Tackling Mobile Combustion Emissions

Part II: Converting Activity Data to GHG Emissions

In the first part of this paper, we focused on the activity data that should be collected for the various types of mobile combustion activity in which an organization is engaged. Our attention now turns to converting that activity data into greenhouse gas (GHG) emissions.

We'll look at three specific examples of activity data– business travel by air, business travel by rail and employee commute by private vehicle. Our goal is to introduce some general methodologies through these examples that can then be applied to any dataset of mobile combustion activity.

4. CATEGORIZING ACTIVITY DATA

Recall that activity data is converted to emissions by multiplying activity (expressed in various units) by *emissions factors*. Before doing so, we must organize our activity data into categories and subcategories and then identify the appropriate emissions factor to apply to each. Herein lies the challenge (and the art) of tracking mobile combustion emissions.

Previously, we discussed the trade-offs inherent in seeking the appropriate level of granularity at which to track our activity data. We explained that finer granularity improves the accuracy and precision of our emissions calculations at the expense of complicating our data collection and maintenance burden[1]. Let's look at converting a mobile combustion activity dataset for a hypothetical organization to see an example of how this trade-off plays out.

[1] Data management is made easier when it's easy for more stakeholders in the reporting chain to categorize activity. It's made harder when no stakeholder can easily determine the appropriate category for a specific activity.

A Hypothetical Activity Dataset

Table 1 provides an example of a simplistic categorization of mobile combustion activities (and the data collected for each) for a hypothetical organization. It exemplifies *coarse* granularity.

Table 1: Simple Subcategorization of Activity Data

Activity Category	Subcategorization of Activity	Total Activity Data
Business Travel	Rail	**843,722** miles
	Air	**3,756,300** miles
Fleets	Delivery Fleet	**188,470** gallons of fuel
	Service Fleet	**914,720** gallons of fuel
Employee Commute	Private Vehicle	**433,980** miles
	Bus	**216,833** miles

4.1 Emissions Factors

Now that we have our activity data categorized and quantified, the next step is to find the right emissions factors to apply. In ***Scope 5***, we provide several emissions factor *libraries*. These pull mobile combustion emissions factors from various reputable sources, most notably, The Greenhouse Gas Protocol (a partnership of the World Resources Institute and The World Business Council for Sustainable Development) and The Climate Registry, referred to from here on as *WRI* and *TCR*, respectively. Each of these organizations in turn, pull emissions factors from multiple sources including the EPA and the IPCC. We mention these specific sources only as examples. There are numerous reputable sources of emissions factors.

Occasionally we may be fortunate enough to find a single emissions factor from an authoritative table that unequivocally applies to one of our specific subcategories of activity data. More often, we'll find it necessary to 'reverse engineer' tables of emissions factors so that we can identify the underlying activity data variables that are material in converting from activity to emissions. We may then readjust the subcategorization of our activity data based on an understanding of these variables and the sensitivity of the emissions factors to each of them. The goal of this iterative process is to arrive at a subcategorization of activity data and a set of emissions factors for each subcategory such that we:

1. Produce a reasonably accurate estimate of our mobile combustion emissions based on reputable emissions factors.

2. Surface opportunities to reduce emissions through specific activity changes, on an ongoing basis.

In the case that an organization is reporting its emissions under a specific protocol, it may be necessary to apply activity subcategorizations and emissions factors from a certain authority's table verbatim. In most cases, some degree of flexibility is appropriate and we will find ourselves iterating through the process described previously. The specific manner in which we do so will vary from one activity subcategory to another and the specific tables of emissions factors that are available.

4.2 The Business Travel Dataset

Our hypothetical business travel dataset includes two numbers—one for total miles flown by air and one for total miles traveled by rail. Appropriate emissions factors for these can be found in Table 16 of the WRI's emissions factors for public transportation, an excerpt of which is illustrated in Figure 1:

These same emissions factors are available within ***Scope 5*** *under the* ***WRI*** *library,* ***Public Transport*** *category.*

Vehicle and Type	Region	CO2	CO2 Unit	CO2 Unit - Denominat
Air - Domestic	Other	0.17147	Kilogram	Passenger Kilometer
Air - Short Haul - Seating Unknown	Other	0.097	Kilogram	Passenger Kilometer
Air - Short Haul - Economy Class	Other	0.09245	Kilogram	Passenger Kilometer
Air - Short Haul - First/Business Class	Other	0.13867	Kilogram	Passenger Kilometer
Air - Long Haul - Seating Unknown	Other	0.11319	Kilogram	Passenger Kilometer
Air - Long Haul - Economy Class	Other	0.08263	Kilogram	Passenger Kilometer
Air - Long Haul - Economy+ Class	Other	0.13221	Kilogram	Passenger Kilometer
Air - Long Haul - Business Class	Other	0.23963	Kilogram	Passenger Kilometer
Air - Long Haul - First Class	Other	0.33052	Kilogram	Passenger Kilometer
Air - Domestic	UK	0.17147	Kilogram	Passenger Kilometer
Air - Short Haul - Seating Unknown	UK	0.097	Kilogram	Passenger Kilometer
Air - Short Haul - Economy Class	UK	0.09245	Kilogram	Passenger Kilometer
Air - Short Haul - First/Business Class	UK	0.13867	Kilogram	Passenger Kilometer
Air - Long Haul - Seating Unknown	UK	0.11319	Kilogram	Passenger Kilometer
Air - Long Haul - Economy Class	UK	0.08263	Kilogram	Passenger Kilometer
Air - Long Haul - Economy+ Class	UK	0.13221	Kilogram	Passenger Kilometer
Air - Long Haul - Business Class	UK	0.23963	Kilogram	Passenger Kilometer
Air - Long Haul - First Class	UK	0.33052	Kilogram	Passenger Kilometer
Air - Domestic	US	0.17147	Kilogram	Passenger Kilometer
Air - Short Haul - Seating Unknown	US	0.097	Kilogram	Passenger Kilometer
Air - Short Haul - Economy Class	US	0.09245	Kilogram	Passenger Kilometer
Air - Short Haul - First/Business Class	US	0.13867	Kilogram	Passenger Kilometer
Air - Long Haul - Seating Unknown	US	0.11319	Kilogram	Passenger Kilometer
Air - Long Haul - Economy Class	US	0.08263	Kilogram	Passenger Kilometer
Air - Long Haul - Economy+ Class	US	0.13221	Kilogram	Passenger Kilometer
Air - Long Haul - Business Class	US	0.23963	Kilogram	Passenger Kilometer
Air - Long Haul - First Class	US	0.33052	Kilogram	Passenger Kilometer

Figure 1: Excerpt from WRI Table 16—Emission's Factors for Public Transport

Business Air Travel

Looking back at our hypothetical activity dataset, we have one number for air travel—3,756,300 miles. The full WRI table has 27 emissions factors for air travel! What do we do? The problem is that the WRI has categorized air travel at a finer granularity than our air travel dataset. We have several options:

- Go back and recategorize our activity data to match the WRI categories.
- Seek an alternate source of emissions factors that more closely corresponds to our level of categorization.
- Start with the WRI's numbers to derive some sort of average or summary numbers that yield a set of emissions factors corresponding to our level of categorization.

In fact, we'll see that variations of the problem illustrated surface when tackling pretty much any set of mobile combustion activity data for any organization. Typically, to resolve this problem, we use some combination of the three options listed above. In deciding which option to use, we must consider the materiality of the specific activity, not just in terms of its proportion of our organization's total emissions but also in terms of our ability to effect change.

In this case, we might decide that our organization's air travel emissions are not material enough to warrant the complexity of tracking activity data in 27 different categories to match the WRI's emissions factors. We might track our organization's air travel data at a slightly finer grain than the single category we imagined, but not in 27 categories.

So, we're faced with the choice of seeking an alternate source of emissions factors or trying to reduce the WRI's set into some sort of summary set. In order to decide how to move forward, it helps to look at some different sets of emissions factors so that we can see which variables across which subcategories are most significant. Looking at the WRI's numbers from Figure 1 in further depth we see that they are sub-categorized using several variables:

- **Length of trip:** long haul vs. short haul
- **Location:** UK, US or Other
- **Class of travel:** Economy or Business/First Class

There's also a category of domestic, which likely corresponds to some combination of the length of the trip and the type of aircraft typically used. Let's take a look at one of these variables—the location. Figure 2 is an excerpt from ***Scope 5's*** WRI library in which we can easily look at a subset of the emissions factors side-by-side:

Air - Long Haul - Business Class - Other			0.528293 lbs/km
Air - Long Haul - Business Class - UK			0.528293 lbs/km
Air - Long Haul - Business Class - US			0.528293 lbs/km

Figure 2: The Same Emissions Factor for Different Categories

We see that the same emission factors apply for long haul, business class regardless of location. In fact, when looking at the 27 categories in Figure 1, we see that there are actually only 9 different emissions factors. So, there's clearly no point in categorizing our organization's activity data into 27 categories.

How then should we sub-categorize our activity data? Further examination of the WRI emissions factors reveal that class of travel is an important variable—traveling first class incurs some three times more emissions than traveling in economy class! Furthermore, class of travel is a variable over which we have a great deal of control and therefore, the ability to effect change. Another variable that is significant is the length of trip. The WRI's emissions factors for long haul travel differ by anywhere from 12–58% from the equivalent factors for short haul travel.

Based on these findings, we would want to subcategorize our air travel activity data by class of travel at the very least and possibly by short haul vs. long haul as well. Thus, we might arrive at the following subcategories in Table 2. These are taken verbatim from the corresponding rows in the WRI table:

Table 2: Proposed Categorization for Air Travel

Distance	Class of Travel	Emissions Factor (kg CO_2/km)
Long Haul	Seating Unknown	0.11319
	Economy	0.08263
	Economy Plus	0.13221
	Business	0.23963
	First	0.33052
Short Haul	Seating Unknown	0.097
	Economy	0.09245
	First/Business	0.13867

Our data maintenance burden is increased—we now have to collect and track business air travel data in eight categories instead of a single category. However, our categories now map directly to the WRI's emissions factors and we know exactly how to convert our distance-traveled data in each category to the corresponding emissions with a great degree of confidence.

We might look at ways of decreasing our data maintenance burden. What would it look like to reduce the number of activity data sub categories by eliminating short haul vs. long haul as a variable? The following table shows the difference in emissions factors between short haul and long haul for the same class of travel:

Table 3: Sensitivity of Emissions Factors to Long vs. Short Haul

Class of Travel	Long Haul EF (kg/km)	Short Haul EF (kg/km)	Difference
Seating Unknown	0.11319	0.097	-14%
Economy	0.08263	0.09245	12%
Business	0.23963	0.13867	-42%
First	0.33052	0.13867	-58%

From Table 3 we see that the differences in emissions factors between short and long haul for the seating unknown subcategory and the economy class subcategory are relatively minor. However, for business and first class, they're substantial. In the interest of balancing our effort to reduce complexity with the resulting loss of accuracy, we might settle for the following subcategorization:

Table 4: Simpler Subcategorization

Class of Travel	Emissions Factor (kg/km)
Seating Unknown	0.1051
Economy	0.0875
Short Haul Business/First	0.13867
Long Haul Business	0.23963
Long Haul First	0.33052

We now have five subcategories instead of eight. For the first two, we've used the average of the short and long haul emissions factors from Table 3. In doing so, we settle for a slight loss in accuracy—if, for example, we have a significant number of miles flown in short haul economy class and none in long haul economy class, we'd end up understating our emissions for economy class air travel by 6%. If on the other hand, the number of miles flow in short haul economy class are close to the number flown in long haul economy class, we will have lost very little accuracy as a result of reducing the number of subcategories.

The Power of Averaging

Taking averages of multiple emissions factors in this manner can be a powerful strategy to reduce the number of subcategories of activity data (and the associated data management burden). We lose some amount of accuracy but we can minimize this loss by being careful in how we apply the strategy. In this example, we used average emissions factors where there was not a big difference between the set of emissions factors averaged. We maintained separate categories where there was a big difference between emissions factors.

In addition, the loss of accuracy is limited if actual activity is evenly distributed between the subcategories that we combine. This is generally more likely to be the case when we have a large number of data points making up our activity dataset.

In fact, it's likely that the WRI's emissions factor for *seating unknown* is an average emissions factor. It's probably a weighted average of the different classes based on the average distribution of passengers across classes of travel. As such, to the degree that our organizations' population of business travelers represents the general flying public, we could probably use the single seating unknown factor with little loss of accuracy—all of which brings us full circle, back to one activity subcategory for business air travel. Although this strategy might ease our data maintenance at a small cost to accuracy it does little to facilitate driving change.

PRESERVING OPPORTUNITIES TO DRIVE CHANGE

To illustrate, assume that air travel is a material activity for our hypothetical organization. We track air travel emissions, for each department or division, for thousands of consultants that fly around the world. Our organization has the option of implementing programs that reduce air travel emissions, such as imposing an internal carbon fee or establishing competitions between departments.

One way for a department to lower their carbon fee or to 'win' a competition is to shift their travel away from the more emissions intensive classes of travel, towards economy class. If our organization doesn't sub-categorize air travel activity based on class of travel, we'll be unable to see or show any progress as a result of our efforts. Departments won't have emissions data at the granularity that enables them to reduce their carbon fee or to compete with each other.

In summary, it makes sense to use averages where possible to simplify our data maintenance burden. We can do so in a manner that maintains a reasonable level of accuracy. This serves our goal of producing credible and defensible emissions reports. However, for many organizations, credible reporting is just one of the goals of emissions reporting. Another goal is to drive behavior change to reduce cost and impact. In many cases, the averaging strategies discussed can be used with no adverse effect. In other cases, averaging might compromise our ability to drive behavior change.

Another Source of Emissions Factors

When our subcategories don't match the subcategories of a particular authority's emissions factors, we suggested looking for an alternate source of emissions factors as one of the options available to us. Figure 3 illustrates a table of emissions factors from the EPA:

Table 8	Business Travel Emission Factors			
Vehicle Type	**CO_2 Factor (kg / unit)**	**CH_4 Factor (g / unit)**	**N_2O Factor (g / unit)**	**Units**
Passenger Car [A]	0.355	0.021	0.015	vehicle-mile
Light-Duty Truck [B]	0.485	0.020	0.022	vehicle-mile
Motorcycle	0.191	0.070	0.007	vehicle-mile
Intercity Rail (i.e. Amtrak) [C]	0.136	0.0083	0.0030	passenger-mile
Commuter Rail [D]	0.169	0.0085	0.0034	passenger-mile
Transit Rail (i.e. Subway, Tram) [E]	0.120	0.0025	0.0017	passenger-mile
Bus	0.055	0.0006	0.0005	passenger-mile
Air Travel - Short Haul (< 300 miles) [F]	0.251	0.0039	0.0083	passenger-mile
Air Travel - Medium Haul (>= 300 miles, < 2300 miles) [F]	0.143	0.0000	0.0047	passenger-mile
Air Travel - Long Haul (>= 2300 miles) [F]	0.167	0.0006	0.0056	passenger-mile

Figure 3: EPA Emissions Factors for Business Travel

The last three rows of this table offer a simple categorization of air travel into only three subcategories. We could readily adopt this subcategorization for our air travel emissions. We'd be using a defensible set of emissions factors but would lose the opportunity to drive behavior change through class of travel as described previously.

Business Rail Travel

For rail travel, like air travel, our initial subcategorization from Table 1 yields a single number corresponding to distance traveled: 843,722 miles. Let's see which emissions factors we might use to calculate the resulting emissions. Figure 4 illustrates another excerpt from the WRI's Table 16:

Vehicle and Type	Reg	CO2	CO2 Unit	CO2 Unit - Deno	CH4	CH4 Ui
Train - Light Rail	US	0.163	Kilogram	Passenger Mile	0.004	Gram
Train - Tram	US	0.163	Kilogram	Passenger Mile	0.004	Gram
Train - Average (Light Rail and Tram)	US	0.163	Kilogram	Passenger Mile	0.004	Gram
Train - National Rail	US	0.185	Kilogram	Passenger Mile	0.002	Gram
Train - Subway	US	0.163	Kilogram	Passenger Mile	0.004	Gram

Figure 4: Another Excerpt from the WRI Tables

Upon examining the original WRI's Table 16, we see that there are two different sets of emissions factors for rail—one for *National Rail* and the other for various forms of light rail—subway, tram, etc. In general, it's likely that our business travel subcategory from Table 1 quantifies travel on national rail rather than light rail. This would be especially likely in Europe and other regions in which national rail is a common form of inter-city business transit[2]. Thus, we would use the emissions factors from the subcategory *Train–National Rail* to convert distance traveled to emissions.

On the other hand, for many organizations, employee commuting activity likely includes travel by subway or tram, for which the alternate emissions factors from the table would be appropriate.

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[2] *In calculating emissions for rail travel outside the US using the WRI's Table 16, be sure to use the emissions factors from the appropriate rows (UK or other). They differ significantly from the US factors.*

4.3 The Employee Commute Dataset

In the employee commute category of our hypothetical dataset, we have two subcategories —*private vehicle* and *bus*. Let's see how we might calculate emissions for the private vehicle subcategory. Referring back to Table 1, we see that we're tracking activity for this subcategory in units of distance traveled. Let's search the WRI tables for an emissions factor for private vehicles that can be used to calculate emissions from distance-traveled activity.

We find what we're looking for in the WRI's Table 12—*Emission Factors for US and Other Regions by Vehicle Distance*. This table includes 166 subcategories of activities (one in each row) with the corresponding emissions factors (in separate columns).

Since we're going to apply this table to our subcategory of employee commute in private vehicles, we can omit the activity subcategories for the following vehicle types:

- Bus
- Heavy Duty Vehicle—Articulated
- Heavy Duty Vehicle—Rigid

We're left with 78 activity subcategories. The resulting table is illustrated in Figure 5.

Table 12. CO2, CH4 and N2O Emission Factors for US and other regions by Vehicle Distance

Vehicle and Fuel and Vehicle Year	Region	CH4	CH4 U	CH4	N2O	N2O Uni	N2O	Fuel E	Fuel E	Fuel Efficier	Fuel	CO2	CO2 Unit	CO2
Passenger Car - Gasoline - Year 1984-1993	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 1994	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 1995	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 1996	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 1997	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 1998	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 1999	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 2000	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 2001	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 2002	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 2003	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 2004	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Gasoline - Year 2005-present	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	Gasoline/Petrol	0.382166	Kilogram	Mile
Passenger Car - Diesel - Year 1960-1982	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	On-Road Diesel	0.450266667	Kilogram	Mile
Passenger Car - Diesel - Year 1983-present	Other	-	-	-	-	-	-	22.5	Mile	US Gallon	On-Road Diesel	0.450266667	Kilogram	Mile
Passenger Car - Fuel Unknown	Other	-	-	-	-	-	-	22.5	Mile	US Gallon				
Light Goods Vehicle - CNG	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	CNG			
Light Goods Vehicle - LPG	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	LPG	0.37654321	Kilogram	Mile
Light Goods Vehicle - Ethanol	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Ethanol		Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1987-1993	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1994	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1995	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1996	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1997	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1998	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1999	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2000	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2001	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2002	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2003	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2004	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2005-prese	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	Gasoline/Petrol	0.530786111	Kilogram	Mile
Light Goods Vehicle - Diesel - Year 1960-1982	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	On-Road Diesel	0.62537037	Kilogram	Mile
Light Goods Vehicle - Diesel - Year 1983-1995	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	On-Road Diesel	0.62537037	Kilogram	Mile
Light Goods Vehicle - Diesel - Year 1996-present	Other	-	-	-	-	-	-	16.2	Mile	US Gallon	On-Road Diesel	0.62537037	Kilogram	Mile
Light Goods Vehicle - Fuel Unknown	Other	-	-	-	-	-	-	16.2	Mile	US Gallon				
Motorbike - Non-Catalyst Control	Other	-	-	-	-	-	-	50	Mile	US Gallon	On-Road Diesel	0.20262	Kilogram	Mile
Motorbike - Uncontrolled	Other	-	-	-	-	-	-	50	Mile	US Gallon	On-Road Diesel	0.20262	Kilogram	Mile
Motorbike - Control Unknown	Other							50	Mile	US Gallon	On-Road Diesel	0.20262	Kilogram	Mile
Passenger Car - Gasoline - Year 1984-1993	US	0.0704	Gram	Mile	0.0647	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1994	US	0.0531	Gram	Mile	0.056	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1995	US	0.0358	Gram	Mile	0.0473	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1996	US	0.0272	Gram	Mile	0.0426	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1997	US	0.0268	Gram	Mile	0.0422	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1998	US	0.0249	Gram	Mile	0.0393	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1999	US	0.0216	Gram	Mile	0.0337	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2000	US	0.0178	Gram	Mile	0.0273	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2001	US	0.011	Gram	Mile	0.0158	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2002	US	0.0107	Gram	Mile	0.0153	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2003	US	0.0114	Gram	Mile	0.0135	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2004	US	0.0145	Gram	Mile	0.0083	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2005-present	US	0.0147	Gram	Mile	0.0079	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Diesel - Year 1960-1982	US	0.0006	Gram	Mile	0.0012	Gram	Mile	22.5	Mile	US Gallon	On-Road Diesel	0.451111111	Kilogram	Mile
Passenger Car - Diesel - Year 1983-present	US	0.0005	Gram	Mile	0.001	Gram	Mile	22.5	Mile	US Gallon	On-Road Diesel	0.451111111	Kilogram	Mile
Passenger Car - Fuel Unknown	US	0.031	Gram	Mile	0.032	Gram	Mile	22.5	Mile	US Gallon				
Light Goods Vehicle - CNG	US	0.737	Gram	Mile	0.05	Gram	Mile	16.2	Mile	US Gallon	CNG			
Light Goods Vehicle - LPG	US	0.037	Gram	Mile	0.067	Gram	Mile	16.2	Mile	US Gallon	LPG	0.357407407	Kilogram	Mile
Light Goods Vehicle - Ethanol	US	0.055	Gram	Mile	0.067	Gram	Mile	16.2	Mile	US Gallon	Ethanol		Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1987-1993	US	0.0813	Gram	Mile	0.1035	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1994	US	0.0646	Gram	Mile	0.0982	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1995	US	0.0517	Gram	Mile	0.0908	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1996	US	0.0452	Gram	Mile	0.0871	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1997	US	0.0452	Gram	Mile	0.0871	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1998	US	0.0391	Gram	Mile	0.0728	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1999	US	0.0321	Gram	Mile	0.0564	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2000	US	0.0346	Gram	Mile	0.0621	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2001	US	0.0151	Gram	Mile	0.0164	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2002	US	0.0178	Gram	Mile	0.0228	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2003	US	0.0155	Gram	Mile	0.0114	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2004	US	0.0152	Gram	Mile	0.0132	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2005-prese	US	0.0157	Gram	Mile	0.0101	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Diesel - Year 1960-1982	US	0.0011	Gram	Mile	0.0017	Gram	Mile	16.2	Mile	US Gallon	On-Road Diesel	0.62654321	Kilogram	Mile
Light Goods Vehicle - Diesel - Year 1983-1995	US	0.0009	Gram	Mile	0.0014	Gram	Mile	16.2	Mile	US Gallon	On-Road Diesel	0.62654321	Kilogram	Mile
Light Goods Vehicle - Diesel - Year 1996-present	US	0.001	Gram	Mile	0.0015	Gram	Mile	16.2	Mile	US Gallon	On-Road Diesel	0.62654321	Kilogram	Mile
Light Goods Vehicle - Fuel Unknown	US	0.036	Gram	Mile	0.047	Gram	Mile	16.2	Mile	US Gallon				
Motorbike - Non-Catalyst Control	US	0.0672	Gram	Mile	0.0069	Gram	Mile	50	Mile	US Gallon	On-Road Diesel	0.203	Kilogram	Mile
Motorbike - Uncontrolled	US	0.0899	Gram	Mile	0.0087	Gram	Mile	50	Mile	US Gallon	On-Road Diesel	0.203	Kilogram	Mile
Motorbike - Control Unknown	US	0.07	Gram	Mile	0.007	Gram	Mile	50	Mile	US Gallon	On-Road Diesel	0.203	Kilogram	Mile

Figure 5: Subset of WRI Table 12

Looking at Figure 5, we see that the table includes two sets of roughly equivalent activity subcategories, differentiated by *region*. The first set of activity subcategories (in the first 39 rows) is for the *Other* region. The second set (in the remaining 39 rows) is for the *US* region. Let's continue under the assumption that the employee commute subcategory for our hypothetical dataset applies only to the US region. We now have the table illustrated in Figure 6.

Table 12. CO2, CH4 and N2O Emission Factors for US and other regions by Vehicle Distance

Vehicle and Fuel and Vehicle Year	Regio	CH4	CH4 Ur	CH4 U	N2O	N2O Uni	N2O U	Fuel E	Fuel E	Fuel Efficien	Fuel	CO2	CO2 Unit	CO2 U
Passenger Car - Gasoline - Year 1984-1993	US	0.0704	Gram	Mile	0.0647	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1994	US	0.0531	Gram	Mile	0.056	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1995	US	0.0358	Gram	Mile	0.0473	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1996	US	0.0272	Gram	Mile	0.0426	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1997	US	0.0268	Gram	Mile	0.0422	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1998	US	0.0249	Gram	Mile	0.0393	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 1999	US	0.0216	Gram	Mile	0.0337	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2000	US	0.0178	Gram	Mile	0.0273	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2001	US	0.011	Gram	Mile	0.0158	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2002	US	0.0107	Gram	Mile	0.0153	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2003	US	0.0114	Gram	Mile	0.0135	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2004	US	0.0145	Gram	Mile	0.0083	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Gasoline - Year 2005-prese	US	0.0147	Gram	Mile	0.0079	Gram	Mile	22.5	Mile	US Gallon	Gasoline/Petrol	0.391555556	Kilogram	Mile
Passenger Car - Diesel - Year 1960-1982	US	0.0006	Gram	Mile	0.0012	Gram	Mile	22.5	Mile	US Gallon	On-Road Diesel F	0.451111111	Kilogram	Mile
Passenger Car - Diesel - Year 1983-present	US	0.0005	Gram	Mile	0.001	Gram	Mile	22.5	Mile	US Gallon	On-Road Diesel F	0.451111111	Kilogram	Mile
Passenger Car - Fuel Unknown	US	0.031	Gram	Mile	0.032	Gram	Mile	22.5	Mile	US Gallon				
Light Goods Vehicle - CNG	US	0.737	Gram	Mile	0.05	Gram	Mile	16.2	Mile	US Gallon	CNG			
Light Goods Vehicle - LPG	US	0.037	Gram	Mile	0.067	Gram	Mile	16.2	Mile	US Gallon	LPG	0.357407407	Kilogram	Mile
Light Goods Vehicle - Ethanol	US	0.055	Gram	Mile	0.067	Gram	Mile	16.2	Mile	US Gallon	Ethanol		Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1987-1	US	0.0813	Gram	Mile	0.1035	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1994	US	0.0646	Gram	Mile	0.0982	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1995	US	0.0517	Gram	Mile	0.0908	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1996	US	0.0452	Gram	Mile	0.0871	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1997	US	0.0452	Gram	Mile	0.0871	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1998	US	0.0391	Gram	Mile	0.0728	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 1999	US	0.0321	Gram	Mile	0.0564	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2000	US	0.0346	Gram	Mile	0.0621	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2001	US	0.0151	Gram	Mile	0.0164	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2002	US	0.0178	Gram	Mile	0.0228	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2003	US	0.0155	Gram	Mile	0.0114	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2004	US	0.0152	Gram	Mile	0.0132	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Gasoline - Year 2005-p	US	0.0157	Gram	Mile	0.0101	Gram	Mile	16.2	Mile	US Gallon	Gasoline/Petrol	0.54382716	Kilogram	Mile
Light Goods Vehicle - Diesel - Year 1960-198	US	0.0011	Gram	Mile	0.0017	Gram	Mile	16.2	Mile	US Gallon	On-Road Diesel F	0.62654321	Kilogram	Mile
Light Goods Vehicle - Diesel - Year 1983-199	US	0.0009	Gram	Mile	0.0014	Gram	Mile	16.2	Mile	US Gallon	On-Road Diesel F	0.62654321	Kilogram	Mile
Light Goods Vehicle - Diesel - Year 1996-pre	US	0.001	Gram	Mile	0.0015	Gram	Mile	16.2	Mile	US Gallon	On-Road Diesel F	0.62654321	Kilogram	Mile
Light Goods Vehicle - Fuel Unknown	US	0.036	Gram	Mile	0.047	Gram	Mile	16.2	Mile	US Gallon				
Motorbike - Non-Catalyst Control	US	0.0672	Gram	Mile	0.0069	Gram	Mile	50	Mile	US Gallon	On-Road Diesel F	0.203	Kilogram	Mile
Motorbike - Uncontrolled	US	0.0899	Gram	Mile	0.0087	Gram	Mile	50	Mile	US Gallon	On-Road Diesel F	0.203	Kilogram	Mile
Motorbike - Control Unknown	US	0.07	Gram	Mile	0.007	Gram	Mile	50	Mile	US Gallon	On-Road Diesel F	0.203	Kilogram	Mile

Figure 6: Even Shorter Subset of WRI's Table 12

We're left with only 39 subcategories to map to our single *miles* driven number from our hypothetical dataset. This is much better than the 166 subcategories in the original Table 12, but we can do better. Let's examine the emissions factors for the remaining 39 subcategories. The table in Figure 6 includes three emissions factors for each subcategory, one each for CH_4, N_2O and CO_2 (in columns D, G and N, respectively).

METHANE AND NITROUS OXIDE (CH_4 AND N_2O)

Recall from section 3.1 in Part I of this whitepaper that the contribution of CH_4 and N_2O to total CO_2 emissions tends to be rather small. Working from our table in Figure 6, the average contribution of CH_4 and N_2O is about 2.5%.

If we further disregard the subcategories for the alternate fuels (LPG, LNG, CNG and Ethanol), and for model years prior to 2004, the average drops to 0.76% [3]. It seems reasonable to drop these subcategories—after all, it's unlikely that our employee commute vehicles include many LPG, LNG or CNG fueled vehicles (there may be a few Ethanol fueled vehicles). While some of our commuting employees may do so in model year vehicles prior to 2004, most probably do not. So, CH_4 and N_2O are not likely to be material to our employee commute activity, especially if we disregard older vehicles. We turn our attention next to the emissions factors for CO_2.

[3] Dropping activity subcategories for motorbikes reduces the contributions of CH_4 and N_2O further yet, to only 0.36%.

CARBON DIOXIDE (CO_2)

The histogram in Figure 7 illustrates the distribution of CO_2 emissions factors across the remaining subcategories from Figure 6[4].

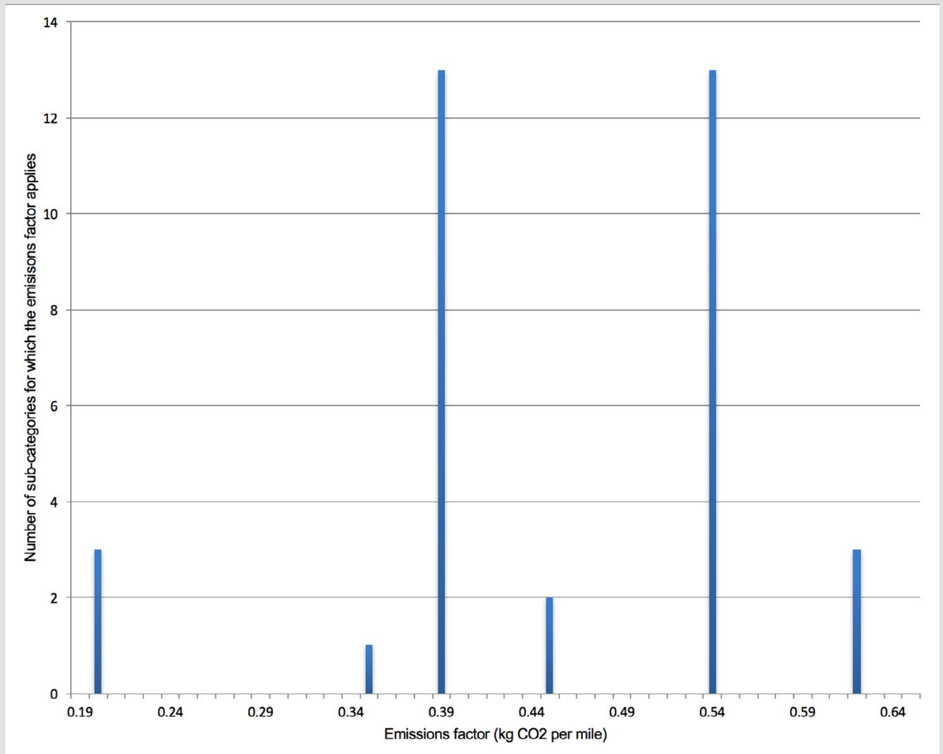


Figure 7: CO_2 Emissions Factors

These correspond, from left to right, to:

- Motorbikes
- Light Goods Vehicle: LPG
- Passenger Car: Gasoline (all years)
- Passenger Car: Diesel (all years)
- Light Goods Vehicle: Gasoline (all years)
- Light Goods Vehicle: Diesel (all years)

If we exclude the single emissions factor for LPG fueled light goods vehicles, we're left with five different emissions factors.

[4] *Charting a histogram in this manner can be a valuable tool in distilling out the meaningful activity subcategories from complex emissions factor tables. In this case, we see that, although there are 39 activity subcategories in the table, there are only six different emissions factors.*

Reducing the Number of Subcategories

As a result, we're ready to consider a reduced set of five activity subcategories for employee commute by private vehicle, as illustrated in Table 5.

Table 5: Five Subcategories for Employee Commute Activity

Vehicle Type	Fuel Type	Emissions Factor (kg/mile)		
		CH_4	N_2O	CO_2
Passenger Car	**Gasoline**	0.0000146	0.0000081	0.3916
	Diesel	0.0000005	0.000001	0.4511
Light Goods Vehicle	**Gasoline**	0.00001545	0.00001165	0.5438
	Diesel	0.000001	0.00000153	0.6265
Motorbike	**n/a**	0.00007	0.000007	0.203

Note that for CH_4 and N_2O emissions factors we used averages across the remaining sub-categories (excluding model years prior to 2004) for both passenger cars and light goods vehicles and we used the emissions factors corresponding to *control unknown* for motor-bikes. This is reasonable as we saw earlier that CH_4 and N_2O contribute negligibly to our overall employee commute emissions.

Let's review quickly how we got here:

• We started with the 166 activity subcategories in the WRI's Table 12.

• We omitted the heavy-duty vehicle subcategories because they're irrelevant to employee commuting.

• We limited the employee commute activity that we're considering to the US region.

• We assumed that the contributions of CH_4 and N_2O emissions would be negligible because most commuting

- would not be in cars with model years prior to 2004
- would be in either gasoline or diesel cars (not LNG, LPG, CNG or Ethanol)

Improving Our Subcategories—The Role of Fuel Efficiency

We've arrived at a very reasonable set of only 5 subcategories and corresponding emissions factors that we can use to calculate our employee commute emissions. We could stop here but we might be missing some opportunities. We might be able to adjust our set of subcategories such that we improve our accuracy or are more likely to identify opportunities for change, without substantially impacting our data maintenance burden.
Let's dig in a little further.

In reviewing Table 5, we see that the variables that materially affect employee commute emissions are:

- Type of fuel (diesel vs. gasoline)
- Type of vehicle (passenger car vs. light goods vehicle vs. motorbike)

Fuel type has an obvious impact on emissions factors—gasoline, diesel and other fuels simply differ in carbon content. But how does vehicle *type* impact emissions?

Vehicle type impacts emissions in two ways:

- Different types of vehicles have different types of engines, which emit different amounts of CH_4 and N_2O per mile.
- Different types of vehicles differ in their fuel efficiencies, which determine the volume of fuel burned and therefore the amount of CO_2 emitted per mile.

Let's ignore the impact on CH_4 and N_2O for the time being and let's focus instead on CO_2 emissions, which dominate. Recall that CO_2 emissions are a function mostly of *the volume of fuel burned* but the activity units we're using are *distance*. The two are linked by a vehicle's *fuel-efficiency*. Looking back at the WRI's table in Figure 6, we see the fuel efficiencies assumed by the WRI in column 'J' for different vehicle types—50 mpg for motorbikes, 22.5 mpg for passenger cars and 16.2 mpg for light goods vehicles. In Figure 8 we see an excerpt from the WRI's Table 10, which documents emissions factors for gasoline and diesel *by volume*.

Table 10. CO2 Emission Factors by Fuel

Fuel	Region	CO2	CO2 Unit -	CO2 Unit -
Jet Fuel	Other	9.428	Kilogram	US Gallon
Aviation Gasoline	Other	8.333	Kilogram	US Gallon
Gasoline/Petrol	Other	8.59873	Kilogram	US Gallon
On-Road Diesel Fuel	Other	10.131	Kilogram	US Gallon
Residual Fuel Oil (3s 5 and 6)	Other	11.125	Kilogram	US Gallon

Figure 8: Emissions Factors by Volume

Using the following formula, these emissions factors, combined with the assumed fuel-efficiencies produce the expected CO_2 emissions factors by distance:

$$\frac{CO_2}{\text{mile}} = \left(\frac{CO_2}{\text{gallon}}\right) / \left(\frac{\text{mile}}{\text{gallon}}\right)$$

It follows that one obvious way to sub-categorize our employee commute activity categories is by fuel type and by fuel-efficiency, as illustrated in Table 6.

Table 6: Eight Subcategories for Employee Commute Activity

Activity Subcategory	Fuel Type	CO_2 Emissions Factor (kg/mile)
Vehicles with fuel-efficiency in the range of 40-50 mpg (Avg. 45 mpg)	Gasoline Diesel	0.1911 0.2251
Vehicles with fuel-efficiency in the range of 30-40 mpg (Avg. 35 mpg)	Gasoline Diesel	0.2457 0.2895
Vehicles with fuel-efficiency in the range of 20-30 mpg (Avg. 25 mpg)	Gasoline Diesel	0.344 0.4052
Vehicles with fuel-efficiency in the range of 10-20 mpg (Avg. 15 mpg)	Gasoline Diesel	0.5733 0.6754

In this example, we've created activity subcategories for each of a number of fuel-efficiency bands. This strategy has a number of advantages over the WRI's approach:

1. By being explicit in identifying our activity subcategories based on fuel-efficiency rather than vehicle type, we make it easier to manage and categorize activity data[5].

2. We can dial in different level of granularity by choosing to use more bands or fewer bands.

3. The WRI uses a fuel-efficiency figure of 22.5 for all passenger car emissions factors. This is an outdated figure which would likely result in overstating emissions.

In this iteration, we adjusted our set of five activity subcategories from Table 5 to produce eight subcategories. We've increased the number of subcategories but our new set is likely to be easier to use and more accurate. We've conveniently brushed over CH_4 and N_2O emissions to get to this point, but, as noted previously, the average values that we're using will likely yield reasonable approximations since the overall contribution of these component gases is so small.

An Alternate Subcategorization

A study conducted for Scope 5 by Scott Salyer proposes a slightly different approach to subcategorizing activity data. In this approach, subcategories are also defined by bands but the bands correspond to a range of *model years* rather than fuel efficiency. Further, three separate sets of bands are identified—one for passenger vehicles, another for light trucks and a third for an overall light duty fleet.

Scott's approach requires a slightly greater number of activity subcategories than the five or eight that we proposed previously but it has the advantage of more faithfully accounting for CH_4 and N_2O emissions and is still simpler and much more accurate than the subcategorization suggested in the WRI's Table 12.

[5] Data management is made easier when it's easy for more stakeholders in the reporting chain to categorize an activity. It's made harder when no stakeholder can easily determine the appropriate category for a specific activity.

4.4 Fuel Volume Activity Data

We've been looking at calculating MCEs for our employee commute activity for which activity data is available in the form of distance-traveled. We've found that the dominant component of MCEs arise from CO_2, which depends on volume of fuel burned rather than distance traveled. As a result, our calculations have depended on subcategorizing our distance-traveled activity data by vehicle type or model year (as proxies for fuel efficiency) or by explicitly identifying bands of fuel efficiency.

It follows that without impractically fine-grain fuel-efficiency data (knowing the fuel efficiency at which each mile of our distance-traveled data was traveled) our MCE calculations are subject to quite a bit of error. We can get much more accurate results if activity data is available in the form of volume of fuel burned[6]. In certain cases, volume of fuel burned may actually be available. In these cases CO_2 emissions can be readily calculated using emissions factors from various sources, such as the WRI's Table 10 (illustrated in Figure 8) or Table 13.1 from The Climate Registry, illustrated below.

The Climate Registry

Table 13.1 US Default CO_2 Emission Factors for Transport Fuels

Fuel Type	Carbon Content (Per Unit Energy)	Heat Content	Fraction Oxidized	CO_2 Emission Factor (Per Unit Volume)
Fuels Measured in Gallons	kg C / MMBtu	MMBtu / barrel		kg CO_2 / gallon
Gasoline	19.150909	5.25	1	8.7775
Diesel Fuel	20.170909	5.796	1	10.20648
Aviation Gasoline	18.886364	5.04	1	8.31

Figure 9: TCR Emissions Factors by Volume of Fuel Burned

[6] CH_4 and N_2O emissions will be less accurate than they would be when the activity data is distance traveled but the contribution of these gases tends to be quite small.

When using activity data in the form of volume of fuel burned, total emissions in the form of CO_2e will be more accurate, however the contributions of CH_4 and N_2O will be elusive as these depend on distance traveled (and engine type) rather than fuel volume[7]. These can still be estimated by assuming fuel-efficiencies, in this case, to convert from volume of fuel burned to distance traveled. Alternatively, The Climate Registry offers a *simple estimation method (SEMS)* that can be used to estimate CH_4 and N_2O emissions given CO_2 emissions (see Figure 10).

The Climate Registry

Table 13.9 SEMS CH_4 and N_2O Emission Factors for Gasoline and Diesel Vehicles

GHG	MT GHG per MT of CO_2
CH_4	0.0000494
N_2O	0.0000353
Source: Derived from EPA Inventory of U.S. GHG Emissions and Sinks 1990-2012 (April 2014), Table 2-15. Only includes data for passenger cars and light-duty trucks.	

Figure 10: TCR's SEMS

CLOSING STATEMENTS

Calculating GHG emissions resulting from various activities is a complex undertaking. It's particularly complicated for mobile combustion emissions (MCEs), which present challenges in the variety of activity data that might be available or required. Deciding how to collect and categorize activity data is the first challenge. Converting that activity data to emissions is the second challenge.

We assume that the motivation to calculate MCEs arises from two underlying goals:

- To be able to communicate a reasonably accurate and defensible number to various stakeholders.

- To be able to identify opportunities to change behaviors such that emissions and costs can be reduced.

With these challenges and goals in mind, we've examined strategies for calculating MCEs, using a few specific examples. We hope that these help guide you, our readers, in a direction that helps you meet your goals in tackling MCEs for your organization.

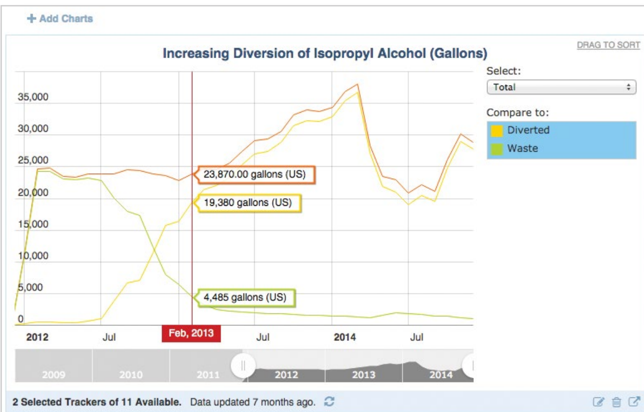
[7] Even when we had distance traveled activity data, CH_4 and N_2O emissions were challenging to calculate because of the practical constraints around categorizing according to engine type.

SCOPE 5

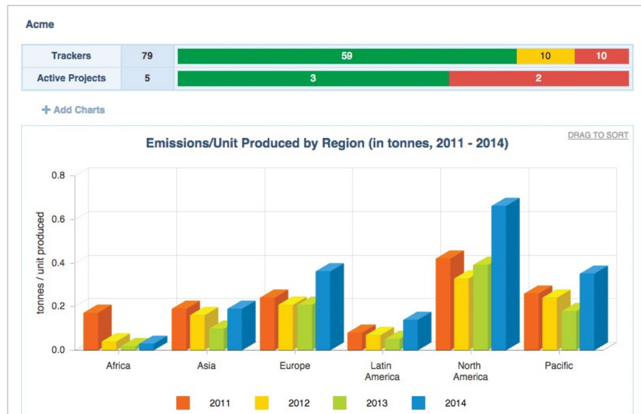
Scope 5 is a cloud-based software service that helps organizations of all types collect, structure, track, analyze and communicate their sustainability data, benefiting their top and bottom lines. In addition to using the service to produce GHG reports, many of our customers use ***Scope 5*** to go beyond reporting to identify opportunities and to communicate their progress to a variety of stakeholders.

Scope 5 includes resource libraries that put up-to-date emission factors from recognized authorities at your fingertips to make it easier for you to calculate your GHG emissions and to assure that your results are reliable and meaningful. ***Scope 5*** is intuitively and flexibly designed to be managed independently by your workforce talent or in conjunction with ours. We'd love the chacge to help make your data easy-to-use, convenient and work for you!

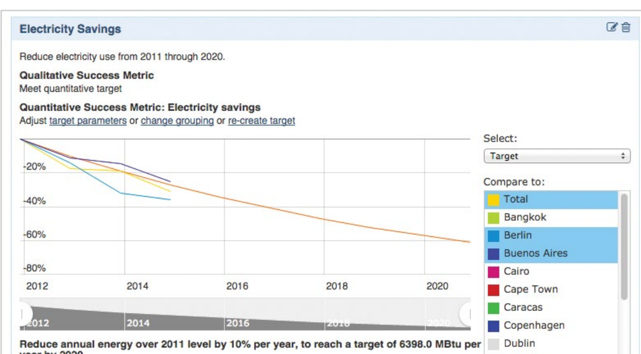
1 Capture and manage any activity data, whether environmental, social or governance.



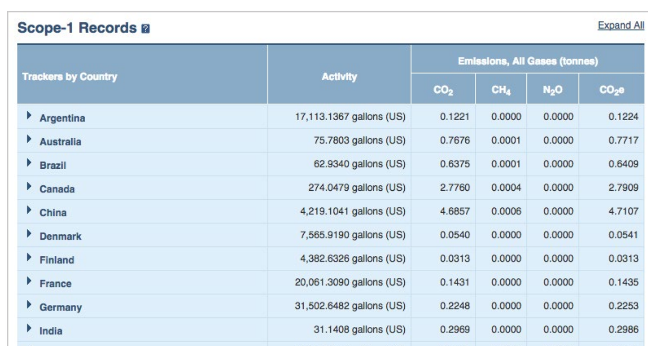
2 Calculate impacts of your activities such as greenhouse gas emissions, cost and other custom impacts.



3 Analyze your data to gain transparency and to identify opportunities to improve performance and save costs—demonstrate success!



4 Make reporting to the Carbon Disclosure Project, Global Reporting Initiative, B Corporation, and other reporting platforms easier.


Scope-1 Records

Expand All

Trackers by Country	Activity	Emissions, All Gases (tonnes)			
		CO_2	CH_4	N_2O	CO_2e
Argentina	17,113.1367 gallons (US)	0.1221	0.0000	0.0000	0.1224
Australia	75.7803 gallons (US)	0.7676	0.0001	0.0000	0.7717
Brazil	62.9340 gallons (US)	0.6375	0.0001	0.0000	0.6409
Canada	274.0479 gallons (US)	2.7760	0.0004	0.0000	2.7909
China	4,219.1041 gallons (US)	4.6857	0.0006	0.0000	4.7107
Denmark	7,565.9190 gallons (US)	0.0540	0.0000	0.0000	0.0541
Finland	4,382.6326 gallons (US)	0.0313	0.0000	0.0000	0.0313
France	20,061.3090 gallons (US)	0.1431	0.0000	0.0000	0.1435
Germany	31,502.6482 gallons (US)	0.2248	0.0000	0.0000	0.2253
India	31.1408 gallons (US)	0.2969	0.0000	0.0000	0.2986
Ireland	30,350.8532 gallons (US)	0.2166	0.0000	0.0000	0.2171