesis and does not necessarily represent the views of individual working group members nor those of the organizations with which they are or were affiliated. NUMO is grateful for the thoughtful contributions of all members. See the Acknowledgements section for a full list of working group members and other contributors.

2.
WAYS TO USE **MICROMOBILITY EMISSIONS DATA** IN YOUR CITY

Use Case 1: Compare Micromobility Operators to Each Other

Example: Preparing an RFP
A city department of transportation is drafting a request for proposals (RFP) for prospective micromobility companies to operate in the city. The city wants to use sustainability as a criterion for comparing operators' proposals. The department wants to request sustainability information in a way that will yield reliable data that allow for direct comparison among operators.

Example: Evaluating operators that participated in a pilot or permitting cycle
A city department of transportation is nearing the end of a micromobility pilot program or permitting cycle. The department wants to compare the environmental performance of the operators that participated, which will inform the design of future programs or the selection of an operator with which to continue working. At the beginning of the program or permitting cycle, micromobility operators signed a permit that enables the city to request as-yet-unspecified operational or sustainability data. The city is now determining what specific request will yield reliable information that allows for direct comparison among operators.

This section offers two options for comparing micromobility operators. The first is a life cycle emissions assessment (LCA), which is a more detailed, resource-intensive, and established approach. The LCA section includes guidance on selecting inputs and interpreting outputs, as well as sample language for requesting an LCA that follows this guidance. The second option, an activities-based emissions assessment, is a simpler, less resource-intensive, and less precise approach. We have included a scorecard (Table 4. Template Scorecard for Activity-Based Emissions) that cities can use to conduct an activities-based emissions assessment.

OPTION 1: LIFE CYCLE EMISSIONS ASSESSMENT

This section suggests best practices for conducting an LCA for shared micromobility services. It includes an introduction to LCAs and a checklist of what makes a high-quality micromobility LCA, which cities can use to request LCAs or to assess the quality of LCAs they receive. The guide then focuses on input data and data quality because these are likely sources of differences among micromobility operators' LCAs and affect whether their results can be directly compared. It then outlines which LCA outputs are most relevant to this use case, how to interpret them, and how to understand the uncertainty in those outputs.

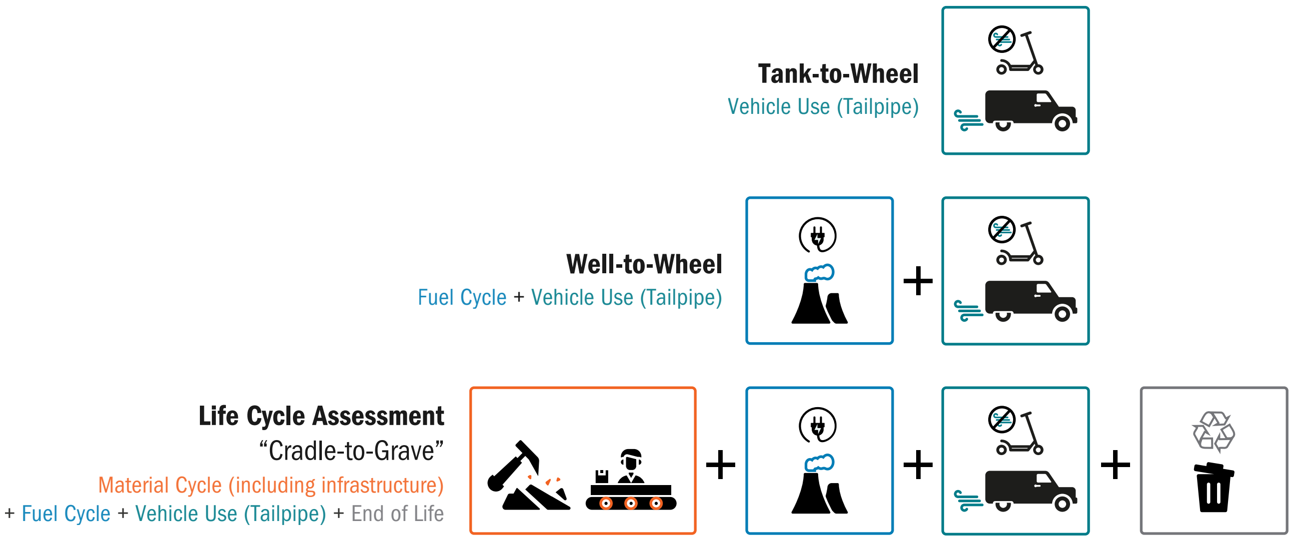
What is a life cycle emissions assessment?

Life cycle emissions assessments (LCAs) are the most rigorous way to compare micromobility operators on their environmental impacts. An LCA is a well-established method of analysis that is widely used across industries to estimate the total emissions associated with a product or service, such as a t-shirt, private car, or, in this case, a micromobility vehicle. The method for conducting LCAs is codified in standards like ISO 14040 and 14044 from the International Organization for Standardization. This guide is aligned with and supplementary to those standards. Since LCAs are complex, micromobility operators usually hire consultants or academics to conduct LCAs using the operator's own data.

An LCA estimates the emissions of multiple pollutants. Many cities are most interested in GHG emissions as quantified in grams of CO_2e per passenger-mile (or -kilometer) (See Glossary for the definition of passenger-mile). However, this metric is not the only indicator of sustainability. LCAs also estimate emissions of other air and water pollutants, as well as ecosystem impacts.

LCAs have the most comprehensive scope of any type of transportation emissions assessment. They include emissions and consumption-related impacts from the entire lifespan of a vehicle ("cradle-to-grave"), in contrast to approaches that include only tailpipe emissions ("tank-to-wheel") or only tailpipe emissions plus upstream emissions from fuel or energy production ("well-to-wheel"). Figure 5 illustrates the different scopes of transportation emissions assessments.

Figure 1: Different Scopes of Transportation Emissions Assessments



Source: Adapted from Portland Bureau of Transportation (2020).

Figure 2: Checklist for Micromobility Life Cycle Emissions Assessments

Standards, Scope, and Boundaries

- ✓ Prepared in accordance with ISO 14040:2006 and ISO 14044:2006
- ✓ Uses the system boundary of "cradle-to-grave"
- ✓ Uses the functional unit of "one passenger-mile/-kilometer of riding a [vehicle model] operated by [operator name] in [location] in [year]." For example, "one passenger-mile of riding a model Bird Three e-scooter operated by Bird in Los Angeles, California, USA, in 2022."
- ✓ The LCA may be prepared by the operator or by a third-party consultant or academic
- ✓ Cities may prefer LCAs that have been critically reviewed by a third party for compliance with ISO standards

Inputs and Assumptions

- ✓ Contains input data that conform to ISO 14044 data quality requirements and the guidance in Table 2. Best Practices for Determining LCA Inputs
    - Includes a list of assumptions used and their rationales, such as the conditions under which those assumptions were met during real-world operations
- ✓ Uses data with quality scores of one or two, according to Table 1. Best Practices for Determining LCA Inputs, for input data related to manufacturing and materials, lifespan, types of auxiliary vehicles, and distance traveled by auxiliary vehicles, and scores of three or better for all other input data
- ✓ Uses a high-quality database for background data and is transparent about which database was used
- ✓ Uses high-quality databases and tools for impact assessment

Outputs

- ✓ Includes a breakdown of emissions by use stage (life cycle phase), as defined in Figure 3. Life Cycle Stages for Life Cycle Emissions Assessments for Shared Micromobility Services
- ✓ Includes information about the type and amount of uncertainty in the LCA

Source: Authors.

Figure 3: Life Cycle Stages for Life Cycle Emissions Assessments for Shared Micromobility Services

Production				Use					End-of-Life				Benefits and Loads Beyond the System Boundaries		
Raw material extraction	Transport of raw materials and intermediate manufactured goods	Manufacturing	Transport of manufactured micromobility vehicle, dock, and other infrastructure	Micromobility vehicle use	Micromobility vehicle maintenance and repair	Servicing	Infrastructure use	Infrastructure maintenance and repair	Dismantling and deconstruction	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	B1	B2	B3	B4	B5	C1	C2	C3	C4	D1	D2	D3

Notes:
A4: Includes transport of manufactured components as well as final products, including the micromobility vehicle, dock (if applicable), and other infrastructure. A4 can be further divided into four sub-stages: 1) transport of manufactured intermediate components, and transport of the final manufactured vehicle 2) from manufacturing site to port, 3) port to port, and 4) port to market. This can help operators to understand their logistics-related emissions and conduct sensitivity analyses on the impacts of shipping via air, overland freight, ocean freight, etc.

B2: Includes emissions associated with the life cycle of replacement components used during maintenance.

B3: Includes transporting micromobility vehicles for rebalancing, charging, maintenance or repair, and any activities associated with the auxiliary vehicles used for servicing.

B4 and B5: Infrastructure includes docking stations and the energy consumption associated with their use, maintenance, and repair (including spare parts). Emissions from manufacturing and transporting docking stations and other infrastructure are included in A1–A4. B4 and B5 can optionally include roadway-based infrastructure like bicycle lanes and parking areas for dockless vehicles. An example of a method for a micromobility LCA that includes roadway infrastructure can be found in de Bortoli (2021).

Sources: Adapted from European Standards (2019); International Standards Organization (2017); and de Bortoli (2021).

How to define the life cycle stages in a micromobility life cycle emissions assessment

LCAs include environmental impacts from all phases of a product or service's life cycle. The phases (also called "stages") can be grouped in different ways (e.g., treating materials extraction separately or as part of manufacturing).
To improve comparability among LCAs, we recommend using a standard set of phases. This aligns with the modularity principle from ISO 14025, which promotes the use of LCA data for environmental product declarations (EPDs). Figure 7 lists all micromobility life cycle phases and was adapted from the EN 15804 and ISO 21930 standards that apply to building construction (European Standards 2019; International Standards Organization 2017). In the future, a product category rule (PCR) for micromobility could further codify the boundaries of these phases. (See Yumpu.com (n.d.) for an example of a PCR for rail vehicles.)

HOW TO SELECT INPUT DATA

Background inputs

All micromobility LCAs require input data that are not specific to any operator or even to micromobility, but rather describe the emissions from general industrial or logistical activity, usually early in the supply chain. Examples include producing raw materials like metals and plastics (e.g., kilograms of CO_2e from producing 1 kg of aluminum), shipping raw materials and components, and generating electricity to manufacture vehicle components.

These background data can be sourced from numerous LCA databases, which vary in their levels of sectoral or geographic disaggregation, recentness, transparency, quality, and cost. Recommended databases for micromobility LCAs include ecoinvent ("Ecoinvent" n.d.) and the SimaPro Industry Data Library 2.0 ("Industry Data LCA Library" n.d.). Additional LCA databases are listed by openLCA Nexus ("openLCA Nexus" n.d.) and in Appendix A. Background data can also be sourced from national emissions inventories and other analyses. It is a red flag if an LCA is not transparent and reproducible (e.g., if the LCA does not state the database used, if it uses a non-transparent database, or if it is not transparent about the entire model).

MICROMOBILITY- AND OPERATOR-SPECIFIC INPUTS

Alignment in micromobility- and operator-specific inputs is vital. Assuming LCAs comply with ISO 14040 and 14044, the choice of input data would result in some of the most significant differences among operators' LCAs, affecting whether the results are directly comparable. Since micromobility (both the operational practices and vehicle models) are relatively new, there are many inputs for which real-world data will not be available, and LCAs will contain assumptions, such as the lifespan of a new vehicle model. Some operators may make more optimistic assumptions than others, leading to variation among LCA results that does not reflect actual differences among the operators.

A standardized approach to selecting inputs is also important to offset additional uncertainty that arises in LCAs that estimate an operator's emissions in a city where the operator does not already operate. It may be challenging to get comparable information from operators that are already active in the city (which will have real-world data) and possible new entrants (which will have to rely on more assumptions and may be less familiar with specific characteristics of the city). New entrants may be more optimistic in their assumptions, such as aspiring to rebalance e-scooters using e-cargo bikes, which may prove impractical given weather conditions.

However, there are legitimate reasons why inputs might vary among operators. For example, an operator may have a sturdier vehicle with a longer projected lifespan, while another may have an operational model that leads to longer average trip lengths. One operator may use electric vehicles to service micromobility vehicles, while another may use internal combustion engine (ICE) vans to transport vehicles to a central charging hub, leading to differing vehicle miles (or kilometers) traveled. It is not necessary for each micromobility operator to use the exact same inputs and assumptions provided that their sources and justifications are transparent and reasonable. Table 1. Best Practices for Determining LCA Inputs provides best practices for determining inputs and assumptions. This guidance assumes a city-level geographic scale, but some cities may find a regional or national scale sufficient. The following section discusses how to assess data quality, with guidance on evaluating the extent to which LCA in put data are in line with best practices.

Assuming LCAs comply with ISO 14040 and 14044, the choice of input data leads to significant differences among operators' LCAs, affecting whether the results are directly comparable.

Table 1: Best Practices for Determining LCA Inputs

INPUT	DESCRIPTION	BEST PRACTICE FOR DETERMINING INPUTS
Vehicle Components	What parts and materials are used in the vehicle (i.e., percent aluminum by weight)?	In order of preference: 1. Bill of material from the operator based on dismantling the vehicle 2. Bill of material from the manufacturer (See Glossary for definition of "bill of material")
Vehicle Utilization	How intensively are the micromobility vehicles used (i.e., miles per week)?	In order of preference: 1. Real-world data on a company's operation in that city 2. Real-world data on a company's operation in a city with similar characteristics in terms of population, density, road design, weather, mobility patterns, etc. 3. Real-world data on other micromobility operators' operations in that same city or a similar city based on academic studies or other non-proprietary data
Vehicle Lifespan	Total miles that a micromobility vehicle travels in its lifetime	In order of preference: 1. Real-world data on a company's operation in a city based on the most recently available data or earlier data (with explanation of why that latter is more representative) 2. a. Real-world data on a company's operation of the same vehicle model in a similar city in terms of population, density, road design, weather, mobility patterns, etc., OR b. Real-world data on a company's operation of a different vehicle model in the same city, adjusted based on factory tests and real-world data from similar cities and/or vehicle models 3. The global observed decay rate of that vehicle model OR If it is a new vehicle model (introduced less than 12 months ago): a. Data from the design and components of the vehicle, including assumptions as stated in the design and development of the vehicle and data from factory tests b. Real-world data from other vehicle models with combined data for characteristics most like this model. (State what characteristics are similar and the resulting uncertainties.)
Emissions Intensity of Electricity	GHG emissions per unit of electricity consumed (i.e., grams CO_2e/kwh)	If an operator has a contract to directly purchase renewable energy (such as a power purchase agreement, or PPA), then the emissions intensity of that electricity source should be used. Otherwise, use data on emissions from the local electricity mix at the highest spatial resolution for which data are available. Some cities may publish this information. The eGRID power profiler (U.S. EPA 2021) offers sub-national estimates in the United States, and Appendix A suggests additional databases. Emissions intensity should not account for electricity covered by renewable energy certificates (RECs). (See box "Renewable energy certificates in micromobility LCAs".)

Table 1: Best Practices for Determining LCA Inputs (cont.)

INPUT	DESCRIPTION	BEST PRACTICE FOR DETERMINING INPUTS
Rebalancing Model	How are micromobility vehicles redistributed across the city? (Includes both the spatial distribution of micromobility vehicles around the city and types of auxiliary vehicles used to move them.)	In order of preference: 1. Real-world data from the same city with the same rebalancing model 2. Real-world data from a similar city with the same or a similar rebalancing model 3. Real-world data from the same city with a similar rebalancing model 4. Real-world data from different city with a different rebalancing model, adjusted to reflect informed assumptions about how the data will change in the city of interest or with the intended rebalancing model. (State what is different and the assumptions made about how those differences will affect the rebalancing model's vehicle miles, fuel consumption, or other environmental impacts.)
Charging Model	How are micromobility vehicles recharged? (Mainly refers to battery design, e.g., swappable vs. embedded batteries, and could also include charging hubs or the location of charging facilities.)	In order of preference: 1. Real-world data from the same city with the same charging model 2. Real-world data from a similar city with the same or a similar charging model 3. Real-world data from the same city with a similar charging model 4. Real-world data from different city with a different charging model, adjusted to reflect informed assumptions about how the data will change in this city or with this model. (State what is different and the assumptions made about how those differences will affect energy use or other environmental impacts.)
End-of-Life	What happens to the micromobility vehicle or its components at the end of its usable lifespan?	In order of preference: 1. Data reflecting a company's approach and partnerships for remanufacturing and recycling micromobility vehicles and components, especially batteries 2. Assumptions as stated in the design and development of the vehicle in combination with usual disposal data from the city, region, or country, including reusability of the components (spare parts) and durability of the components (based on the materials used) *Note:* Many micromobility vehicles will operate in several cities over their lifetime. Since their end-of-life is the responsibility of the operator, the operator's recycling practices are more relevant than the city's. Many operators contract with centralized recycling companies. As of October 2022, there were approximately five U.S. companies that recycle lithium-ion batteries (Meeting of Working Group on Micromobility Emissions Assessment 2022).

Sources: Author's analysis based on working group input.

Renewable energy certificates in micromobility LCAs

A renewable energy certificate (REC), also called guarantee of origin or contractual emissions factor, is "a market-based instrument that represents the property rights to the environmental, social, and other non-power attributes of renewable electricity generation" (US EPA 2022). Buying a REC demonstrates demand for renewable electricity, but the buyer does not directly receive or use renewable electricity; they still draw electricity from a shared grid. This is a major difference from long-term contracts to source electricity directly from a renewable energy plant.

The use of RECs in emissions accounting is controversial. Many experts state that RECs are unlikely to lead to additional renewable electricity generation, since most of the electricity purchased would have been generated even without the REC, meaning that they don't contribute to real-world GHG emissions reductions (Bjørn et al. 2022; Brander, Gillenwater, and Ascui 2018; Climate Change Committee 2020). This perspective has led major corporations like IBM and Walmart to eschew RECs as an emissions reduction strategy (Gautam Naik 2021). However, this refers primarily to the U.S. market and regulatory environment. In Europe, different standards and regulations may diminish these concerns (RECS International 2023).

This guide recommends that LCAs for micromobility primarily present electricity-related GHG emissions that reflect the electricity mix in the studied location with as much geographic specificity as possible, unless the operator has a contract to directly source and use renewable electricity. Operators may opt for their LCA to include an additional, alternative version of results reflecting emission factors associated with the renewable electricity from their REC. Moreover, RECs can indirectly promote emissions reductions and are evidence of an operator's commitment to sustainability. Cities can give qualitative preference to operators that purchase RECs, treating RECs like other demonstrations of environmental or social leadership.

HOW TO ASSESS DATA QUALITY

Table 2. Data Quality Pedigree Matrix provides a framework for assessing data quality in terms of how well LCA inputs match the real-world product and context. Inputs are scored based on their reliability, completeness, temporal match, geographic match, and technological match, with the "best practice" receiving a score of one. This matrix is meant to be applied to each individual input, not to the LCA as a whole, since each input can score differently.

We recommend cities look for data quality scores of one or two in the areas that generate the largest share of emissions: manufacturing and materials, lifespan, types of auxiliary vehicles, and distance traveled by auxiliary vehicles. A score of three is acceptable for other data.

For example, the data on vehicle utilization might have a stronger geographic correlation than the data on electricity generation. In general, real-world data are always better than data from factory tests, and transparency about the data source is essential. Data quality should be assessed by the entity producing or verifying the LCA (i.e., the micromobility operator or consultant), and they should share the data quality scores along with the LCA results.

There are varying approaches to comparing LCAs with different data quality scores. The most technical approaches to quantify uncertainty use mathematical models and Monte Carlo simulations, but city governments rarely have the capacity or expertise for these methods.

Table 2: Data Quality Pedigree Matrix

		BEST SCORE <————————> WORST SCORE				
INDICATOR	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5 (DEFAULT)**
Reliability	The quality of the data generation method and the verification/validation of the data collection methods used	Verified data based on measurements	Verified data partly based on assumptions or non-verified data based on measurements	Non-verified data partly based on qualified estimates	Qualified estimate (e.g., by an industrial expert)	Non-qualified estimate
Completeness	Does the input data represent the entire area of interest (i.e., the entire area where micromobility operates in the city, not just the central business district)? Was it collected over a representative period (i.e., a 1-year average, not a 1-week average during a major holiday)?	Representative data from all sites relevant for the market considered over an adequate period to even out normal fluctuations	Representative data from over 50% of the sites relevant for the market considered over an adequate period to even out normal fluctuations	Representative data from only some sites (over 50%) relevant for the market considered or under 50% of sites but from shorter periods	Representative data from only 1 site relevant for the market considered or some sites but from shorter periods	Representative-ness unknown or data from a small number of sites and from shorter periods
Temporal Correlation	How recent is the input data?	Less than 3 years of difference to the time period of the dataset	Less than 6 years of difference to the time period of the dataset	Less than 10 years of difference to the time period of the dataset	Less than 15 years of difference to the time period of the dataset	Age of data unknown or more than 15 years of difference to the time period of the dataset
Geographical Correlation	How closely do the geographic resolution and location of the input data match the area of interest? [i]	Data from area under study	Average data from a larger area in which the area under study is included	Data from an area with similar production	Data from an area with slightly similar production conditions	Data from an unknown or distinctly different area (e.g., North America in-stead of the Middle East)
Further Technological Correlation	How closely do the input data match the technology and materials of interest (i.e., the specific vehicle model or components like batteries)?	Data from enterprises, processes, and materials under study [ii]	Data from processes and materials under study (i.e., identical technology) but from different enterprises	Data from processes and materials under study but from different technology	Data on related processes and materials	Data on related processes on laboratory scale Data from processes and materials under study but from different technology **or** from different technology

Notes:

[i] The "area of interest" is the area being studied when the LCA is conducted, not the city where the LCA may later be sent to as part of a permitting/licensing process. For example, if an LCA was conducted for Paris, France, but was later sent to London, England, as part of London's application process, the geographical correlation score would still refer to Paris.

[ii] For new vehicle models (introduced less than 12 months ago) for which real-world data is not available, best practice is to use data from the design and components of the vehicle, including assumptions as stated in the design and development of the vehicle and data from factory tests. See Table 2. Best Practices for Determining LCA Inputs for details.

Source: Adapted from Ciroth, Muller, and Weidema (2012).

Table 3: . Geographic Resolution Levels

RESOLUTION	Global	Continental	Sub-Region	National	Province/ State/Region	County/City	Site-Specific
EXAMPLE	World	North America	North America	USA	Ohio	Hamilton	26 W Martin Luther King

Source: EPA 2016.

Can you compare LCAs of different geographies?

Most operators conduct LCAs for just one city or country, or for an average of countries in a certain region. For example, Lyft's e-bike LCA included scenarios for San Francisco, Chicago, and New York, while the scope for Bird's e-scooter LCA was Europe. Conducting or revising an LCA for a specific city can be too time intensive and costly to be comfortably feasible in the context of an RFP, tender, or program reporting period, especially when operators work with external LCA consultants. Additionally, some RFP or tender processes prohibit dialogue between the city and operators; therefore, even if an operator has LCAs for multiple geographies, the operator must determine which is the most appropriate proxy. As a result, a city may receive LCAs that refer to a range of geographies. To what extent can these be directly compared and how?

The geographic location of a shared micromobility service would primarily impact emissions related to electricity use, transportation of manufactured components, and distance traveled by auxiliary vehicles. As noted above, the largest share of emissions usually derives from raw materials extraction and manufacturing, followed by the type and distance of auxiliary vehicles. The main overlap between high-emitting life cycle stages and city-specific elements is the distance traveled by auxiliary vehicles. If possible, then, a proxy city should have auxiliary vehicle mileage similar to the city of interest. Moreover, since the location where the shared micromobility service operates does not impact many of the highest-emitting life cycle stages, comparing LCAs from different cities may be appropriate. Cities concerned about this aspect of comparability could focus on comparing the production stage of LCAs and possibly the end-of-life stage.

For a simpler approach, we recommend cities look for data quality scores of one or two in the areas that generate the largest share of emissions: manufacturing and materials, lifespan, types of auxiliary vehicles, and distance traveled by auxiliary vehicles. A score of three is acceptable for other data. If an LCA meets those criteria, it can be considered to have high quality data and can be directly compared to other LCAs with high data quality, regardless of their specific scores. According to expert members of the working group, an LCA that does not meet those criteria is likely underestimating emissions, which should be factored into the city's assessment of that operator.

In the "Geographical Correlation" row, the levels of resolution refer to the following spatial resolutions, with examples given for a U.S. context.

City staff may struggle to assess whether inputs or assumptions are reasonable. If there is an opportunity for a city to bring in experts to assess the LCA (which may only be possible for a handful of cities), we suggest they focus on this aspect. Cities may also consider how to incentivize operators to use real-world data and realistic assumptions or reward operators with a better environmental performance than their LCAs predicted.

Docked versus dockless operations and embedded versus swappable batteries

Shared micromobility services can operate as docked (typically for bicycles or e-bikes), dockless (typically for e-scooters but also bicycles and e-bicycles), or hybrid (users return vehicles to a dock or leave them free-floating) systems. This guide is applicable to any of these systems, and LCAs for docked, dockless, and hybrid shared micromobility services can be compared directly. Compared to a dockless system, there are two main differences to account for when estimating emissions from a docked or hybrid system. The most important is the dock infrastructure itself. LCAs should include the production, maintenance, electricity use, and end-of-life of docks (see B4 and B5 in Figure 3). Second, some docks charge e-bikes, reducing or eliminating the need to transport e-bikes to a charging facility. This difference would be accounted for in the electricity use of the dock and the mileage of auxiliary vehicles.

There may be other differences in miles traveled by auxiliary vehicles to service docked versus dockless systems. Dockless systems, for example, may entail more vehicle travel to rebalance micromobility vehicles or distribute them after charging, since it is typical to place a smaller number of vehicles in many locations. In addition, some docked systems reduce the need for rebalancing by incentivizing users to return vehicles to docks in less popular locations. These differences, however, do not necessitate any change in method, especially since other factors like urban form can also impact miles traveled by auxiliary vehicles. LCAs should just include the best available data on the mileage of the auxiliary vehicle fleet.

The same applies to micromobility vehicles with embedded versus swappable batteries. No change in LCA method is required. The established method and life cycle stages would adequately capture differences in battery production and lifespan, miles traveled by auxiliary vehicle, and other differences.

HOW TO ACCOUNT FOR VEHICLE END-OF-LIFE AND SECOND LIFE

A common source of non-comparability in LCAs is how emissions resulting from vehicles' end-of-life and "second life" are allocated. There is ambiguity in how LCAs should reflect certain situations, such as if an operator sells a used micromobility vehicle to a different operator for use in another city, or if an operator sells a vehicle to a company that will dismantle it and sell the components. Different approaches can make similar vehicles erroneously appear to have different lifespans and lifetime emissions.

Early in a vehicle's lifespan, there may be significant uncertainty about how its end-of-life or second life will be handled. The operator conducting or commissioning the LCA may not have information about or control over the vehicle's use after it leaves their ownership. Additionally, market conditions and technologies may change significantly between when the operator conducts the LCA and when the vehicle reaches the end of its life.

Given this uncertainty, the best practice is to use a scenario approach. LCAs can report emissions excluding end-of-life and second life (stages A1–C4 in Figure 3) and then represent these final stages (stages D1–D3) with a range of different strategies and scenarios. Using a scenario approach enables cities to compare values that reflect the same life cycle stages, such as excluding all end-of-life or second life emissions impacts, or based on a moderate scenario for all LCAs.

HOW TO INTERPRET AND USE OUTPUTS OF LIFE CYCLE EMISSIONS ASSESSMENTS

For many cities, the most important high-level output of an LCA is grams of CO_2e per passenger-mile (or -kilometer). This is the simplest way to compare operators based on climate impacts. This information may be labeled "global warming potential" (GWP) or one of several other recognized labels. Beyond this metric, cities may seek to understand what is driving the differences between operators. In that case, they can look at the breakdown of emissions from each life cycle phase (see Figure 3).

It is possible that micromobility operators' LCA results will fall within a narrow range, primarily because the largest share of emissions often come from manufacturing the vehicles, not from operational differences among operators. Most of the variation among operators' LCA results is because of differences in a small number of inputs, specifically vehicle lifespan, electricity source, e-scooter charging model/battery design, and auxiliary vehicle fleets. Given rapidly evolving micromobility operational scenarios and vehicle models, these inputs can shift in mere months (e.g., new scooter models may enter fleets just months after an operator conducts an LCA).

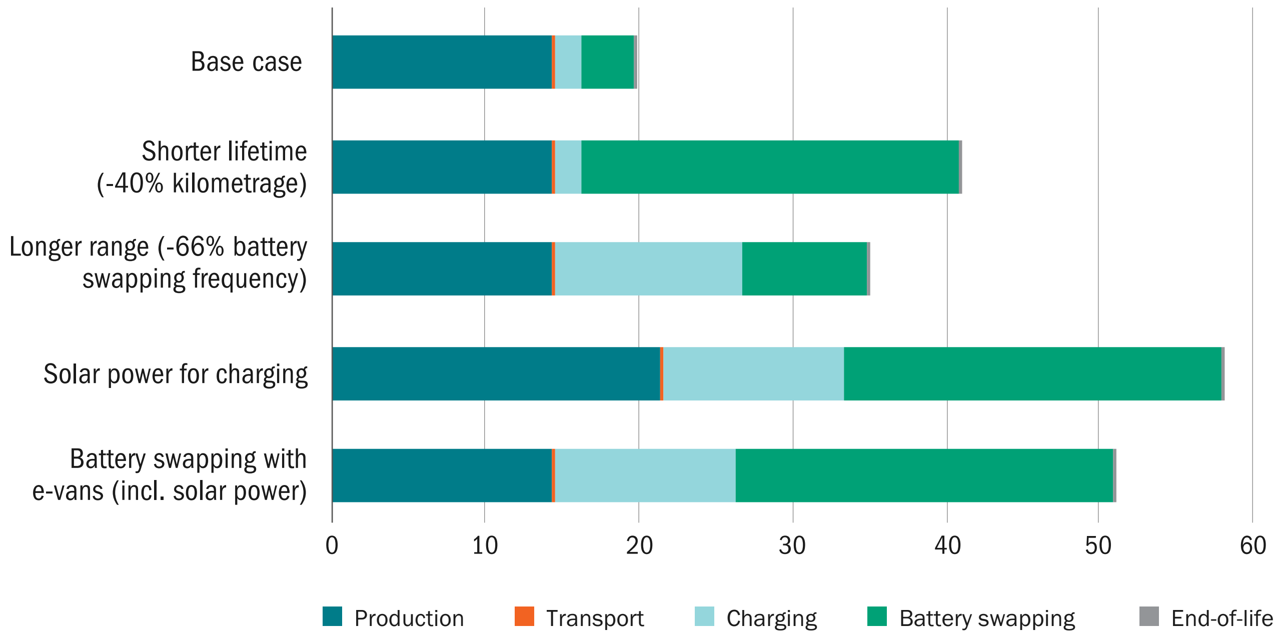
Ranking LCA results that fall within a narrow range, therefore, may not reflect meaningful differences among operators or translate to real-world avoided emissions, especially given the uncertainties in these analyses. There is not a very strong environmental case for selecting an operator with an LCA reporting 153 g CO_2e per passenger-mile over one reporting 160 g CO_2e per passenger-mile.

Ranking LCA results that fall within a narrow range may not reflect meaningful differences among operators or translate to real-world avoided emissions, especially given the uncertainties in these analyses. There is not a very strong environmental case for selecting an operator with an LCA reporting 153 g CO_2e per passenger-mile over one reporting 160 g CO_2e per passenger-mile.

To understand the real-world differences among those results, cities could multiply the grams of CO_2e per passenger-mile (or -kilometer) of each operator by the total annual of micromobility passenger-miles (or -kilometers) traveled in the city or a proxy city. The results would estimate the gross annual emissions if all the city's micromobility trips were taken with that operator. Cities can then compare the real-world impacts of choosing different operators (though this approach disregards differences among operators that could change the total of number of trips taken or scenarios where multiple operators serve the city). Cities may only be interested in differences that are equivalent to, for example, the annual emissions of 10 passenger cars or some other threshold. Another approach, especially if sustainability is one of many criteria used to assess operators, is to create a threshold that represents a "passing score" on sustainability. Cities can then differentiate among operators that pass that filter using other criteria like equity and cost.

Of all the life cycle phases of micromobility vehicles, cities have the most influence on the use phase (sometimes called operations) because micromobility operators can change their use phase practices more dynamically and vary practices among cities much more easily than with upstream phases like manufacturing. Generally, there are two primary sources of use phase emissions: electricity used to charge micromobility vehicles and larger auxiliary vehicles used to transport micromobility vehicles across the city for charging, maintenance, or rebalancing. For the latter, cities can request information on the types of auxiliary vehicles used and their projected mileage during different times of the year. Cities can also select operators with certain upstream practices like more sustainable manufacturing, though at best this would mean choosing among existing options. Figure 4 shows how changes in use-phase operational practices can drastically alter the life cycle GHG emissions for a shared e-moped service.

Figure 4: Alternative Scenarios of Life Cycle Emissions of Shared Electric Mopeds



Source: Schelte et al. 2021.

LCA results should include uncertainty analyses, which further enable cities to assess an LCA's data quality. The three main sources of uncertainty in LCAs are:

1. **Parameter uncertainty: uncertainty because of data quality or the representativeness of the data samples**

2. **Scenario uncertainty: uncertainty because of choices made when constructing scenarios, such as the choice of functional unit, time horizon, geographical scale, or other methodological choices**

3. **Model uncertainty: uncertainty because of the structure of the model and its mathematical relationships (Bamber et al. 2020)**

The level of uncertainty associated with some components or operational practices can inform the actions that cities take to reduce emissions from micromobility. Cities may prefer to focus on areas with lower uncertainty, even if those areas are not the largest source of emissions, so that their interventions will be more likely to create the intended impact.

OPTION 2: ACTIVITIES-BASED EMISSIONS COMPARISON

WHEN IS AN ACTIVITIES-BASED EMISSIONS COMPARISON USEFUL?

An LCA is the most thorough, rigorous way to assess emissions from micromobility and will yield comparable results in standard units—but LCAs have drawbacks. The process is complex and time- and resource-intensive for micromobility operators, often requiring specialized consultants. Typical costs can range from $30,000-$50,000 or more (Meeting of Working Group on Micromobility Emissions Assessment 2022). LCA results also require technical expertise to interpret. City departments of transportation may decide they do not require an LCA for their use cases. For example, a city may select sustainability as one of many criteria in assessing permit applications, but that city may not have the interest or capacity to look at such detailed information. Likewise, that city may only have a small amount of staff time dedicated to evaluating the emissions impact of an e-scooter pilot program or a short time frame during which to prepare that evaluation; in this case, requesting, waiting for, and interpreting full LCA results may not be the best use of limited time. In addition, smaller or newer micromobility operators may be less likely to have conducted LCAs, but a city may wish to include them in the pool of possible applicants.

Often, fewer than 10 key inputs relating to operators' operations and equipment explain a large share of the differences among LCA results; therefore, cities can compare operators based on those key data points as a proxy for comparing their relative GHG emissions—an "activities-based emissions comparison." Operators can compile this primary data more conveniently and less expensively than conducting a full LCA. Activities-based emissions comparisons, however, do not result in an explicit estimate of GHG emissions (i.e., grams of CO_2e/passenger-mile); they can only compare micromobility operators with each other, not with other modes. Importantly, they also exclude emissions from manufacturing, which typically represent a large majority of a micromobility vehicle's life cycle emissions.

> Often, fewer than 10 key inputs describing operational practices and equipment explain a large share of the differences among operators' LCA results. Cities can compare operators on those key data points as a proxy for comparing their GHG emissions.

HOW TO CONDUCT AN ACTIVITIES-BASED EMISSIONS COMPARISON

NUMO researchers consulted working group members, other experts, and published research to determine what operational information is most important and which practices are most likely to lead to lower emissions. Table 4. Template Scorecard for Activity-Based Emissions Assessment summarizes information for an activities-based emissions comparison, as well as how to the evaluate the results. When requesting the information in Table 4, cities should specify the period of time to which the data should refer.

One drawback of an activities-based emissions assessment is that verifying operators' self-reported data is more challenging. Unlike in an LCA, there is no third-party consultant conducting the analysis, and there is no possibility of third-party verification. Cities can, however, ask operators to score the quality of their self-reported data based on the matrix in Table 3. Data Quality Pedigree Matrix and the guidance in Table 1. Best Practices for Determining LCA Inputs. This approach allows for comparison of operators on the quality of their data as well as on their results. For example, if two operators report similar activities but one includes more real-world data (and thus had a higher data quality score), the city may prefer the operator with better data quality.

It is often the most sustainable option to deploy an operator's existing vehicle fleet. If cities prioritize new micromobility vehicles with the latest technology or hardware, they may inadvertently compel operators to enter a cycle of purchasing new vehicles before the end of the usable lifespan of their existing vehicles. This practice can lead to increased overall emissions due to manufacturing of new vehicles.

Table 4: Template Scorecard for Activity-Based Emissions Comparison

TOPIC	QUESTIONS	UNIT OR DATA TYPE	EXAMPLE	RESPONSE	DATA QUALITY (Score each input 1–5 for each indicator based on Table 3. Data Quality Pedigree Matrix)	RESPONSE THAT WOULD INDICATE LOWER GHG EMISSIONS
Time Period of Data in Scorecard	What time period does the following data refer to?	Dates included	September 1, 2021–August 31, 2022		N/A	N/A
Lifespan (Lifetime Mileage)	What is the average lifespan of the micromobility vehicle (including lost and vandalized vehicles)?	Miles (or kilometers)	1,000 miles			Longer lifespan
	Optional: What percentage of micromobility vehicles are experiencing a lifespan close to what was estimated in factory tests? Have any steps been taken to increase that percentage?	Percentage; qualitative	The vehicle was designed to enable easy repair or replacement of components, or vehicles have sensors that prevent operation if more than one passenger is detected, since avoiding overloaded use can increase vehicle lifespan			Higher percentage; yes
Charging	What is the battery charging model?	Qualitative	Swappable batteries, charging hubs, "juicers," or other			Most likely swappable batteries, since a smaller, low-emissions vehicle (e.g., an e-cargo bike) can be used to transport swappable batteries to the micromobility vehicles, while a larger, higher-emitting vehicle (e.g., a van) is needed to transport scooters to a charging location. This difference could be partially offset by using electric vans or trucks to transport scooters to charging locations.
Auxiliary Vehicle Fleet	What vehicles are used for rebalancing or retrieval of micromobility vehicles?	Vehicle model(s) and fuel type	Dodge Ram Promaster 2500			Smaller, more fuel-efficient, and/or electric vehicles
	What vehicles are used for transport of swappable batteries (if applicable and different from above)?	Vehicle model(s) and fuel type (can include seasonal breakdown if appropriate)	20 e-cargo bikes			Smaller, more fuel-efficient, and/or electric vehicles
	What was the total mileage driven by those vehicles in the city?	Miles	Total mileage of 100,000 miles between October 2020–October 2021 (average of 10,000 miles per van for a fleet of 10 vans)			Lower total mileage or fuel consumption

Table 4: Template Scorecard for Activity-Based Emissions Comparison (cont.)

TOPIC	QUESTIONS	UNIT OR DATA TYPE	EXAMPLE	RESPONSE	DATA QUALITY (Score each input 1–5 for each indicator based on Table 3. Data Quality Pedigree Matrix)	RESPONSE THAT WOULD INDICATE LOWER GHG EMISSIONS
Electricity Source	Are the micromobility vehicles charged with renewable electricity?	Qualitative (electricity source)	The micromobility vehicles are charged with 100% renewable energy obtained through direct utility contracts			Yes
Utilization Rate	How intensively are the micromobility vehicles used?	Hours or miles (or kilometers) used per represen-tative time period	A citywide average of 4 hours per vehicle per day between October 2020–October 2021			Higher utilization
	Are there any external factors that would decrease the utilization rate?	Qualitative	A COVID-19 lockdown during the relevant time period or requirements to deploy micromobility vehicles an in a designated “equity area” that may result in lower utilization rates or greater need for rebalancing			N/A. This question was included to give operators the opportunity to explain utilization rates that may be lower than their typical rates or than other operators’.
End-of-life Practices	What happens to the batteries at the end of their usable life in the micromobility vehicle?	Qualitative	Batteries are shipped back to the battery supplier for recycling			Responsible recycling practices that prioritize reuse when possible
	What happens to the rest of the vehicle or other components when they reach the end of their usable life?	Qualitative	Any unusable parts are disposed of or recycled in compliance with local hazardous waste laws. Other usable parts are reused in our vehicles where possible and otherwise recycled by a third-party vendor.			

This scorecard is available for download as an editable spreadsheet from https://www.numo.global/resources/micromobility-emissions-life-cycle-assessment-guide/

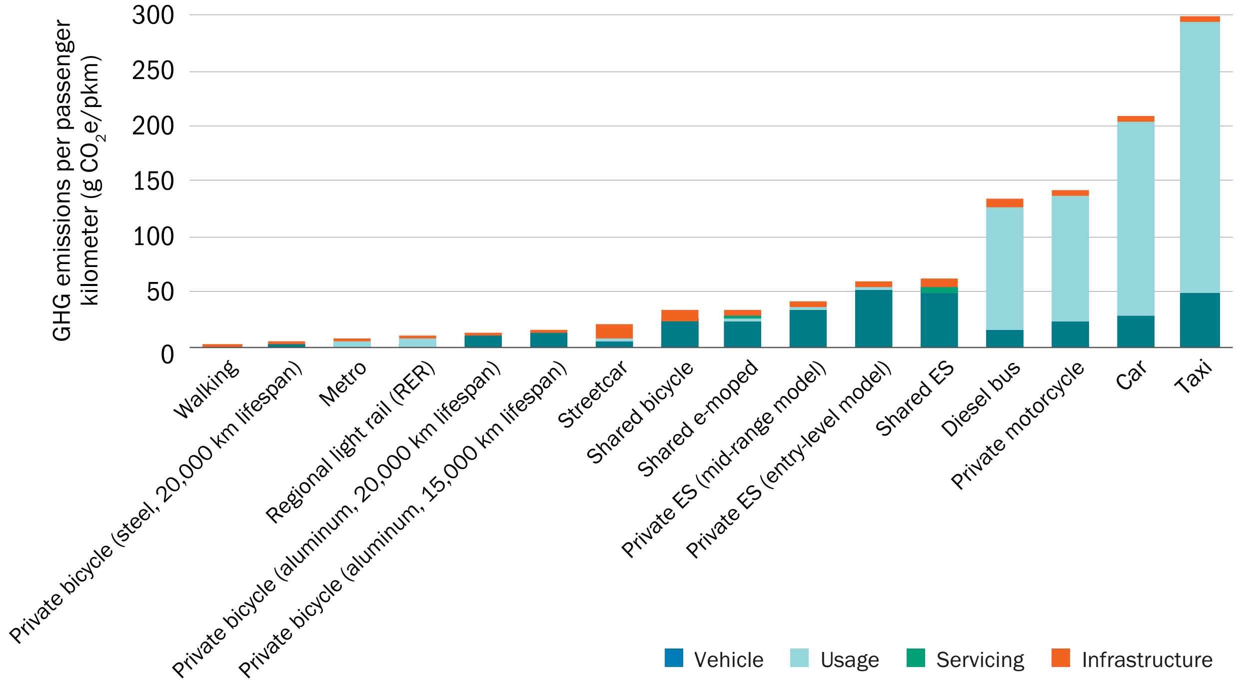
Use Case 2: Compare Micromobility to Other Transportation Modes

Example: A city plans to allocate funds to subsidize the use of low-emissions modes for low-income residents. The city is deciding how to allocate the funds among various programs and transportation modes, such as shared e-scooters, an e-bike subsidy program, and free bus passes. The city wants to use GHG emissions as a criterion for making that decision, alongside criteria related to equity and accessibility. First, though, the city needs to know how GHG emissions from e-scooter trips compare to emissions from trips using other modes.

Cities may seek more information about emissions from micromobility to better understand the relative emissions of their existing transportation modes. This understanding could inform decisions about which modes to support or prioritize using policies, regulations, or infrastructure investments. Additionally, this information could help to build support for micromobility programs (such as securing public subsidies) and enable cities to track changes in the relative impacts of different modes, given the rapid rate of change in micromobility vehicle models and other electric vehicles.

For this use case, the city needs the results from an LCA, specifically the average GHG emissions per passenger-mile for micromobility modes (as described in Use Case 1: Compare Micromobility Operators). It is not necessary to distinguish among the emissions of different micromobility operators for the same mode; a city average emissions per e-scooter passenger-mile or e-bike passenger-mile would suffice. The city would also need to know the GHG emissions per passenger-mile for every other mode in the city. Examples of such analyses are below. These examples refer to a range of locations and time periods and are intended to serve as examples of how to structure the results of an analysis that compares micromobility to other modes in a particular city. They also do not necessarily reflect up-to-date relative emissions of modes in any given city.

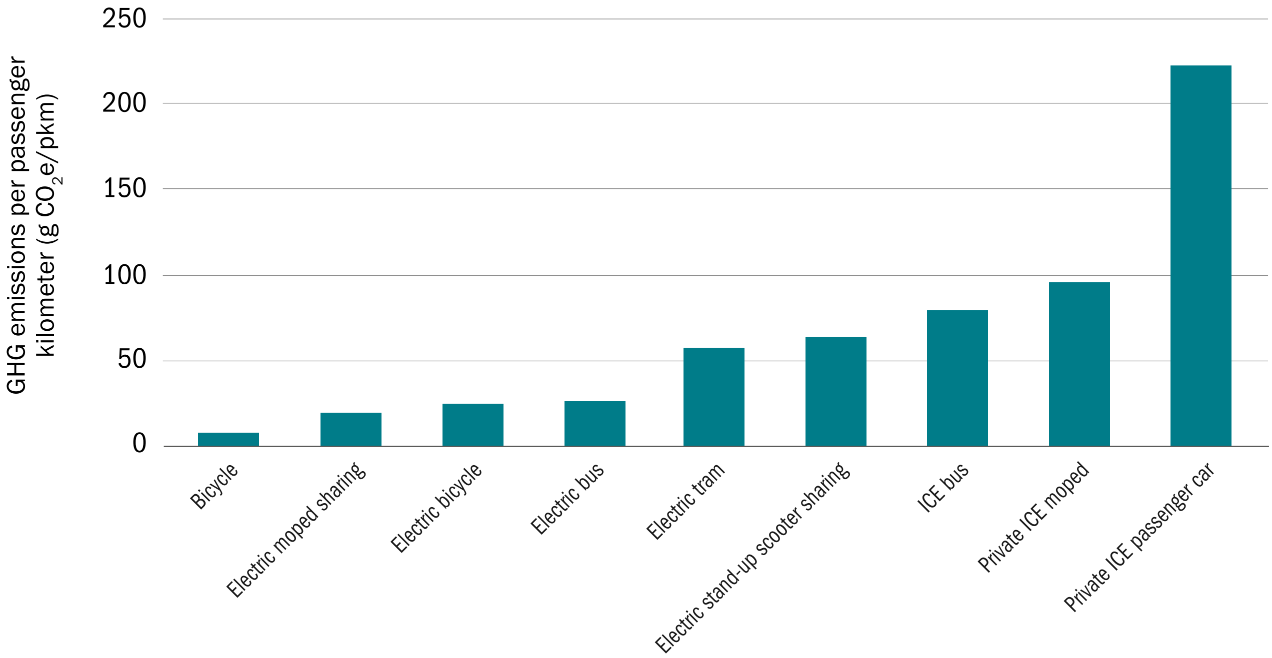
Figure 5: Example 1, Life Cycle CO_2e Emissions per Passenger-Kilometer of Various Shared or Urban Transport Modes in Paris, France



Note: ES stands for electric scooter.

Source: de Bortoli 2021.

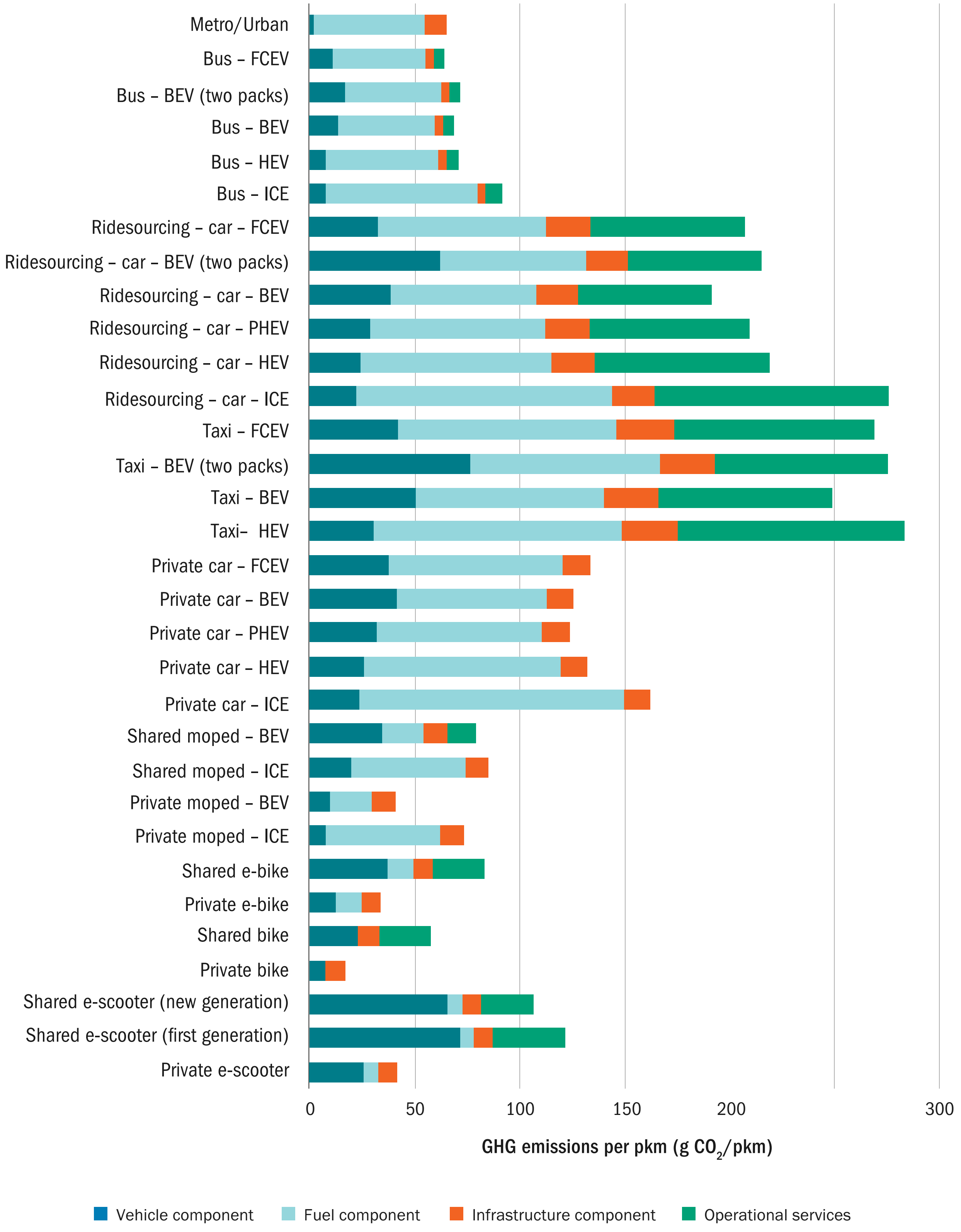
Figure 6: Example 2, Life Cycle CO_2e Emissions per Passenger-Kilometer of Various Shared or Urban Transport Modes of Various Shared or Urban Transport Modes



Notes: Data for private bicycles, e-bikes, and mopeds with internal combustion engines (ICE) are based on Weiss et al. (2015). ICE bus, tram, and private car data are based on Allekotte et al. (2020). Electric bus data are based on Helmers, Dietz, and Weiss (2020). Data for shared stand-up e-scooters are based on Severengiz et al. (2020).

Source: Schelte et al. 2021.

Figure 7: Example 3, Life Cycle CO_2e Emissions per Passenger Kilometer of Various Shared or Urban Transport Modes



Notes: BEV = battery electric vehicle; HEV = hybrid electric vehicle; ICE = internal combustion engine; FCEV = fuel cell electric vehicle; PHEV = plug-in hybrid electric vehicle. These estimates have been developed using key inputs (such as average number of passengers, the electricity mix, and the ratio of operational kilometers per active kilometers) defined by global averages (see Annex A of Cazzola and Crist (2020) for further details and source used) observed prior to the COVID-19 pandemic. Specific circumstances occurring in different geographic regions, changes in operational practices, and the COVID-19 pandemic should, therefore, be modeled as individual cases, modifying input data accordingly. Sensitivity results are presented in Cazzola and Crist (2020).

Source: Cazzola and Crist 2020.

Table 5: Example 4, Life Cycle CO_2e Emissions per Passenger Kilometer of Various Shared or Urban Transport Modes in Portland, Oregon, USA

MODE	FUEL	TYPE	LIFE CYCLE EMISSIONS ($g\ CO_2e/mi$)
Walk	None	N/A	0
Bicycle	None	Personal	8 (Weiss et al. 2015)
Bicycle	None	Shared (docked)	105 (Lou et al. 2019)
Bicycle	None	Shared (dockless)	190 (Lou et al. 2019)
E-bike	BEV	Personal	40 (Weiss et al. 2015)
E-bike	BEV	Shared (docked)	
E-bike	BEV	Shared (dockless)	
Electric scooter	BEV	Shared (dockless)	172[i]
Transit	Diesel	Bus (peak)	83 (Chester and Horvath 2009)
Transit	Diesel	Bus (off-peak)	664 (Chester and Horvath 2009)
Transit	BEV	Bus	
Transit	BEV	Light rail	68 (Chester and Horvath 2009)
Transit	BEV	Commuter rail	166 (APTA 2018)
Private for-hire vehicle (e.g., ride-hailing, taxi)	ICE	Non-pooled	683 (UCS 2020)
Private for-hire vehicle (e.g., ride-hailing, taxi)	ICE	Pooled	456 (UCS 2020)
Vehicle	ICE	Personal	457 (Argonne National Laboratory 2016)
Vehicle	Hybrid	Personal	343 (Argonne National Laboratory 2016)
Vehicle	PHEV	Personal	331 (Argonne National Laboratory 2016)[ii]
Vehicle	BEV	Personal	319 (Argonne National Laboratory 2016)[iii]

[i] Weighted average from company-provided LCAs of two scooter companies operating in Portland, Oregon, USA
[ii] Average of PHEV10 and PHEV35
[iii] Average of BEV90 and BEV210

Source: Portland Bureau of Transportation 2020.

Some cities may decide they need information specific to their city, while others may determine that existing, available data from similar cities are sufficient. The most important characteristics to consider when identifying similar cities include population density, mobility patterns/mode share, road design/conditions (e.g., cobbled streets versus cycle paths), and weather. To obtain this information, cities can:

- Request that information from micromobility operators, which may have the data from an LCA conducted for a similar city
- Consult published literature on micromobility emissions. Table 6 includes GHG emissions per passenger-kilometer from reputable research published as of July 2022. These analyses used a range of different sources, methods, geographic scopes, and study years, leading to significant variation in results. Cities can use these data to identify values from a city like theirs or to contextualize LCA results they may receive.

Table 6: Compiled Results of LCAs of Micromobility Vehicles

			GREENHOUSE GAS EMISSIONS (g CO_2e/passenger-kilometer (pkm), unless otherwise noted)			
AUTHORS	**YEAR**	**PLACE**	**SHARED E-SCOOTER**	**SHARED E-BIKE (BSEB)**	**SHARED MANUAL BIKE**	**SHARED E-MOPED (SSEB)**
Bird	2022	USA and Europe	57–120 (depending on e-scooter model)			
Lime	2022	Europe	19.7; 25.5; 22.6 (depending on city)	49.4; 64.9 (depending on city)		
Lyft	2022	USA		E-bike 1.0: 47.8	18.8	
Spin	2021	USA	38			
Lyft	2021	USA	Base case: 50.1 Stretch case (best-case scenario): 34.8 Stress case (worst-case scenario): 280.3			
TIER, Hochschule Bochum	2021	Europe	42.8–46.7 (depending on operational scenario)			
Schelte, Nora; Severengiz, Semih; Schünemann, Jaron; Finke, Sebastian, Bauer, Oskar; Metzen, Matthias	2021	Germany				Base Case: 51 Green Scenario (best case): 20 Short lifetime (worst case): 58
Deutsche Energie-Agentur GmbH (dena) with Schelte, Nora, and Severengiz, Semih	2021	Germany	Scenario 2019: 197 Scenario 2020: 130 Scenario 2021+: 63 61			
de Bortoli, Anne	2020	Paris, France	61		32.9	34
Browne, Kerry; Kaji, Daisuke; Kaplan, Hank; Luo, Jun; Tanikura, Makoto	2020	Santa Monica, California, USA	93.8 g CO_2/pkm			
Severengiz, Semih; Finke, Sebastian; Schelte, Nora; Wendt, Norman	2020	Berlin, Germany	Base Case: 77.4 Green scenario (best case): 64 Short lifetime scenario (worst case): 237			
Voi; EY	2020	Paris, France	34.7			
ITF	2020	Global average	107	84	48	80
de Bortoli, Anne; Christoforou, Zoi	2019	Paris, France	109		59	28
Hollingsworth, Joseph; Copeland, Brenna; Johnson, Jeremiah X.	2019	USA	125 (87.6 in best-case scenario)			

Table 6: Compiled Results of LCAs of Micromobility Vehicles (cont.)

			GREENHOUSE GAS EMISSIONS (g CO_2e/passenger-kilometer (pkm), unless otherwise noted)			
AUTHORS	YEAR	PLACE	SHARED E-SCOOTER	SHARED E-BIKE (BSEB)	SHARED MANUAL BIKE	SHARED E-MOPED (SSEB)
Kazmaier, Markus; Taefi, Tessa T.; Hettesheimer, Tim	2019	Germany	165 (46 in best-case scenario)			
Moreau, Hélie; de Jamblinne de Meux, Loïc; Zeller, Vanessa; D'Ans, Pierre; Ruwet, Coline; Achten, Wouter M. J.	2019	Brussels, Belgium	131			
McQueen, Michael; MacArthur, John; Cherry, Christopher	2019	Portland, Oregon, USA		3		
Portland Bureau of Transportation	2019	Portland, Oregon, USA	107			
Luo, Hao; Kou, Zhaoyu; Zhao, Fu; Cai, Hua	2018	10 US cities			65 (station-based), 118 (dockless)	
Liu, Wei; Sang, Jing; Chen, Lujun; Tian, Jinping; Zhang, Huatang; Palma, Grecia Olvera	2015	China		338 kg CO_2e (for battery only)		
Cherry, Christopher R.; Weinert, Jonathan X.; Xinmiao, Yang	2008	China		15.6 to 31.2 g CO_2/pkm		
Cherry, Christopher	2007	China		22 g CO_2/pkm	4 g CO_2/pkm	30.44 g CO_2/pkm

Note: To enable comparison, results published per passenger-mile were converted to passenger-kilometer. "Year" refers to the year that the data were collected, not the year that the study was published, to enable analysis of changes in emissions over time.

Source: As listed in table.

Cities may wish to use emissions factors that incorporate the emissions from the additional energy expenditure required to travel by walking and cycling, based on emissions per calorie, as well as the emissions associated with the infrastructure that supports the use of those modes, like sidewalks (pavements) and bicycle lanes (Mizdrak et al. 2020). In addition to the above charts and tables, sources for data on emissions from other modes include state or local departments of transportation; public agencies like Argonne National Laboratory, California Air Resources Board (CARB), or International Transport Forum (ITF); non-profit organizations like the American Public Transportation Association (APTA) or Union of Concerned Scientists; and academic studies. ITF published an Excel-based interactive tool to compare life cycle GHG emissions from several kinds of micromobility vehicles and other modes (Cazzola and Crist 2020).

Use Case 3: Estimate the Net GHG Emissions Impact of Micromobility

Example: A city is deciding whether to allow e-scooters to operate on its streets. The city wants to know whether micromobility is likely to cause net GHG emissions to increase or decrease.

Example: A city is considering how to prioritize micromobility to prioritize micromobility in their policymaking, transportation planning, and allocation of incentives for transportation modes. The city wants to use the net GHG emission impact of micromobility as one factor in determining prioritization, alongside other considerations like accessibility and air quality.

To assess the real-world impact of micromobility on a city's GHG emissions, cities need to understand how micromobility interacts with their wider transportation landscapes. Most importantly, they must know what modes micromobility trips replace. If a micromobility trip replaces a trip that would have otherwise been taken by walking, private bicycle, or shared (non-motorized) bicycle—or creates a trip when one would not originally have been taken—the net impact of that micromobility trip is likely a net increase in emissions as compared to a baseline scenario in which micromobility is not available. Conversely, if a micromobility trip (or trip segment) replaces a trip that would have otherwise been taken using a private car, ride-hailing vehicle, or a diesel bus, then that shift represents a net decrease in emissions (Bortoli and Christoforou 2020; Hollingsworth et al. 2019; Bortoli 2021; Krauss et al. 2022).

This framing, however, only focuses on a per-trip basis. There is a broader story about how micromobility trips interact with other modes and goals outside of sustainability, such as accessibility and equity. For example, micromobility can provide a first- and last-mile connection to public transit, sometimes replacing a long walk or a trip by private bicycle (which compels someone to return home via the same transit station), car, or taxi. If the availability of micromobility makes public transit more accessible or convenient, then residents may not feel compelled to buy private cars; they may even consider giving up existing cars. This wider impact would not be captured in a user survey focused on single trip replacements, in which a first- or last-mile trip might be shown as replacing walking and thus increasing emissions. This dynamic would be better captured in surveys and studies focused on longer-term mode shift and travel decision-making.

The following section describes the input data needed to estimate the net emissions impact of micromobility on a per-trip basis. It is based on "shifted trips" that would otherwise have been taken by other modes (or not at all) but instead were taken using micromobility. Shifted trips can be expressed as the percentage of micromobility trips that would otherwise have been taken by car, walking, etc. We then offer two methods of analyzing that data. Option 1 is a consequential LCA, a variation on the more widely used "attributional" LCA described in the first use case. **Consequential LCAs estimate the environmental impact of a product as compared to a scenario in which that product does not exist.** Option 2 is a simpler, less resource-intensive way of calculating the change in emissions based on the share of trips shifted from other modes to micromobility. The section also includes a case study of how Portland, Oregon, made use of the method outlined in Option 2, as well as additional resources for estimating the net GHG impacts of micromobility.

INPUT DATA FOR ESTIMATING THE NET GHG EMISSIONS IMPACT OF MICROMOBILITY

For this use case, the most important input is what mode micromobility trips typically replace. The best source for this is a recent user survey from that city. If a user survey is unavailable, or if it is not possible to conduct one, the next best source is the results of a user survey in a city with similar characteristics in terms of population density, mobility patterns, road conditions, and weather. Alternatively, cities can use an average of results of surveys from similar cities.

Peer-reviewed and gray literature on mode shift due to micromobility is growing rapidly. Table 7 and Table 8 compile survey results from over 35 cities. They can be read as: In Los Angeles, California, USA, 11 percent of e-scooter trips would have otherwise been made by "driving alone," 22 percent of e-scooter trips would otherwise have been made by "taxi or TNC," and so on. Another source is the Micromobility Survey Library (U.S. cities only) (Wen and Cherry 2022). Other sources and relevant research include Astegiano, Fermi, and Martino (2019); McQueen, MacArthur, and Cherry (2020); Sun et al. (2020); and Winslott, Hiselius, and Svensson (2017).

Table 7: Modes Replaced by Shared E-Scooter Trips

	DISAGGREGATED RESULTS					AGGREGATED RESULTS	
STUDY AREA	DRIVING ALONE	TAXI OR TNC	PUBLIC TRANSPORT	WALKING	OTHER MICROMOBILITY	DRIVING ALONE AND TAXI OR TNC	PUBLIC TRANSPORT, WALKING, AND OTHER MICROMOBILITY
North America							
Tempe, Arizona (Arizona State University campus)		25%		57%	8%	25%	65%
Tucson, Arizona	24%	14%	3%	36%	8%	38%	47%
Los Angeles, California	11%	22%	9%	48%	5%	33%	62%
Oakland, California	14%	25%	9%	42%	12%	39%	63%
San Francisco, California (Lime 2018)	9%	51%	34%	61%	20%	60%	115%
San Francisco, California (SFMTA 2019)	5%	36%	11%	31%	9%	41%	51%
Denver, Colorado	10%	22%	7%	43%	14%	32%	64%

Table 7: Modes Replaced by Shared E-Scooter Trips (cont.)

	DISAGGREGATED RESULTS					AGGREGATED RESULTS	
STUDY AREA	**DRIV-ING ALONE**	**TAXI OR TNC**	**PUBLIC TRANS-PORT**	**WALK-ING**	**OTHER MICRO-MOBIL-ITY**	**DRIVING ALONE AND TAXI OR TNC**	**PUBLIC TRANSPORT, WALKING, AND OTHER MICROMO-BILITY**
North America							
Santa Monica, California		49%	4%	39%	7%	49%	50%
Denver, Colorado	10%	22%	7%	43%	14%	32%	64%
Tampa, Florida	21%	27%	1%	38%	6%	48%	45%
Atlanta, Georgia		42%	2%	48%	4%	42%	54%
Bloomington, Indiana	25%	16%	7%	54%		41%	61%
Chicago, Illinois	11%	32%	14%	30%	8%	43%	52%
St. Louis Park, Minnesota	34%	37%		5%	8%	71%	13%
Hoboken, New Jersey	11%	37%	13%	51%	13%	48%	77%
Raleigh, North Carolina		34%	11%		49%	34%	60%
Portland, Oregon (2018)	19%	15%	10%	37%	5%	34%	52%
Portland, Oregon (2019)	19%	23%	11%	39%	8%	42%	58%
Portland, Oregon (2020)	14%	23%	10%	41%	5%	37%	56%
Alexandria, Virginia	46%	41%	18%	50%	13%	87%	81%
Arlington County, Virginia	13%	19%	5%	37%	4%	32%	46%
Arlington County, Virginia (Rosslyn area)	7%	39%	7%	33%	12%	46%	52%
Blacksburg, Virginia (Virginia Tech campus)		6%	7%	77%		6%	84%
Milwaukee, Wisconsin	23%	22%	7%	40%	7%	45%	54%
Calgary, Canada	21%	12%	6%	56%	5%	33%	67%
Toronto, Canada		44%	53%	57%	36%	44%	146%
Europe							
Paris, France (May–June 2019)	4%	6%	37%	35%	7%	10%	79%
Paris, France (September–October 2019)	5%	8%	36%	37%	12%	13%	85%
Paris, Lyon, Marseille, France (April 2019)	3%	6%	30%	44%	12%	9%	86%
Munich, Germany		24%	59%	80%	59%	24%	198%
Thessaloniki, Greece		17%	33%	44%	7%	17%	84%
Oslo, Norway	3%	5%	23%	60%	6%	8%	89%
Zurich, Switzerland		10%	24%	52%	14%	10%	90%
New Zealand							
Auckland, New Zealand		21%	7%	53%	6%	21%	66%
Christchurch, New Zealand	14%	9%	5%	52%	6%	23%	63%

Note: Not all modes were included in all surveys. Due to survey methods of the data sources, some rows sum to more or less than 100 percent. See Wang et al. (2022) for original data sources with methodological information.

Source: Wang et al. 2022.

Table 8: Modes Replaced by Shared E-Scooter and Shared E-Bike Trips

	SHARED E-SCOOTERS						SHARED E-BIKES				
	BERLIN	DUSSEL-DORF	MEL-BOURNE	PARIS	SEATTLE	STOCK-HOLM	BERLIN	DUSSEL-DORF	MEL-BOURNE	PARIS	SEATTLE
Walk	50%	49%	49%	40%	64%	42%	28%	29%	30%	25%	49%
Subway or train	19%	21%	16%	30%	1%	24%	33%	29%	22%	31%	2%
Bus or shuttle	7%	5%	6%	5%	9%	15%	6%	4%	8%	7%	10%
Taxi or ridehailing	4%	6%	12%	9%	11%	8%	6%	11%	14%	11%	12%
Personal car or truck - gas	2%	5%	5%	1%	7%	2%	1%	9%	5%	1%	6%
Personal car or truck - electric	0.2%	0.0%	0.7%	0.2%	0.5%	0.2%	0.0%	2%	0.0%	0.3%	0.4%
Carshare	2%	0.4%	0.7%	0.5%	0.9%	0.2%	4%	0%	3%	0%	2%
Personal motorcycle or moped - gas	0.2%	0.6%	0%	1.3%	0%	0%	0.6%	0%	0%	0.3%	0%
Personal motorcycle or moped - electric	0.1%	0.2%	0%	0.3%	0%	0%	0%	0%	0%	0.3%	0%
Shared moped	0.9%	0.7%	0%	2%	0.2%	0.0%	1%	0%	0%	3%	0.4%
Personal e-scooter	0.3%	0.4%	0.7%	0.3%	0.0%	0.2%	0.0%	0.0%	0.0%	0.3%	0.4%
Shared e-scooter	n/a	n/a	n/a	n/a	n/a	n/a	8%	2%	5%	15%	7%
Personal bike	4%	4%	3%	1%	1%	3%	10%	7%	5%	2%	3%
Personal e-bike / pedelec	0.2%	0.2%	0.4%	0.6%	0.0%	0.7%	0.6%	0%	3%	0.6%	0.4%
Bikeshare	4%	2%	0.4%	5%	1%	1%	n/a	n/a	n/a	n/a	n/a
I would not have made this trip	1%	2%	3%	2%	2%	1%	1%	4%	5%	2%	6%
Other	3%	4%	3%	1%	0.7%	2%	1%	2%	0%	2%	0.4%

Source: Krauss et al. 2022. See source for details on survey methods.

OPTION 1: CONSEQUENTIAL LIFE CYCLE EMISSIONS ASSESSMENT

The LCA method in Use Case 1 is more specifically an "attributional" LCA, meaning that it describes the environmental impacts of material flows to and from a product over its life cycle. Another kind of LCA—a consequential LCA—looks beyond solely focusing on the individual product to determine the environmental impact of the production and use of a product *as compared to a scenario in which that product does not exist*. Conducting a consequential LCA requires estimating the environmental impacts of economic or behavioral changes that may result from the product. For example, if a smart thermostat leads people to use less energy for heating, then a consequential LCA of the thermostat might show net environmental benefits that outweigh the pollution and emissions associated with the direct material life cycle of the thermostat. This method is more complex and resource-intensive than Option 2; therefore, it is best suited to cities with more funding, capacity, or a deeper interest in the topic.

In the case of micromobility, a consequential LCA can account for the environmental impact of changes in users' travel behaviors that result from their having access to micromobility—in other words, an LCA that includes mode shift. Overall, the guidance for a consequential LCA is the same as an attributional LCA (see Option 1: Life cycle emissions assessment) in terms of relevant industry standards, how to select inputs, assessing data quality, etc. The main difference is that consequential LCAs require additional input data regarding mode shift and emissions from the modes that micromobility vehicles replaced. As of October 2022, the only consequential LCA for micromobility vehicles is de Bortoli and Christoforou (2020).

The simpler approach hinges on the concept of "shifted miles," which are miles (or kilometers) traveled using a micromobility vehicle that would otherwise have been traveled using a different mode.

OPTION 2: ESTIMATING EMISSIONS FROM E-SCOOTER SHIFTED TRIPS

Like in Use Case 1: Compare Micromobility Operators to Each Other, net GHG emissions can be estimated with a full LCA or with a simpler but less precise estimate. The simpler approach hinges on the concept of "shifted miles," which are miles (or kilometers) traveled using a micromobility vehicle that would otherwise have been traveled using a different mode. Subtracting emissions associated with "micromobility miles" from emissions that would have been generated by traveling by the modes that micromobility replaced generates an estimate of the net change in emissions as a result of the miles that were shifted to micromobility.

To use this method at the scale of a city, the following inputs are needed:

1. **Emissions per mile (or kilometer) for every mode of interest in CO_2e/mi**
2. **Data from user surveys for a comparable city regarding the modes that micromobility replaced (i.e., 8 percent of micromobility trips replaced buses, 20 percent replaced walking, etc. See Table 9. Reported Modes Replaced by Shared E-Scooter Trips for data sources.)**
3. **Average trip distance of the micromobility mode of interest (i.e., e-scooter, e-bike) from that city or a similar city**
4. **Total number of micromobility trips taken in the city in a given period (i.e., most recent year)**

Most mode shift data is from user surveys; therefore, these data are usually listed on a per-trip basis, not per-mile. In other words, the data state how many micromobility *trips* were shifted from other modes to micromobility, not how many *miles* were shifted from other modes. However, since a large share of transportation emissions accrue incrementally with each mile traveled, estimating the net emissions impact of micromobility requires converting these data from number of trips to number of miles. This conversion can be approximated by multiplying the average micromobility trip distance by the number of trips replaced, and then by the percentage of micromobility trips shifted from each other mode.

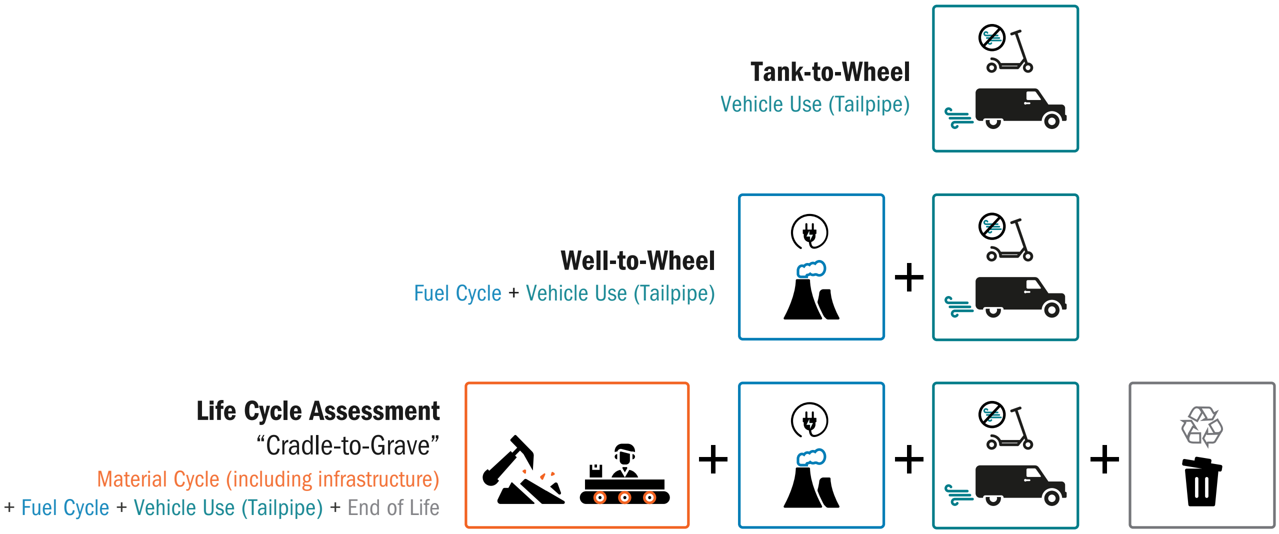
Example: 2 miles average e-scooter trip distance x 1,000 trips x 20% of trips shifted from cars = 400 miles shifted from cars to e-scooters

The above approach uses a single value for average micromobility trip length, which assumes that micromobility trips lengths do not vary in correlation with the mode they replaced; in other words, micromobility trips that replace walking tend to be the same length as micromobility trips that replace cars. In reality, this assumption may be incorrect. Micromobility trips that replace cars or transit may be longer than micromobility trips that replace walking or non-motorized bicycles. If so, the approach illustrated in Table 9 would underestimate the avoided GHG emissions resulting from micromobility.

It may not be possible to obtain life cycle emissions per mile for every mode of interest. In that case, it is essential to at least to ensure that the emissions for different modes cover the same scope of emissions (e.g., all life cycle or all fuel cycle) to allow for direct comparison (see Figure 5. Different Scopes of Transportation Emissions Assessments).

Ideally, the per-mile emissions of each mode would also account for emissions associated with that mode's infrastructure, such as railroad tracks for rail modes, though that data may be harder to find. Table 9. E-Scooter Shifted Trips and Associated Emissions in Portland, Oregon, USA, in 2019 offers an example of this approach, which was conducted by the Portland Bureau of Transportation (PBOT) as part of their assessment of an e-scooter pilot.

Figure 8: Different Scopes of Transportation Emissions Assessments



Source: Krauss et al. 2022. See source for details on survey methods.

Case study: Portland, Oregon, USA

As part of the city of Portland, Oregon's 2019 E-Scooter Pilot Program, e-scooter operators were required to submit LCAs consistent with ISO 14040/14044 Standards, per their permit requirements. This requirement was due to findings from the city's 2018 E-Scooter Pilot, which noted how e-scooters may be a less-polluting travel option but that more data were needed before cities could determine whether e-scooters contribute to a reduction in GHG emissions (Portland Bureau of Transportation 2019a).

PBOT staff analyzed the LCAs and used the findings to estimate a per-mile CO2e emissions factor for e-scooters. Staff paired this e-scooter emissions factor with e-scooter user survey responses regarding mode shift (Portland Bureau of Transportation 2019b) and life cycle emissions associated with other modes to estimate net emissions reductions from the program. PBOT staff determined that the E-Scooter Pilot Program yielded substantial emissions reductions of approximately 91,468,717 g CO2e during the eight-month pilot period in 2019 (see Table 9. E-Scooter Shifted Trips and Associated Emissions). This result helped to build the case for creating a permanent e-scooter program in Portland and informed permanent program design criteria. This is an illustrative example, as results would vary among cities based on rates of car ownership, availability of transit, and other factors.

Table 9: E-Scooter Shifted Trips and Associated Emissions in Portland, Oregon, USA, in 2019

MODE	LIFE CYCLE EMISSIONS PER MILE (g CO_2e/mi)	PERCENTAGE OF MICRO-MOBILITY TRIPS SHIFTED FROM THAT MODE	SHIFTED MILES	BASELINE EMISSIONS (g CO_2e)	SHIFTED EMISSIONS (g CO_2e)	NET CHANGE IN GHG EMISSIONS RESULTING FROM SHIFTING TO E-SCOOTERS (g CO_2e)
Walk	0	38%	392,992	0	67,594,659	67,594,659
Bike	8	7%	69,319	554,556	11,922,947	11,368,391
E-scooter (new trips)	172	6%	56,766	0	9,763,673	9,763,673
Private for-hire vehicle	655	27%	275,640	180,628,513	47,410,143	-133,218,370
Personal vehicle	449	14%	143,005	64,228,168	24,596,945	-39,631,222
Transit	253	9%	90,607	22,930,173	15,584,324	-7,345,848
TOTAL		100%	1,028,330	268,341,409	176,872,692	-91,468,717

SUMMARY	GHG EMISSIONS (g CO_2e)	PERCENT CHANGE
GHG Emissions Avoided by E-Scooter Trips	-180,195,441	
GHG Emissions Added by E-Scooter Trips	88,726,723	
Net Change in GHG Emissions Resulting from Shifting to E-Scooters	**-91,468,717**	**-34%**

Note: These data include only miles traveled during the eight-month 2019 pilot period (April 26–December 31, 2019) and do not necessarily reflect the miles typically traveled during a full year.

Sources: Adapted from Portland Bureau of Transportation (2020).

Another example of this approach is in the North American Bikeshare & Scootershare Association's (NABSA) 2021 Shared Micromobility State of the Industry Report, which estimated the net change in tailpipe emissions of CO_2 based on the share of micromobility trips that replaced car trips (NABSA 2022).

ADDITIONAL RESOURCES FOR ESTIMATING THE NET GHG IMPACTS OF MICROMOBILITY

GUIDES, TOOLS, AND METHODS FOR ESTIMATING THE NET GHG IMPACTS OF MICROMOBILITY

- *Consequential LCA for Territorial and Multimodal Transportation Policies: Method and Application to the Free-Floating E-Scooter Disruption in Paris*, by de Bortoli and Christoforou, presents a methodology for consequential LCAs tailored specifically to micromobility (de Bortoli and Christoforou 2020)

- *The Electric Scooter Survey Question Toolkit* provides guidance on designing surveys for e-scooter users (Wen and Cherry 2022)

- *Estimating and Reporting the Comparative Emissions Impacts of Products* from the GHG Protocol outlines a framework for reporting avoided emissions from products, compared to a baseline scenario in which the product does not exist (i.e., if e-scooters were not available in a city, like in a consequential LCA) (Russell 2019)

- *Guidelines for Assessing the Contribution of Products to Avoided Greenhouse Gas Emissions* from The Institute of Life Cycle Assessment, Japan, provides guidance for comparing avoided emissions between two products (i.e., emissions avoided by switching from first-generation to second-generation e-scooters) (The Institute of Life Cycle Assessment, Japan 2015)

RESOURCES ON MODE SPLIT AND EMISSIONS BY TRANSPORTATION MODE

- Bundesministerium für Digitales und Verkehr. 2017. "Mobilität in Deutschland." https://www.mobilitaet-in-deutschland.de/publikationen2017.html.

- European Commission. 2022. "European Market Surveillance of Motor Vehicles." JRC Publications Repository. March 24, 2022. doi:10.2760/59856.

- Heinrich Böll Stiftung. n.d. "European Mobility Atlas 2021: Facts and Figures about Transport and Mobility in Europe." Heinrich-Böll-Stiftung. https://eu.boell.org/en/European-Mobility-Atlas.

- Umweltbundesamt. 2022. "Emissionsdaten." https://www.umweltbundesamt.de/themen/verkehr-laerm/emissionsdaten.

- U.S. Department of Transportation, Federal Highway Administration. 2017. "National Household Travel Survey." 2017. https://nhts.ornl.gov/.

- U.S. Environmental Protection Agency. 2016. "Estimating Greenhouse Gas Emissions." Data and Tools. April 19, 2016. https://www.epa.gov/state-and-local-transportation/estimating-greenhouse-gas-emissions.

Excluded Use Cases

Other use cases for micromobility emissions data emerged during meetings of the Working Group on Micromobility Life Cycle Emissions Assessments. The following section describes those use cases, provides reasons as to why they were not included in this guide, and notes preliminary guidance on how to approach them.

ESTIMATE THE WIDER LOCAL ENVIRONMENTAL AND SOCIAL IMPACT OF MICROMOBILITY

In addition to GHG emissions, cities may seek to understand the local-level environmental, health, and accessibility impacts of micromobility in their city. Detailed guidance on methods for local health and ecosystem impacts are beyond the scope of this guide; however, LCAs can be a useful resource for this. Most LCAs assess multiple environmental impacts, such as human health or natural resource damage as captured in disability-adjusted life-years per mile (DALY/pkt), ozone depletion, eutrophication, smog, and more (Krauss et al. 2022; de Bortoli 2021). To estimate the impact of micromobility on air pollution *within the city*, a city could request data on emissions of certain air pollutants (depending on the impact categories used) from the use phase, minus electricity-related emissions, which likely occur outside of the city. As discussed in Use Case 3, an attributional LCA estimates *gross* emissions (total emissions associated with micromobility), whereas a consequential LCA estimates net emissions (gross emissions, minus avoided emissions, e.g., from mode shift). Accessibility impacts could be captured through qualitative questions in user surveys about whether users have greater access to jobs and services because of the availability of micromobility services. This is especially important as an equity consideration for low-income users in transit deserts without access to personal modes of transportation.

ESTIMATE THE TOTAL (GROSS) GHG EMISSIONS FROM MICROMOBILITY

Many cities have begun conducting emissions inventories that estimate their total GHG emissions, supported by programs like The Clean Cities ClimAccelerator ("Clean Cities ClimAccelerator" n.d.) and C40 Cities ("C40 Cities" n.d.), as well as standards like the GHG Protocol for Cities (Greenhouse Gas Protocol n.d.). Over 700 cities, states, and regions reported their emissions to CDP, a non-profit global emissions disclosure system, as of August 2022 (CDP 2022). These inventories include all emissions from all sectors, including transportation, meaning that, in theory, city departments of transportation would need to submit data on total (gross) GHG emissions from micromobility.

However, representatives of departments of transportation in several cities reported that these emissions inventories are often a rough estimate, or a "10,000-foot view" (Meeting of Working Group on Micromobility Emissions Assessment 2022). Given the small contribution of micromobility to transportation-sector emissions, it seems unlikely that city departments of transportation will be asked to report gross GHG emissions from micromobility. Therefore, this guide does not include guidance on that topic. In general, the approach would be like that of Use Case 3 but would not account for factors like mode shift that subtract from gross emissions.

REDUCE EMISSIONS FROM MICROMOBILITY

We chose not to include reducing emissions as a standalone use case because the underlying goal of all other use cases was understood to be reducing emissions from micromobility or leveraging micromobility to reduce transportation-related emissions.

WHAT'S **NEXT**

This guide focuses on how to assess emissions from micromobility, but it does not discuss why it is important to do so. The introduction notes that assessing GHG emissions from micromobility is a contentious subject. Some of that contention is not regarding technical methods, but rather the very need for those emissions assessments.

Some stakeholders perceive a mismatch between the scale of micromobility emissions, which often amount to a small fraction of transportation-related emissions in a city, and the amount of effort dedicated to assessing their environmental and other impacts, as compared to other higher-emitting modes. For example, transit buses owned by private operators make up a larger share of transportation-related emissions than micromobility, but the private operators that often own those buses are less frequently asked to describe plans for procuring renewable electricity or promoting equity.

This guide avoids the question of whether such scrutiny is fair, but a more productive question is how it can be useful. Emerging thinking about how to estimate emissions from micromobility may pave the way for how cities think about transportation-related emissions in an increasingly electric and multimodal future. The newness of micromobility has prompted attention through through the lens of sustainable, equitable mobility, an effort likely heightened by many cities' challenging experiences with the advent of ride-hailing. As the first and only fully electric (or sometimes people-powered) mode in cities, micromobility may compel city departments of transportation to grapple for the first time with how to understand and reduce GHG emissions from modes for which most emissions occur outside the city but are the direct result of transportation usage inside the city.

Simultaneously, as more vehicles become electric, city departments of transportation are developing frameworks, capacity, and reporting systems around micromobility. Hopefully, this effort will lay the groundwork for a robust approach to assessing the environmental impact of electric mobility of all kinds.

This may also be many cities' entry-point into consumption-based emissions accounting. Traditional production-based emissions accounting includes only GHGs emitted within the boundaries of a city. Consumption-based emissions accounting includes GHGs emitted within a city as well as emissions embedded in all products and services a city consumes (C40 Cities 2018). A consumption-based emissions inventory for a city is conceptually similar to a consequential LCA for an entire city.

A shift toward consumption-based emissions accounting is critical for equitable, ambitious climate action. Globally, 22 percent of CO_2 emissions are from imports, but those emissions are only attributed to the country of origin, not the importing country (Peters, Davis, and Andrew 2012). In other words, richer countries are not held accountable for the emissions they create abroad, meaning that consumption-based emissions reductions may be more in line with a just transition. For example, in Spring 2022, Sweden set the world's first national consumption-based emissions target, and their consumption-based emissions inventory was almost three times higher than their production-based inventory (Darby 2022; Global Utmaning 2022). While there is a long road from asking micromobility operators for LCAs to achieving consumption-based emissions reductions targets, the growing interest in life cycle- and consumption-based emissions may both herald and support that shift.

Similarly, shifting from private cars as the predominant mode of travel in cities will require a range of modes and a larger share of multimodal journeys, such as commutes that involve riding a bike to a transit station and then a train ride to work. Currently, there is significant room for further development and dissemination of approaches to track, analyze, and promote multimodal trips. As discussed in Use Case 3: Estimate the Net GHG Emissions Impact of Micromobility, for example, many e-scooter user surveys are not designed to capture multimodal trips. As a result, a first- or last-mile trip to a transit stop that replaces a walking trip would be considered to increase emissions, even if that trip makes transit more accessible or convenient and, therefore, may encourage the user to not use a car or forego car ownership entirely. Cities' interest in the net emissions impact of micromobility—including mode shift, as demonstrated in NABSA's 2021 Shared Micromobility State of the Industry Report (NABSA 2022) and Portland's 2019 E-Scooter Findings Report (Portland Bureau of Transportation 2019a)—indicates a major step toward developing capacity and systems to track, analyze, and promote multimodal mobility.

References

Allekotte, M., F. Bergk, K. Biemann, C. Deregowski, W. Knörr, H. Althaus, D. Sutter, and T. Bergmann. 2020. "Ökologische Bewertung von Verkehrsarten. Abschlussbericht." 237. https://repository.difu.de/jspui/handle/difu/577743.

American Public Transportation Association (APTA). 2018. "Quantifying Greenhouse Gas Emissions from Transit." https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-SUDS-CC-RP-001-09_Rev-1.pdf.

Argonne National Laboratory. 2016. "Cradle-to-Grave Lifecycle Analysis of US Light-Duty Vehicle-Fuel Pathways: A Greenhouse Gas Emissions and Economic Assessment of Current (2015) and Future (2025-2030) Technologies. https://greet.es.anl.gov/publication-c2g-2016-report.

Astegiano, P., F. Fermi, and A. Martino. 2019. "Investigating the Impact of E-Bikes on Modal Share and Greenhouse Emissions: A System Dynamic Approach." Transportation Research Procedia, 21st EURO Working Group on Transportation Meeting, EWGT 2018, 17–19 September 2018, Braunschweig, Germany, 37 (January): 163–70. doi:10.1016/j.trpro.2018.12.179.

Bamber, N., I. Turner, V. Arulnathan, Y. Li, S. Zargar Ershadi, A. Smart, and N. Pelletier. 2020. "Comparing Sources and Analysis of Uncertainty in Consequential and Attributional Life Cycle Assessment: Review of Current Practice and Recommendations." The International Journal of Life Cycle Assessment 25 (1): 168–80. doi:10.1007/s11367-019-01663-1.

Bjørn, A., S.M. Lloyd, M. Brander, and H.D. Matthews. 2022. "Renewable Energy Certificates Threaten the Integrity of Corporate Science-Based Targets." Nature Climate Change 12 (6): 539–46. doi:10.1038/s41558-022-01379-5.

de Bortoli, A. 2021. "Environmental Performance of Shared Micromobility and Personal Alternatives Using Integrated Modal LCA." Transportation Research Part D: Transport and Environment 93 (April): 102743. doi:10.1016/j.trd.2021.102743.

de Bortoli, A., and Z. Christoforou. 2020. "Consequential LCA for Territorial and Multimodal Transportation Policies: Method and Application to the Free-Floating e-Scooter Disruption in Paris." Journal of Cleaner Production 273 (November): 122898. doi:10.1016/j.jclepro.2020.122898.

Bird. 2022. "Bird Rides, Inc. Life Cycle Assessment of Transportation Using Bird's Electric Scooters Executive Summary." https://www.bird.co/wp-content/uploads/2022/10/Bird-LCA-Report-10-03-2022-Executive-Summary.pdf.

Brander, M. 2012. "Greenhouse Gases, CO_2, CO_2e, and Carbon: What Do All These Terms Mean?." https://ecometrica.com/assets/GHGs-CO2-CO2e-and-Carbon-What-Do-These-Mean-v2.1.pdf.

Brander, M., M. Gillenwater, and F. Ascui. 2018. "Creative Accounting: A Critical Perspective on the Market-Based Method for Reporting Purchased Electricity (Scope 2) Emissions." Energy Policy 112 (January): 29–33. doi:10.1016/j.enpol.2017.09.051.

C40 Cities. 2018. "Consumption-Based GHG Emissions of C40 Cities." https://www.c40knowledgehub.org/s/article/Consumption-based-GHG-emissions-of-C40-cities?language=en_US.

"C40 Cities." n.d. Accessed August 12, 2022. https://www.c40.org/.

California Public Utilities Commission. n.d. "Transportation Network Companies." Accessed January 4, 2023. https://www.cpuc.ca.gov/regulatory-services/licensing/transportation-licensing-and-analysis-branch/transportation-network-companies.

Cazzola, P., and P. Crist. 2020. "Good to Go? Assessing the Environmental Performance of New Mobility," September. https://trid.trb.org/view/1741964.

CDP. 2022. "Open Data Portal." 2022. https://data.cdp.net/.

Chester, M. and A. Horvath. 2009. "Environmental Assessment of Passenger Transportation Should Include Infrastructure and Supply Chains." http://www.transportationlca.org/tlcadb-passenger.php#chester-and-horvath-2009.

Ciroth, A., S. Muller, and B.P. Weidema. 2012. "Refining the Pedigree Matrix Approach in Ecoinvent." Greendelta, Berlin.

"Clean Cities ClimAccelerator." n.d. Clean Cities Network. Accessed August 10, 2022. https://www.cleancities.network/about.

Climate Change Committee. 2020. "Corporate Procurement of Renewable Energy: Implications and Considerations." London. https://www.theccc.org.uk/wp-content/uploads/2020/12/Corporate-Procurement-of-Renewable-Energy-Implications-and-Considerations-Terri-Wills.pdf.

European Standards. 2019. "CSN EN 15804+A2 Core Rules for the Product Category of Construction Products." https://www.en-standard.eu/csn-en-15804-a2-sustainability-of-construction-works-environmental-product-declarations-core-rules-for-the-product-category-of-construction-products/.

Darby, M. 2022. "Sweden Set to Be World's First Country to Target Consumption-Based Emission Cuts." Climate Home News. April 8, 2022. https://www.climatechangenews.com/2022/04/08/sweden-set-to-be-worlds-first-country-to-target-consumption-based-emission-cuts/.

"Ecoinvent." n.d. Accessed September 28, 2022. https://ecoinvent.org/.

EPA. 2016. "Guidance on Data Quality Assessment for Life Cycle Inventory Data." Washington, DC. https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NRMRL&dirEntryId=321834.

EPD International. n.d. "The PCR." Accessed September 28, 2022. https://www.environdec.com/product-category-rules-pcr/the-pcr.

Feldman, H., and B. Bunte. 2022. "Life Cycle Assessment of Generation 4.0 Lime e-Bikes and e-Scooters." https://cdn.li.me/content/uploads/placeholder/RESULTS-Lime_Gen4_eBike_eScooter_Paris_LCA_Results_v4.1_web.pptx.pdf.

Gautam Naik. 2021. "Problematic Corporate Purchases of Clean Energy Credits Threaten Net Zero Goals." S&P Global, May 5, 2021. https://www.spglobal.com/esg/insights/problematic-corporate-purchases-of-clean-energy-credits-threaten-net-zero-goals.

Global Utmaning. 2022. "Towards Net Zero: Reducing Consumption-Based Emissions!" https://globalutmaning.se/wp-content/uploads/2022/04/Towards-Net-Zero_Reducing-consumption-based-emissions_Global-Utmaning_20220306sg.pdf.

Greenhouse Gas Protocol. n.d. "GHG Protocol for Cities." Accessed August 12, 2022. https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities.

Helmers, E., J. Dietz, and M. Weiss. 2020. "Sensitivity Analysis in the Life-Cycle Assessment of Electric vs. Combustion Engine Cars under Approximate Real-World Conditions." Sustainability 12 (3): 1241. doi:10.3390/su12031241.

"Industry Data LCA Library." n.d. SimaPro. Accessed August 26, 2022. https://simapro.com/databases/industry-data-lca-library/.

International Transport Forum. 2020. "Safe Micromobility." Text. https://www.itf-oecd.org/safe-micromobility.

International Standards Organization. 2017. "ISO 21930:2017." August 11, 2017. https://www.iso.org/standard/61694.html.

Krauss, K., C. Doll, F. Isi, and C. Thigpen. 2022. "The Net Sustainability Impact of Shared Micromobility in Six Global Cities".

Lou, H., Kou, Z., Zhao, F., and H. Cai. 2019. "Comparative Life Cycle Assessment of Station-Based and Dock-Less Bike Sharing Systems." https://www.sciencedirect.com/science/article/abs/pii/S092134491930109.

Lyft. 2021. "Lyft, Inc. Transit, Bikes & Scooters Life Cycle Assessment Report in Conformance with ISO 14044 and ISO 14040." https://assets.ctfassets.net/q8mvene1wzq4/6Yxdymme9liYsJ8tsG5Sm2/147a2ab8423a22cb2c70e545a134f4b4/LCA_Report_-_Lyft_Scooter_2.2_Final_Public.pdf

Lyft. 2022. "Lyft, Inc. Transit, Bikes & Scooters Life Cycle Assessment Report in Conformance with ISO 14044 and ISO 14040 Lyft Classic, Ebike 1.0, and Ebike 2.0 Bicycles." https://assets.ctfassets.net/q8mvene1wzq4/plEcP7GDvLdzRyerIPzy3/e28a0f11956696de62764adc1aed7e55/Classic__Watson__and__Cosmo_Bike_LCIA_Report_FINAL.pdf.

McQueen, M., J. MacArthur, and C. Cherry. 2020. "The E-Bike Potential: Estimating Regional E-Bike Impacts on Greenhouse Gas Emissions." Transportation Research Part D: Transport and Environment 87: 102482.

Meetings of the Working Group on Micromobility Life Cycle Emissions Assessment. 2022. New Urban Mobility alliance (NUMO).

Mizdrak, A., L.J. Cobiac, C.L. Cleghorn, A. Woodward, and T. Blakely. 2020. "Fuelling Walking and Cycling: Human Powered Locomotion Is Associated with Non-Negligible Greenhouse Gas Emissions." Scientific Reports 10 (1): 9196. doi:10.1038/s41598-020-66170-y.

"Mottu." n.d. Mottu. Accessed September 28, 2022. https://mottu.com.br/.

NABSA. 2022. "2021 Shared Micromobility State of the Industry Report for North America." https://nabsa.net/about/industry/.

"OpenLCA Nexus." n.d. Accessed August 26, 2022. https://nexus.openlca.org/databases.

Peters, G.P., S.J. Davis, and R. Andrew. 2012. "A Synthesis of Carbon in International Trade." Biogeosciences 9 (8): 3247–76. doi:10.5194/bg-9-3247-2012.

Portland Bureau of Transportation. 2019a. "2019 E-Scooter Findings Report." https://www.portland.gov/transportation/escooterpdx/2019-e-scooter-report-and-next-steps.

Portland Bureau of Transportation. 2019b. "Appendix C: Summer 2019 E-Scooter User Survey Findings." https://www.portland.gov/sites/default/files/2020-09/appendix-c-summer-2019-e-scooter-user-survey-findings.pdf.

Portland Bureau of Transportation. 2020. "Climate Impacts of Electric Scooters."

RECS international. 2023. “Public Information.” https://recs.org/public-information/#EAC%20market%20in%20Europe%20and%20the%20EECS%20standard.

Russell, S. 2019. “Estimating and Reporting the Comparative Emissions Impacts of Products.” https://www.wri.org/research/estimating-and-reporting-comparative-emissions-impacts-products.

Schelte, N., S. Severengiz, J. Schünemann, S. Finke, O. Bauer, and M. Metzen. 2021. “Life Cycle Assessment on Electric Moped Scooter Sharing.” Sustainability 13 (15): 8297. doi:10.3390/su13158297.

Severengiz, S., S. Finke, N. Schelte, and N. Wendt. 2020. “Life Cycle Assessment on the Mobility Service E-Scooter Sharing.” In 2020 IEEE European Technology and Engineering Management Summit (E-TEMS), 1–6. doi:10.1109/E-TEMS46250.2020.9111817.

Sun, Q., T. Feng, A. Kemperman, and A. Spahn. 2020. “Modal Shift Implications of E-Bike Use in the Netherlands: Moving Towards Sustainability?” Transportation Research Part D: Transport and Environment 78 (January): 102202. doi:10.1016/j.trd.2019.102202.

The Institute of Life Cycle Assessment, Japan. 2015. “Guidelines for Assessing the Contribution of Products to Avoided Greenhouse Gas Emissions.” https://www.ilcaj.org/lcahp/doc/iLCAj_Guidelines_avoided_emissions_assessment_v1_1_english.pdf.

Union of Concerned Scientists (UCS). 2020. “Ride-Hailing’s Climate Risks: Steering a Growing Industry toward a Clean Transportation Future: Methodology.” https://www.ucsusa.org/sites/default/files/2020-02/Ride-Hailings-Climate-Risks-Methodology_0.pdf.

US EPA. 2021. “Power Profiler.” Data and Tools. July 23, 2021. https://www.epa.gov/egrid/power-profiler.

US EPA, O. 2022. “Renewable Energy Certificates (RECs).” Overviews and Factsheets. January 19, 2022. https://www.epa.gov/green-power-markets/renewable-energy-certificates-recs.

Wang, K., X. Qian, D.T. Fitch, Y. Lee, J. Malik, and G. Circella. 2022. “What Travel Modes Do Shared E-Scooters Displace? A Review of Recent Research Findings.” Transport Reviews 0 (0): 1–27. doi:10.1080/01441647.2021.2015639.

Weiss, M., P. Dekker, A. Moro, H. Scholz, and M.K. Patel. 2015. “On the Electrification of Road Transportation – A Review of the Environmental, Economic, and Social Performance of Electric Two-Wheelers.” Transportation Research Part D: Transport and Environment 41: 348–66.

Wen, Y., and C. Cherry. 2022. “Electric Scooter Survey Question Toolkit.” https://www.numo.global/resources/electric-scooter-survey-question-toolkit.

Winslott Hiselius, L., and Å. Svensson. 2017. “E-Bike Use in Sweden – CO_2 Effects Due to Modal Change and Municipal Promotion Strategies.” Journal of Cleaner Production 141 (January): 818–24. doi:10.1016/j.jclepro.2016.09.141.

Yumpu.com. n.d. “PRODUCT CATEGORY RULES (PCR) Rail Vehicles - Unife.” Yumpu.Com. Accessed August 26, 2022. https://www.yumpu.com/en/document/view/36496664/product-category-rules-pcr-rail-vehicles-unife.