VCS Methodology

VM0028

Methodology for Carpooling

Version 1.0

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Sectoral Scope 7

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1 SOURCES

This methodology uses the latest version of the following tool:

- CDM *Tool to calculate the emission factor for an electricity system*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality	Project Method
Crediting Baseline	Project Method

This methodology provides procedures to estimate the avoided greenhouse gas (GHG) emissions from using carpools and vanpools for commuting to and from work as facilitated by the use of a carpool management application (CMA). This methodology is applicable only to carpools and vanpools used for commuting purposes; carpools or vanpools used for any other purpose are not eligible. GHG emission reductions are achieved through fewer single-occupancy vehicular trips that rely on fossil fuels or emission-intensive electricity for motive power.

Each carpool member must agree to run a CMA, which is a smartphone application used to track member and carpool vehicle information. The CMA must have the ability to record unique details about each carpool member, including historic routes to and from work and start and end points of commutes. Finally, the CMA must report trip details to a carpool server for occupancy and carpool membership detection and validation. Carpool servers hold the database of information relayed from the CMA about all carpool members and carpool trips.

Baseline emissions are quantified based upon the single-occupancy vehicular trips that would have taken place in the absence of the carpool. Project emissions are quantified by estimating the fuel consumption of eligible carpool trips. Monitoring is primarily based on the CMA's recordation of information about carpool members and trips.

3 DEFINITIONS

3.1 Defined Terms

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Baseline Emission Quantification Co-efficient (BEQC)
A number between 0 and 1 that represents how often a carpool member commutes by driving alone in the baseline scenario, assigned to a carpool member based on their commuting practice before joining the carpool program. BEQC adjusts the baseline emissions of a carpool member based on past commuting practice.

Carpool
A group of two or more people who share one or more vehicles during any part of their journey to and/or from work. Where referred to in this methodology, carpools also includes vanpools.

Carpool Management Application (CMA)
A software application that runs on a carpool member's smartphone, and that monitors and records trip information and reports it to the carpool server

Carpool Management and Monitoring System (CMMS)
A system consisting of carpool servers, smartphones running a CMA and OBDII dongles, which collectively enable carpool formation, management and GHG emissions monitoring

Carpool Member (Member)
An individual who participates in a carpool by providing rides with a carpool vehicle, receiving a ride from other carpool members, or both

Carpool Server (CS)
A computer system that records and manages data received from a CMA

Carpool Sub-trip
One of the following types of car trip:

- A trip by a carpool vehicle taken by one or more members of the carpool to reach a designated pick-up location
- A multi-occupancy trip by a carpool vehicle taken by members to the pick-up location of other member(s), or to the designated drop off location of one or more members, or both
- A trip by a carpool vehicle taken by the last member or members of a carpool to their final destination

Carpool Trip
The combination of one or more carpool sub-trips taken by members of a carpool to reach their final destination(s) from their point(s) of origin

Carpool Vehicle
A vehicle used in at least one carpool sub-trip

Community Area
A pre-defined geographic area(s) within which carpool activity monitoring takes place (eg, *Very Large Urban Area* and *Large Urban Area* as defined by Texas A&M Transportation Institute). The defined geographic area(s) need not be connected.

Fampool
A carpool consisting of carpool members who all reside within 200 meters of each other and commute to the same work address, or where all carpool members reside at the same residential address and commute to work addresses that are within 200 meters of each other

Fossil Fuel Vehicle (FFV)
A vehicle that relies on fossil fuel as a fuel source (eg, vehicles powered by gasoline, diesel, ethanol-gasoline mixed (E85) or compressed natural gas). Hybrid vehicles using fossil fuel as the single fuel source with regenerative braking to charge the battery are also included in this definition.

Herfindahl-Hirschman Index (HHI)

An indicator of the amount of competition among commuting modes within a specific community area derived from the market share of each commuting mode. The market share of a commuting mode is determined by the number of commuters using that commuting mode relative to that of all commuting modes within the community area.

On-Board Diagnostics II (OBDII)
On-Board Diagnostics specification, version 2 in North America. For this methodology, equivalent standards in Europe (European On Board Diagnostics - EOBD), Japan (Japan On Board Diagnostics – JODB) and Australia (Australian Design Rule 79/01-79/02, Australian OBD standard) are also referred to as OBDII. Additional standards are accepted under this definition if, at a minimum, the Vehicle Identification Number (VIN) can be directly obtained from the vehicle engine control unit (ECU).

OBDII Dongle
A device attached to the carpool vehicle's OBDII port that allows other devices to wirelessly connect to it and access the vehicle OBDII port. Wireless connection uses short range wireless technologies such as Bluetooth or WiFi. If a vehicle manufacturer traditionally supports wireless access to the vehicle ECU using Bluetooth or WiFi without the use of an externally connected OBDII dongle, such mechanism is also referred to as an OBDII dongle for the purpose of this methodology.

Plug-in Electric Vehicle (PEV)
A vehicle that runs on electric energy stored in on-board batteries and has no other source of external energy to propel the vehicle. Batteries are charged via electricity from the grid.

Plug-in-Hybrid Electric Vehicle (PHEV)
A vehicle that is similar to a plug-in electric vehicle, but also has a fuel tank to power the vehicle beyond the battery charge. The vehicle runs on the battery until the charge is lost, at which point the vehicle runs on an internal combustion engine and the battery to propel the vehicle. The battery may be charged through regenerative braking.

Pre-program Carpool Co-efficient (PCC)
A number between 0 and 1 that represents how often a carpool member commutes by carpooling in the baseline scenario, assigned to a carpool member based on their commuting practice before joining the carpool program

Residential Address
The address of a carpool member's residence, or address of a transit stop to which the carpool member travels and then drives to their work place in the baseline scenario

Single-Occupancy Baseline Trip Distance
The distance of the single-occupancy vehicular trip a member of a carpool would have taken in the baseline scenario. The distance of such trip is calculated as the shortest time or distance between commute start and endpoints as specified in Section 8.1.2.

Single-Occupancy Baseline Trip Vehicle
The vehicle that would be used by a member of a carpool for a single-occupancy vehicular trip in the baseline scenario

Work Address
The address of a carpool member's work place, or address of a transit stop to which a carpool member drives and then takes a follow-on journey on a transit system to their work place in the baseline scenario

3.2 Acronyms

BEQC Baseline Emission Quantification Co-efficient

CMA Carpool Management Application

CMMS Carpool Management and Monitoring System

ECU Engine control unit

FFV Fossil fuel vehicle

HHI Herfindahl-Hirschman Index

IMEI International Mobile Equipment Identity

OBD On board diagnostic

OBDII On board diagnostics specification, version 2

PCC Pre-program Carpool Co-efficient

PEV Plug-in electric vehicle

PHEV Plug-in-hybrid electric vehicle

SOBT Single-occupancy baseline trip

4 APPLICABILITY CONDITIONS

This methodology applies to project activities that reduce GHG emissions by using carpools for commuting to and from work, as facilitated by the use of a CMMS that enables a community of people to more effectively engage in carpooling.

This methodology is applicable under the following conditions:

1) Each carpool member must be registered with a CMMS and be uniquely identified via smartphone identity (eg, IMEI and/or phone number). The carpool member's residential address, work address and single-occupancy baseline trip (SOBT) vehicle must be registered and confirmed by the user biennially through the CMA.
2) All carpool vehicles must support OBDII interface.
3) Each carpool member must run a CMA during all carpool trips.
4) Each carpool member must own a private vehicle that is available for their commute and register that vehicle with the CMMS.
5) Each carpool sub-trip must start and end within one of the defined community areas, though the start and end community area may be different and need not be connected.

5 PROJECT BOUNDARY

The sources of GHG emissions included within the project boundary are (1) emissions from burning of fossil fuels by fossil fuel vehicles (FFVs) and plug-in-hybrid electric vehicles (PHEVs), (2) indirect emissions from off-site generation of electricity required for charging plug-in electric vehicles (PEVs) and PHEVs, and (3) indirect emissions from off-site generation of electricity required to run the carpool server(s). The GHG sources included in and excluded from the project boundary are shown in Table 1 below.

The spatial extent of the project boundary encompasses carpool vehicles and carpool servers. Not all carpool members need to be specifically identified at the project start date. For example, a project could be defined as "the first 10,000 members in the Boston metro area" or "employees of Company X in the San Francisco Bay area, Atlanta metro area, and Boston metro area".

Table 1: GHG Sources Included in or Excluded from the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Fossil fuel emissions from FFVs and/or PHEVs used in SOBTs	CO_2	Yes	Main emission source in the combustion of fossil fuel and electricity generation.
		CH_4	No	Minor source excluded for simplification; this is conservative

Source		Gas	Included?	Justification/Explanation
		N_2O	No	Minor source excluded for simplification; this is conservative
		Other	No	Not applicable
	Indirect fossil fuel emissions from electricity generation used for charging PHEVs and/or PEVs used in SOBTs	CO_2	Yes	Main emission source in the combustion of fossil fuel.
		CH_4	No	Minor source excluded for simplification; this is conservative
		N_2O	No	Minor source excluded for simplification; this is conservative
		Other	No	Not applicable
Project	Fossil fuel emissions from FFVs and/or PHEVs used in carpool trips	CO_2	Yes	Main emission source in the combustion of fossil fuel and electricity generation.
		CH_4	No	Minor source excluded for simplification.
		N_2O	No	Minor source excluded for simplification.
		Other	No	Not applicable
	Indirect fossil fuel emissions from electricity generation used for charging PHEVs and/or PEVs used in carpool trips	CO_2	Yes	Main emission source in the combustion of fossil fuel for electricity generation.
		CH_4	No	Minor source excluded for simplification.
		N_2O	No	Minor source excluded for simplification.
		Other	No	Not applicable
	Indirect fossil fuel emissions from electricity generation used for running the carpool servers	CO_2	Yes	Main emission source in the combustion of fossil fuel for electricity generation.
		CH_4	No	Minor source excluded for simplification.
		N_2O	No	Minor source excluded for simplification.
		Other	No	Not applicable

6 BASELINE SCENARIO

The baseline scenario is the most likely means by which a carpool member would have made their commute (ie, the trip from their residential address to their work address, and the trip from their work address to their residential address) in the absence of the project. To identify the most likely means by which a carpool member would have made their commute in the absence of the project, the commuting modes used in the last 12 months by the carpool member must first be specified at the time of registration with the CMMS. Such data must be updated where a member's work address, residential address or commuting vehicle ownership status changes. The carpool member must attest that all data provided is true, accurate and complete in all material respects. This attestation may be included as part of the terms and conditions of using the application or any other appropriate means.

Assuming members have had their current work and residential addresses for the last 12 months, the following information must be collected with respect to each season[1]:

a) Average number of (fractional) days per week commuting by driving alone

b) Average number of (fractional) days per week commuting by carpooling

c) Average number of (fractional) days per week using an alternative transport mode (ie, public transit, taxicab, motorcycle, walking and bicycling) to commute

d) Average number of (fractional) days per week working from home

The steps below use the information gathered above to establish the baseline transport mode for the carpool member.

Step 1. Determination of PCC and BEQC

Determine PCC and BEQC for the carpool member using the following:

$$PCC_i = \frac{\sum_m C_{i,m}}{5 * M} \quad (1)$$

$$BEQC_i = \frac{\sum_m S_{i,m}}{5 * M} \quad (2)$$

Where:

PCC_i Pre-program carpooling co-efficient of carpool member i

[1] Seasons must be defined according to local climate. For example, spring, summer, fall and winter months (ie, March-May, June-Aug, Sept-Nov, Dec-Feb respectively) could be used as a demarcation of seasons for projects located in the Northeastern United States.

$BEQC_i$ Baseline emission quantification co-efficient of carpool member i

m Season identifier (eg, spring, summer, fall and winter)

M Number of seasons

i Individual carpool member identifier

$C_{i,m}$ Number of days per 5-day week that carpool member i carpools during season m

$S_{i,m}$ Number of days per 5-day week that carpool member i commute by driving alone during season m

Step 2. Determine the most likely means by which a carpool member would have made their commute in the absence of the project (ie, *driving alone*, *carpool*, *periodic carpool*, *alternative transport mode* or *work from home*), based on the following criteria:

a) Where an alternative transport mode (eg, public transit, walking or bicycling) is available, and travel time with such alternative is no more than 15 minutes longer than driving alone, as determined using mapping software such as Google Maps[2] (see Annex 1 for additional requirements on using Google Maps or similar software), the baseline transport mode for the member is *alternative transport mode*.

b) Where a carpool member does not register their commuting vehicle or does not own one, the baseline transport mode for the member is *alternative transport mode*.

c) Where a member's BEQC is less than 0.2, the baseline transport mode for the member is *work from home*.

d) Where a member's PCC is greater than BEQC, it is assumed that the member carpools periodically in the baseline scenario, and the baseline transport mode for the member is *periodic carpool*.

e) Where a member's PCC is greater than or equal to 0.8, it is assumed that the member always carpools in the baseline scenario, and the baseline transport mode for the member is *carpooling only*.

f) Where a member's BEQC is greater than or equal to PCC, the baseline transport mode for the member is *driving alone.*

Only individuals whose baseline scenario is *driving alone* or *periodic carpool* may be included in the project; all other individuals must be excluded from the quantification of emission reductions.

Note that an ineligible member's participation in any sub-trip does not render the entire sub-trip ineligible; eligible members included in such sub-trip may still be included in the quantification of emission reductions. In addition, where a previously ineligible member demonstrates that their commuting practices in the past 12 months have changed such that they now exhibit an eligible baseline scenario, such members may be added to the project.

[2] Software available at www.google.com/maps

7 ADDITIONALITY

This methodology uses a project method for demonstrating and assessing additionality of the project. The project proponent must follow the three-step procedure set out below for this purpose. Where multiple community areas are included in the project, a separate analysis must be undertaken for each community area and only community areas meeting the criteria set out below may be included as part of the project.

Step 1. Regulatory Surplus

The project proponent must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard.*

Where carpooling is not mandated by relevant laws, statutes, policies or other regulatory frameworks within the community area, proceed to Step 2. Where carpooling is mandated by relevant laws, statues or other regulatory frameworks within the community area, the project activity is not additional.

Step 2. Implementation Barriers

Carpooling as facilitated by use of a CMMS within a community area may face a variety of barriers to implementation. The project proponent must demonstrate the existence of one or more barriers that it faces and describe how the additional revenues associated with the sale of VCUs can help to overcome the barrier. The *VCS Standard* sets out three types of barriers, and the project proponent should identify and describe only the relevant and credible barriers they face from the list below:

- Investment barriers (eg, lack of funding for the development and implementation of application software purposed for the formation of carpool programs; sources of capital investment for similar project activities have primarily been from grants or on other non-commercial finance terms)
- Technological barriers (eg, development of software solution to facilitate the formation of carpool programs faces greater implementation risks than conventional approaches to carpool formation; novelty and complexity of software solution increases development risks)
- Institutional barriers (eg, limited inherent interest in carpooling from individuals or companies, due to low desirability of carpooling; lack of incentives to encourage a shift in commuting practices from driving alone to carpooling (eg, employer does not provide dedicated parking spot for carpool vehicles))

Where the project proponent demonstrates the existence of one or more barriers within a community area, and is able to describe how the additional revenues associated with the sale of VCUs can help to overcome the barrier, proceed to Step 3. Where the project proponent is not

able to demonstrate the existence of at least one barrier within the community area, the project activity is not additional.

Step 3. Common Practice

The following two steps must be followed to demonstrate that the project activity is not common practice within a community area:

Step 3-A. Demonstration of Dominant Commuting Modes within a Community Area

Step 3-a is completed by calculating a Herfindahl-Hirschman Index (HHI)[3], which is used in economics to measure market competitiveness. The HHI must be used to determine whether the market (potential commuting modes within the community area) is an oligopoly or monopoly market dominated by few commuting modes. An HHI value of 2,500 or higher indicates that there are dominant commuting modes within a community area.

$$HHI = \sum M_k^2 \quad \textbf{(3)}$$

Where:

HHI Measurement of market competiveness

M_k Percentage market share of commuting mode k (percent)

Percentage market share of a commuting mode must be established using data from a recognized, credible source and such data must be reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.

Step 3-B. Demonstration that Carpooling is Not a Dominant Commuting Mode within a Community

Step 3-b must be completed using the square of market share values for various commuting modes. Specifically, a mode is a dominant mode where:

1) The mode has the highest market share of all modes; or
2) The sum of the square of the market shares of all the modes with market share greater than the mode in question is <2,500. For example, in a community area where mode A represents 40 percent of the commuting practices and mode B represents 60 percent of the commuting practices, to determine whether mode A is a dominant mode, all modes with larger market share (ie, mode B) must be squared and added together. In this

[3] Herfindahl index (HHI): http://www.justice.gov/atr/public/guidelines/hhi.html

example, 60^2 is 3600, which is greater than 2,500, meaning that mode A is not a dominant mode.

If carpooling is not a dominant commuting mode, it is not considered common practice.

To illustrate step 3 above, using the online tool on the United States census website[4] and data from the *2012 American Community Survey 1-year Estimate, for New York-Northern New Jersey-Long Island NY-NJ-PA metro area* study, the market share of different commuting modes in the NY-NJ-PA metro area may be derived, as shown in Table 2 below.

Table 2: Data from 2012 American Community Survey 1-year Estimate for New York-Northern New Jersey-Long Island metro area

	New York-Northern New Jersey-Long Island, NY-NJ-PA Metro Area	
	Estimate	Margin of Error
Total:	8,822,701	+/-28,922
Car, truck, or van:	4,989,077	+/-32,665
Drove alone	4,394,811	+/-30,999
Carpooled:	594,266	+/-16,108
In 2-person carpool	440,494	+/-14,236
In 3-person carpool	82,577	+/-5,349
In 4-or-more-person carpool	71,195	+/-5,307
Public transportation (excluding taxicab)	2,739,141	+/-22,580
Walked	538,986	+/-13,357
Taxicab, motorcycle, bicycle, or other means	191,038	+/-8,080
Worked at home	364,459	+/-9,627

Using the data in Table 2 above, and by converting numerical values into percentages, ignoring error margin and combining all “carpooled” types, the percentage market share of each commuting mode may be derived, as shown in Table 3 below.

Table 3: Percentage market share of commuting modes in NY-NJ-PA metro area

NY-NJ-PA Metro	Percentage
Drove alone	49.81%
Public transportation (excluding taxicab)	31.05%
Carpooled	6.74%

[4] US Census online tool: http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

Walked	6.11%
Worked at home	4.13%
Other means	0.90%
Taxicab	0.63%
Bicycle	0.57%
Motorcycle	0.06%
Total:	100%

Using the percentage market share of each commuting mode, an HHI of 3,546 for commuting modes in the NY-NJ-PA metro area can be calculated, as illustrated below.

$$HHI_{ny} = \sum 49.8^2 + 31^2 + 6.74^2 + 6.11^2 + 4.13^2 + .9^2 + .63^2 + .57^2 + .06^2 = 3546$$

Since the HHI is greater than 2,500, this indicates that there are dominant commuting modes within the NY-NJ-PA metro area (step 3-a). In addition, since the sum of the square of the market shares of all the modes with market share greater than carpooling is >2500 ($49.8^2 + 31^2 = 3441$), carpooling is not considered a dominant mode (step 3-b).

Where the project proponent demonstrates that carpooling is not common practice in the community area, the project is additional. Where the project proponent is not able to demonstrate that the project is not common practice, the project activity is not additional.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

The baseline emissions of a specific carpool trip are calculated after the trip has been completed. The identity of carpool members who participated in a carpool trip must be recorded by the CMMS, and the baseline emissions are calculated assuming that in the absence of the carpool trip, each eligible carpool member would have undertaken a SOBT. Baseline emissions for a specific carpool trip are calculated by summing emissions from all carpool trips.

8.1.1 Carpool Membership Set

For each carpool trip, the carpool membership set consists of people who travelled together in at least one carpool sub-trip. Each carpool member of the set must be uniquely identified in the CMMS by an assigned number linked to their smartphone (eg, International Mobile Equipment Identity (IMEI), ESN, Mobile Equipment Identifier (MEID)), username and password, a security association (eg, Facebook login token) and/or phone number.

$$N_{y,t} = \bigcup_{j \in S_{y,t}} N_j \quad (4)$$

Where:

$N_{y,t}$ Membership set of a carpool associated with carpool trip *t* in year *y*

$S_{y,t}$ Set of carpool sub-trips in carpool trip *t* in year *y*

N_j Carpool sub-trip j membership set (ie, set of occupants *i* on sub-trip *j*)

j Particular carpool sub-trip identifier

i Individual carpool member identifier who travelled in trip *t* in year *y*

8.1.2 Baseline Emissions Estimate for a Member of a Carpool Trip

In the absence of the carpool trip, it is assumed that each member of the carpool would have taken two individual, single-occupancy car trips. The first would be from their registered residential address to their registered work address, and the second would be to their registered residential address from their registered work address. Each of these individual trips is called a Single-Occupancy Baseline Trip (SOBT). Note that baseline emissions must be quantified separately for the trip to work and for the trip from work.

For each member in the carpool trip membership set, SOBT emissions ($BE_{i,ć}$) are the summation of emissions from fossil fuel consumption in the SOBT vehicle, and indirect emissions from electricity generation used for charging the SOBT vehicle.

The SOBT trip must be defined at the time of registration with the CMMS, and when a member updates their residential or work address. The SOBT trip must be defined as the route taking the least amount of time and which does not account for traffic. Where the CMMS is capable of obtaining the route which takes the least amount of time each time a member makes a carpool trip, such dynamic SOBT trip may be used as an alternative.

Where the carpool member's registered SOBT vehicle is a PEV, the equation below must be used to estimate the carpool member's baseline emissions:

$$BE_{i,ć} = D_i \cdot W_ć \cdot GE_p \quad (5)$$

Where:

$BE_{i,ć}$ Baseline emissions for carpool member *i* in SOBT vehicle *ć* (tCO_2e)

i Identifier for carpool member

D_i SOBT distance for carpool member i (km)

$W_ć$ Electric efficiency for SOBT vehicle identified by VIN number *ć* (kWh/km)

GE_p Electricity generation GHG emission factor corresponding to project community area *p*, adjusted for transmission loss, if available (tCO_2e/kWh)

Where the carpool member's registered SOBT vehicle is an FFV, the equation below must be used to estimate the carpool member's baseline emissions:

$$BE_{i,ć} = D_i \cdot V_ć \cdot EF_{f(c)} \quad (6)$$

Where:

$BE_{i,c}$ Baseline emissions for carpool member *i* in SOBT vehicle *ć* (tCO_2e)

i Identifier for carpool member

D_i SOBT distance for carpool member i (km)

$V_ć$ Vehicle fossil fuel efficiency for SOBT vehicle *ć* (L/km)

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number *c* (tCO_2e/L)

ć VIN of SOBT vehicle

Where the carpool member's registered SOBT vehicle is a PHEV, the equation below must be used to estimate the carpool member's baseline emissions:

$$BE_{i,ć} = max(0, D_i - R_ć) \cdot V_ć \cdot EF_{f(c)} + min(D_i, R_ć) \cdot W_ć \cdot GE_p \quad (7)$$

Where:

$BE_{i,c}$ Baseline emissions for carpool member *i* in SOBT vehicle *ć* (tCO_2e)

i Identifier for carpool member

D_i SOBT distance for carpool member i (km)

$R_ć$ Vehicle all-electric range for SOBT vehicle identified by VIN *ć* (km)

$W_ć$ Vehicle electric efficiency for SOBT vehicle identified by VIN *ć* (kWh/km)

GE_p Electricity generation GHG emission factor corresponding to project community area p, adjusted for transmission loss, if any (tCO_2e/kWh)

$V_ć$ Vehicle fossil fuel efficiency for SOBT vehicle *ć* (L/km)

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number c (tCO_2e/liter)

ć VIN of SOBT vehicle

8.1.3 Baseline Emissions for a Carpool Trip

The baseline emissions for a carpool trip are estimated as the summation of baseline emissions for each carpool member that participated in the carpool trip as follows:

$$BE_{y,t} = \sum_{i \in N_{y,t}} BEQC_i \cdot BE_{i,ć} \quad (8)$$

Where:

$BE_{y,t}$ Baseline emissions for a carpool trip *t* in year *y* (tCO_2e)

$N_{y,t}$ Membership set of a carpool associated with the carpool trip t in year y

$BEQC_{i,}$ Baseline emission quantification co-efficient of carpool member

$BE_{i,ć}$ Baseline emissions for carpool member *i* in SOBT vehicle *ć* (tCO_2e)

$ć$ VIN of SOBT vehicle

8.1.4 Baseline Emissions for Year *y*

Baseline emissions for year *y* are calculated by summing the baseline emissions of all carpool trips taken in year *y*.

$$BE_y = \sum_{t \in T_y} BE_{y,t} \quad (9)$$

Where:

BEy Baseline emissions for year *y* (tCO_2e)

T_y Set of all carpool trips in year *y*

$BE_{y,t}$ Baseline emissions for a carpool trip *t* in year *y* (tCO_2e)

8.2 Project Emissions

Project emissions are calculated from monitored data for each carpool trip. Project emissions for a specific carpool trip are calculated by summing emissions from all carpool sub-trips.

The emissions from each carpool sub-trip ($PE_{j,c}$) are estimated as the summation of emissions from burning fossil fuels in carpool vehicles and indirect emissions from electricity generation used for charging carpool vehicles. Note that project emissions must be quantified separately for the trip to work and for the trip from work.

A carpool trip where the carpool vehicle's internal systems are not functioning properly, as indicated by the check engine light or Malfunction Indicator Light (MIL) being on, or where the carpool vehicle does not have the OBDII dongle attached to its OBD port, is not eligible to be included in the quantification of emission reductions.

Where the carpool vehicle is a PEV, the equation below must be used to estimate project emissions for the carpool sub-trip *j*:

$$PE_{j,c} = d_j \cdot W_c \cdot GE_p \quad (10)$$

Where:

$PE_{j,c}$ Project emissions for carpool sub-trip *j* in vehicle identified by VIN number *c* (tCO_{2e})

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool trip

d_i CMA measured travel distance of carpool sub-trip *j* (km)

$W_{\acute{c}}$ Vehicle electric efficiency of a carpool vehicle identified by VIN number *c* (kWh/km)

GE_p Electricity generation GHG emission factor corresponding to project community area p, adjusted for transmission loss, if any (tCO_2e/kWh)

c VIN of carpool vehicle used in sub-trip *j*

Where the carpool vehicle is an FFV, and a fossil fuel consumption measurement is available over the OBDII interface during carpool sub-trip *j*, the equation below must be used to estimate project emissions for the carpool sub-trip *j*:

$$PE_{j,c} = FC_{j,c} \cdot EF_{f(c)} \quad (11)$$

Where:

$PE_{j,c}$ Project emissions for carpool sub-trip *j* in vehicle identified by VIN number c (tCO_2e)

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number *c* (tCO_2e /liter)

$FC_{j,c}$ Measured fuel consumption (or cubic feet for natural gas) over OBDII interface during carpool sub-trip j for a carpool vehicle identified by VIN number *c* (liters)

c VIN of carpool vehicle used in sub-trip *j*

Where the carpool vehicle is an FFV, but a fossil fuel consumption measurement is not available over the OBDII interface during carpool sub-trip *j*, the equation below must be used to estimate project emissions for the carpool sub-trip *j*:

$$PE_{j,c} = d_j \cdot V_c \cdot EF_{f(c)} \quad (12)$$

Where:

$PE_{j,c}$ Project emissions for carpool sub-trip *j* in vehicle identified by VIN number *c* (tCO_2e)

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool

d_j CMA measured travel distance of carpool sub-trip *j* (km)

V_c Vehicle fossil fuel efficiency of a carpool vehicle identified by VIN number *c*, (L/km)

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number *c* (tCO_2e/L)

c VIN of carpool vehicle used in sub-trip *j*

Where the carpool vehicle is a PHEV, and a fossil fuel consumption measurement is available over the OBDII interface during carpool sub-trip *j*, the equation below must be used to estimate project emissions for the carpool sub-trip *j*:

$$\boldsymbol{PE_{j,c} = FC_{j,c} \cdot EF_{f(c)} + min\left(d_j, \max(0, R_c - dd_{j,c})\right) \cdot W_c \cdot GE_p} \quad (13)$$

Where:

$PE_{j,c}$ Project emissions for carpool sub-trip *j* in vehicle identified by VIN number *c* (tCO_2e)

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool

$FC_{j,c}$ Measured fuel consumption (or cubic feet for natural gas) over OBDII interface during carpool sub-trip *j* for a carpool vehicle identified by VIN number *c* (liters)

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number *c* (tCO_2e/liter)

d_j CMA measured travel distance of carpool sub-trip *j* (km)

R_c Vehicle all electric range of a carpool vehicle identified by VIN number *c* (km)

$dd_{j,c}$ Cumulative distance travelled by a carpool vehicle c before sub-trip *j* within carpool trip *t* in year *y*

W_c Vehicle electric efficiency of a carpool vehicle identified by VIN number *c* (kWh/km)

GE_p Electricity generation GHG emission factor corresponding to project community area p , adjusted for transmission loss if any (tCO_2e /kWh)

c VIN of carpool vehicle used in sub-trip *j*

Where the carpool vehicle is a PHEV, but a fossil fuel consumption measurement is not available over the OBDII interface during carpool sub-trip *j*, the equation below must be used to estimate project emissions for the carpool sub-trip *j*:

$$PE_{j,c} = \begin{matrix} \left(\left(d_j - min\left(d_j, \max(0, R_c - dd_{j,c})\right)\right) \cdot V_c\right) \cdot EF_{f(c)} \\ + min\left(d_j, \max(0, R_c - dd_{j,c})\right) \cdot W_c \cdot GE_p \end{matrix} \quad (14)$$

Where:

$PE_{j,c}$ Project emissions for carpool sub-trip *j* in vehicle identified by VIN number *c* (tCO_2e)

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number *c* (tCO_2e/liter)

d_j CMA measured travel distance of carpool sub-trip *j* (km)

R_c Vehicle all electric range of a carpool vehicle identified by VIN number *c* (km)

$dd_{j,c}$ Cumulative distance travelled by a carpool vehicle c before sub-trip *j* within carpool trip t in year *y*

W_c Vehicle electric efficiency of a carpool vehicle identified by VIN number *c* (kWh/km)

V_c Vehicle fossil fuel efficiency of a carpool vehicle identified by VIN number *c* (l/km)

GE_p Electricity generation GHG emission factor corresponding to project community area p, adjusted for transmission loss if any (tCO_2 /kWh)

c VIN of carpool vehicle used in sub-trip *j*

Cumulative distance travelled by carpool vehicle c before sub-trip j is determined as follows:

$$dd_{j,c} = \sum_{\{j:j\in S_{y,t}, C(j)=c, j<j\}} d_j \quad (15)$$

Where:

$C(j)$ VIN number of vehicle used in sub-trip j

8.2.1 Project Emissions for Carpool Trip

The project emissions for a carpool trip *t* in year *y* ($PE_{y,t}$) are calculated as the summation of the project emissions for each carpool sub-trip *j* included in the carpool trip t as follows:

$$PE_{y,t} = \sum_{j\in S_{y,t}} PE_{j,c} \quad (16)$$

Where:

$PE_{y,t}$ Project emissions for a carpool trip t in year y (tCO_2e)

$PE_{j,c}$ Project emission for carpool sub-trip *j* in vehicle identified by VIN number *c* (tCO_2e)

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool

c VIN of carpool vehicle used in sub-trip *j*

8.2.2 Project Emissions from Off-site Generation of Electricity

Project emissions are calculated for the off-site generation of electricity for powering the central carpool server(s), which may or may not be owned and operated by the project proponent, using the equation below:

$$PE_{of,y} = \sum EC_{CS} \cdot GE_p \quad (17)$$

Where:

$PE_{of,y}$ Project emissions for off-site generation of electricity for powering central carpool servers (tCO_2e)

EC_{CS} Electricity consumption by the central carpools server(s) (kWh)

GE_p Electricity generation GHG emission factor corresponding to project community area p, adjusted for transmission loss if any (tCO_2 /kWh)

8.2.3 Project Emissions for Year *y*

Summation over all carpool trips in year *y* provides project emissions for year *y* (PE_y), as follows:

$$PE_y = \sum_{t \in T_y} PE_{y,t} + PE_{of,y} \quad (18)$$

Where:

PE_y Total project emissions for year y (tCO_2e)

$PE_{y,t}$ Project emissions for a carpool trip t in year y (tCO_2e)

$\boldsymbol{PE_{of,y}}$ Project emissions for off-site generation of electricity for powering central carpool servers (tCO_2e)

8.3 Leakage

Leakage is not considered an issue for this methodology, particularly because it is unlikely that individuals would move their commute outside the project boundary due to an increase in carpooling within the project boundary.

$$LE_y = 0 \quad (19)$$

Where:

LE_y Leakage emissions from the project in year *y* (tCO_2e)

8.4 Summary of GHG Emission Reductions and Removals

The net GHG emission reductions are quantified as a function of baseline emissions, project emissions and leakage, and the equation below must be used to estimate net GHG emission reductions for the project in year *y*:

$$ER_y = BE_y - PE_y - LE_y \quad (20)$$

Where:

ER_Y Net GHG emission reductions in year *y*

BE_Y Baseline emissions in year *y*

PE_y Project emissions in year *y*

LE_y Leakage in year *y*

9 MONITORING

9.1 Data and Parameters Available at Validation

Data Unit / Parameter	GE_p
Data unit	Tonnes of CO_2e per kWh
Description	Electricity generation GHG emission factor corresponding to project community area p
Equations	5, 7, 10, 13, 14, 16
Source of data	Data must be from a recognized, credible source and the data must be reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency. The emission calculator from the EPA may be used for projects within the United States: http://www.epa.gov/cleanenergy/energy-resources/refs.html The most recent version of the CDM *Tool to calculate the emission factor for an electricity system* may be used when no published source is available. The project proponent must use the combined margin from this tool with preference being given to the weighted combined margin, if possible. Note that the units from the output of this tool must be converted to match the units of this parameter.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The United States EPA maintains its calculator based on extensive research
Purpose of data	Calculation of baseline and project emissions
Comments	

Data Unit / Parameter	$EF_{f(c)}$
Data unit	Tonnes of CO_2e per liter

Description	GHG emission factor of fuel used by vehicle identified by VIN *c*
Equations	6, 7, 11, 12, 13, 14
Source of data	Data must be from a recognized, credible source and the data must be reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency. The emission calculator from EPA may be used for projects within the United States: http://www.epa.gov/cleanenergy/energy-resources/refs.html
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The United States EPA maintains its calculator based on extensive research
Purpose of data	Calculation of baseline and project emissions
Comments	The appropriateness of this value must be reviewed at each project crediting period renewal

Data Unit / Parameter	R_c
Data unit	Kilometers
Description	All electric range of vehicle identified by VIN *c*
Equations	7, 13, 14
Source of data	Manufacturer or government published data. In the United States, values from the following website may be used: http://www.fueleconomy.gov
Valued applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The government or manufacturer published fuel economy value must be converted to kilometers to match the calculation units. Where city and highway values are provided by the source of the fuel economy data, the average of the two must be used.
Purpose of data	Calculation of baseline and project emissions
Comments	The value of this parameter must be established ex-post if the model of vehicle *c* was not released until after validation or if new vehicle models join the project after validation

Data Unit / Parameter	M_k
Data unit	Percent
Description	Percentage market share of commuting transport mode *k* in the carpool community area
Equations	3
Source of data	Data must be from a recognized, credible source and the data must be reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency. In the United States, the United States Census website may be used: http://factfinder2.census.gov.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The United States Census is an authoritative source of data. The online tool provides easy access to a specific population's commuting data for customizable geographic areas.
Purpose of data	Demonstration of additionality
Comments	

Data Unit / Parameter:	j
Data unit	Unitless
Description	Unique carpool sub-trip numerical identifier, assigned in a way so that the current sub-trip identifier is greater than that of all previous sub-trips within a specific carpool
Equations	4, 10, 11, 12, 13, 14, 15
Source of data	Member's CMA
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of data	Calculation of baseline and project emissions
Comments	

Data Unit / Parameter	m
Data unit	Unitless

Description	Season identifier
Equations	1, 2
Source of data	Project proponent
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The project proponent must justify the choice of the number of seasons
Purpose of data	Demonstration of additionality
Comments	

Data Unit / Parameter	p
Data unit	Unitless
Description	Geographic area (community area) within which all or part of carpool or SOBT trip takes place.
Equations	5, 7, 10, 13, 14, 16
Source of data	Project proponent
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of data	Demonstration of additionality
Comments	

9.2 Data and Parameters Monitored

Data Unit / Parameter	V_c
Data unit	Liters per kilometer
Description	Fossil fuel efficiency of carpool vehicle identified by VIN *c*
Equations	12, 14
Source of data	Government or manufacturer public fuel economy statistics
Description of measurement methods and procedures to be applied	The government or manufacturer published fuel economy value must be converted to kilometers to match the calculation units. Where city and highway values are provided by the source of the fuel economy data, the average of the two must

	be used. In the United States, data may be available at: http://www.fueleconomy.gov.
Frequency of monitoring/recording	This parameter must be added when the carpool vehicle of a specific model, make and year is not present in CMMS
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	The value of this parameter must be established *ex-post* if the model of vehicle *c* was not released until after validation or if new vehicle models join the project after validation

Data Unit / Parameter	W_c
Data unit	kWh per kilometer
Description	Electric efficiency of a carpool vehicle identified by VIN *c*
Equations	10, 13, 14
Source of data	Government or manufacturer public fuel economy statistics
Description of measurement methods and procedures to be applied	The government or manufacturer published fuel economy value must be converted to kilometers to match the calculation units. Where city and highway values are provided by the source of the fuel economy data, the average of the two must be used. In the United States, data available at http://www.fueleconomy.gov may be used.
Frequency of monitoring/recording	This parameter must be added when the carpool vehicle of a specific model, make and year is not present in CMMS
QA/QC procedures to be applied	None
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	The value of this parameter must be established *ex-post* if the model of vehicle *c* was not released until after validation or if new vehicle models join the project after validation

Data Unit / Parameter	$FC_{j,c}$

Data unit	Liters
Description	Fossil fuel consumption for sub-trip *j* in vehicle *c*
Equations	11, 13
Source of data	Member's CMA
Description of measurement methods and procedures to be applied	The CMA running on member's smartphone programmatically queries the vehicle's ECU over OBDII interface for various fuel cycle parameters to monitor fossil fuel consumption
Frequency of monitoring/recording	Every carpool sub-trip
QA/QC procedures to be applied	Check documentation supporting appropriateness of method used to calculate fuel consumption
Purpose of data	Calculation of project emissions
Calculation method	Based on reference 1 identified in Section 10 below, or based on a similar calculation method found in a study that was reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or published by a government agency
Comments	

Data Unit / Parameter	$V_{\acute{c}}$
Data unit	Liters per kilometer
Description	Fossil fuel efficiency of SOBT vehicle identified by VIN $\acute{c}$
Equations	6, 7
Source of data	There are two possible sources for this parameter, listed in order of preferred use: 1) Average of last 3 months of measured values 2) Government or manufacturer public fuel economy statistics
Description of measurement methods and procedures to be applied	Depending on the capabilities of the OBDII dongle, CMA, carpool member's smartphone and vehicle ECU, if measured values of fuel consumption and trip distance are available, the vehicle fossil fuel efficiency is calculated as the last 3 months of measured fuel consumption divided by trip distance. If measured values are not available, government or manufacturer values may be used. The government or manufacturer published fuel economy value must be converted to kilometers to match the calculation units. Where city and highway values are provided by the source of the fuel

	economy data, the average of the two must be used. In the United States, data may be available at http://www.fueleconomy.gov.
Frequency of monitoring/recording	Where measured values are available, measured fuel efficiency must be updated after every carpool trip of the member. Otherwise, only update when the model, make and year of SOBT vehicle was not present in CMMS.
QA/QC procedures to be applied	Verify that the CMAs and the CS software product is a released product, a released product with a patch or a beta version, and are at least within two major revisions of latest released code version supported on underlying hardware
Purpose of data	Calculation of baseline emissions
Calculation method	Where using the average of 3 months of data, individual values are obtained by dividing $FC_{j,c}$ by d_j
Comments	The value of this parameter must be established *ex-post* if the model of vehicle *c* was not released until after validation or if new vehicle models join the project after validation

Data Unit / Parameter	$W_{\acute{c}}$
Data unit	kWh per kilometer
Description	Electric efficiency of SOBT vehicle identified by VIN $\acute{c}$
Equations	5, 7
Source of data	Government or manufacturer public fuel economy statistics
Description of measurement methods and procedures to be applied	The government or manufacturer published fuel economy value must be converted to kilometers to match the calculation units. Where city and highway values are provided by the source of the fuel economy data, the average of the two must be used. In the United States, data available at http://www.fueleconomy.gov may be used.
Frequency of monitoring/recording	This parameter must be added when the carpool vehicle of a specific model, make and year is not present in CMMS
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comments	The value of this parameter must be established *ex-post* if the

	model of vehicle *c* was not released until after validation or if new vehicle models join the project after validation

Data Unit / Parameter	d_j
Data unit	Kilometers
Description	Distance travelled during sub-trip *j*
Equations	10, 12, 13, 14
Source of data	One or more members of the CMA
Description of measurement methods and procedures to be applied	The CMA running on each member's smartphone records geodetic coordinates at periodic intervals and reports to the CS as part of the trip report. Alternatively, the CMA may also query the carpool vehicle ECU to obtain the distance traveled.
Frequency of monitoring/recording	Every sub-trip
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	A carpool trip consists of associated sub-trips reported from one or more CMA. The CMA reports can be used to validate this sub-trip distance parameter.

Data Unit / Parameter	$dd_{j,c}$
Data unit	Kilometers
Description	Cumulative distance travelled by a carpool vehicle c before sub-trip *j* within carpool trip t in year *y*
Equations	13, 14
Source of data	One or more member's CMA
Description of measurement methods and procedures to be applied	The CMA running on each member's smartphone records geodetic coordinates at periodic intervals and reports to the CS as part of the trip report. Alternatively, the CMA may also query the carpool vehicle ECU to obtain the distance traveled.
Frequency of monitoring/recording	Every sub-trip
QA/QC procedures to be applied	N/A

Purpose of data	Calculation of project emissions
Calculation method	Determined as the sum of the distance of all carpool sub-trips prior to the current carpool sub-trip for a given carpool trip
Comments	

Data Unit / Parameter	$S_{i,m}$
Data unit	Unitless
Description	Number of days a carpool member i drove alone during seasons m before registering with carpool program
Equations	2
Source of data	Member registration process
Description of measurement methods and procedures to be applied	Members provide this information at the time of registration. Seasons must be defined according to local climate. For example, spring, summer, fall and winter months (ie, March-May, June-Aug, Sept-Nov, Dec-Feb respectively) could be used as a demarcation of seasons for projects located in the Northeastern United States. Number of days can be whole or fractional number between 0 and 5.
Frequency of monitoring/recording	Once at the time of registration
QA/QC procedures to be applied	Due to cost and privacy concerns, individual member review may not be feasible for validation/verification bodies to perform quality check. Instead, mean, variance and distribution of all or randomly sampled new member registration data for given year may be reviewed to ensure quality.
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comments	

Data Unit / Parameter	$C_{i,m}$
Data unit	Unitless
Description	Number of days a carpool member i commuted to work as part of a carpool during seasons m before registering with the carpool program

Equations	1
Source of data	Member registration process
Description of measurement methods and procedures to be applied	Members provide this information at the time of registration. Seasons must be defined according to local climate. For example, spring, summer, fall and winter months (ie, March-May, June-Aug, Sept-Nov, Dec-Feb respectively) could be used as a demarcation of seasons for projects located in the Northeastern United States. Number of days can be whole or fractional number between 0 and 5.
Frequency of monitoring/recording	Once at the time of registration
QA/QC procedures to be applied	Due to cost and privacy concerns individual member review may not be feasible for validation/verification bodies to perform quality check. Instead mean, variance and distribution of all or randomly sampled new member registration data for given year may be reviewed to ensure quality.
Purpose of data	Calculation of baseline scenario
Calculation method	N/A
Comments	

Data Unit / Parameter	c
Data unit	Unitless
Description	VIN of vehicle used for sub-trip j
Equations	10, 11, 12, 13, 14, 15
Source of data	One or more member's CMA
Description of measurement methods and procedures to be applied	A CMA running on a member's smartphone programmatically queries vehicle's ECU over OBDII interface for VIN of the carpool vehicle. Must be queried at periodic intervals and reported to the CS as a part of the trip report. At least one member's CMA must report the VIN of the carpool vehicle in every sub-trip.
Frequency of monitoring/recording	Every sub-trip
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions

Calculation method	N/A
Comments	A carpool trip consists of associated sub-trip reported from one or more CMA. Examine the CMA report to validate the sub-trip of the carpool vehicle's VIN.

Data Unit / Parameter	N_j
Data unit	Unitless
Description	Set of members i carpooling together in sub-trip j. Each member is identified using meta-data (eg, phone number or username).
Equations	4
Source of data	One or more member's CMA
Description of measurement methods and procedures to be applied	A CMA running on member's smartphone reports the wirelessly detected OBDII dongle ID associated to the carpool vehicle in the trip report. CS determines co-occupancy of members by checking for members who report the same OBDII device ID with appropriate timestamp.
Frequency of monitoring/recording	Every sub-trip
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comments	A carpool trip consists of associated sub-trip reports from one or more CMA. Examine CMA reports to validate sub-trip membership.

Data Unit / Parameter	D_i
Data unit	Kilometers
Description	Single-occupancy baseline trip distance of member i
Equations	5, 6, 7
Source of data	Mapping or navigational software (eg, Google Maps) or member provided
Description of measurement methods and procedures to be applied	Where CMMS is capable of obtaining the shortest time in-traffic route every time a member makes a carpool trip, such a dynamic SOBT trip distance may be used. Otherwise, SOBT

	trip distance along the shortest time with no traffic route must be used. Where the project proponent can justify that the shortest time distance cannot be established using a mapping software, this parameter may be based on member provided SOBT trip distance at time of registration.
Frequency of monitoring/recording	Where CMMS is capable, this parameter must be determined at start of the carpool trip. Otherwise, it must be determined at the time of registration and again when a member updates their residential or work address.
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comments	

Data Unit / Parameter	$S_{y,t}$
Data unit	Unitless
Description	Set of sub-trips making up carpool trip t in year y
Equations	4
Source of data	One or more member's CMA
Description of measurement methods and procedures to be applied	The CMA running on a member's smartphone records geodetic co-ordinates and/or the detected OBDII device ID attached to the vehicle and corresponding timestamp at periodic intervals for the trip report. Upon receiving the trip report, the CS determines the nature of sub-trip as: carpool multi-occupancy sub-trip, carpool single-occupancy sub-trip or not a carpool sub-trip.
Frequency of monitoring/recording	Every carpool trip
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	A carpool trip consists of associated sub-trip reports from one or more CMA. Examine all CMA reports to validate carpool trip.

Data Unit / Parameter	i
Data unit	Unitless
Description	CMMS assigned unique identifier for a member
Equations	1, 2, 4, 5, 6, 7
Source of data	Member registration process
Description of measurement methods and procedures to be applied	CMMS-assigned unique identifier for a member identified by username and password, social media security-token (eg, facebook), phone number and/or smartphone IMEI. The information to identify unique members (eg, username and password) must be obtained during registration and stored in CMMS.
Frequency of monitoring/recording	Once at the time of registration with the CMA
QA/QC procedures to be applied	N/A
Purpose of data	Determination of baseline scenario and calculation of baseline emissions
Calculation method	N/A
Comments	

Data Unit / Parameter	$\acute{c}$
Data unit	Unitless
Description	VIN of SOBT vehicle registered to member i
Equations	6, 7, 8
Source of data	Member registration process and/or wirelessly transmitted to the CMA via OBDII dongle
Description of measurement methods and procedures to be applied	During member registration process, where a member owns a private SOBT vehicle, an identifier assigned by CMMS for that SOBT vehicle based on vehicle registration number (ie, vehicle tag plate and/or license plate) and/or year, make, model and/or trim entered by the member. This identifier may be updated to actual vehicle VIN if member uses the same vehicle for carpooling and actual vehicle VIN is reported by CMA.
Frequency of monitoring/recording	At registration with the CMA and updated by the member as necessary.
QA/QC procedures to be	N/A

applied	
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comments	Where members do not use their SOBT vehicle for the carpool trips, actual vehicle VIN may not be available to obtain vehicle make, year and model from the VIN number. In such cases, where free or low cost programmatic interface to motor vehicle department registration is available, such facility may be used by project proponent or VVBs to verify the vehicle year, make and model provided by the member during registration.

Data Unit / Parameter	EC_{CS}
Data unit	kWh
Description	Electricity consumption of the central carpools server(s)
Equations	16
Source of data	Project proponent
Description of measurement methods and procedures to be applied	Where the CS hardware is owned and operated by the project proponent, the electricity consumption of the CS is either measured (eg, using an electricity meter), or estimated based on the rated power of the CS and its operating hours. Where the CS hardware is not owned or operated by the project proponent (ie, is deployed in public or private cloud), then the kWh attributable to the CS are estimated based on the server usage (or allocated server sizing) information. In case of public hosting, such information may be obtained from the invoices from the external CS service provider.
Frequency of monitoring/recording	Either monthly or dependent on the frequency of external CS service provider invoices
QA/QC procedures to be applied	Electric meter and usage logs, hardware or CS sizing documentation
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	

9.3 Description of the Monitoring Plan

The project proponent must establish, maintain and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling and analyzing data, parameters and other information important for quantifying and reporting GHG emissions.

Key data for calculating the baseline and project emissions must be centrally managed and stored by the project proponent.

Each carpool member participating in the project must download the CMA on their smartphone, and provide the following information:

1) Personal identifying information (eg, name, address, phone number, etc)
2) Details of one or more single-occupancy trip (SOBT):
    a) End-points (ie, residential and work addresses)
    b) Vehicle ID (ie, vehicle identification number (VIN))
    c) A carpool vehicle if that vehicle is only used for carpooling (eg, if an employer provided or arranged vans for vanpool).

The CMA running on a carpool member's smartphone must perform the following operations:

1) Detect and record identity of OBDII device in the vehicle. Medium Access Address (MAC address) uniquely identifies each OBDII device (other temper proof IDs may also be used).
2) Calculate and record time, distance and trip endpoints using smartphone geodetic function or querying vehicle ECU over OBDII device
3) When authorized, establish a wireless link to the OBDII device, query and record VIN, create a trip report that includes all required parameters and send it to the carpool server

The CMA may also estimate and record fuel consumption along trip endpoints by reading fuel cycle parameters from vehicle ECU through OBDII device. Depending on available fuel cycle parameters, fuel consumption is estimated using the most suitable method.

Upon receiving a trip report from two or more CMAs, the carpool server must establish the following:

1) The carpool membership set
2) The carpool GHG emissions based on carpool sub-trip's fuel consumption data reported by CMAs
3) Carpool sub-trip distance
4) Vehicle VINs combined with EPA/manufacturer fuel efficiency. Vehicle VIN enables determination of vehicle EPA/manufactures estimated fossil fuel efficiency to estimate fuel consumption when OBDII based fuel consumption is not reliable or feasible.
5) The baseline emissions by assuming SOBT trips in absence of the carpool trip, based on the membership set and their registered SOBTs

All monitored data for emission reduction calculations must be archived in a secure and retrievable manner for at least two years after the end of the project crediting period.

10 REFERENCES

Consumption calculation of vehicles using OBD data by Adriano Alessandrini, Francesco Filippi, Fernando Ortenzi, AT Centre For Transport and Logistics, University of Rome “La Sapienza” Accessed at: http://www.epa.gov/ttnchie1/conference/ei20/session8/aalessandrini.pdf

Herfindahl index (HHI): http://www.justice.gov/atr/public/guidelines/hhi.html

US Census online tool: http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

APPENDIX 1: USE OF GOOGLE MAPS OR SIMILAR SOFTWARE

Google Maps provides multiple route options between source and destination addresses with an estimate of travel time in current traffic conditions, travel time with no traffic and travel time with public transportation, walking or biking.

At the time of registration with the CMMS, or when an update to residence and/or work address is enacted by the member, the travel time and distance of the member's commute (ie, the trip from residential address to work, and back) may be obtained using Google Maps or similar software that is capable of providing the same information required by this annex. In order to obtain this information, the project proponent must select the route which provides the shortest travel time without traffic as the commuting route from the registered residential to the work address and the return trip. The travel time obtained from the commuting route must be compared with that from using public transportation, walking and biking (alternate transportation mode). Note that the query to Google Maps (or similar service) must be performed during typical member commute hours to obtain accurate and shorter travel times for the public transport modes. If the travel time using one of the alternate transportation modes is no more than 15 minutes compared to the commute using a car either to work or from work, *alternate transportation mode* is the mode of transportation in the baseline scenario for the member (see Section 6 above).

Where the CMMS is capable of querying services like Google Maps in real time during members' carpool trips, the CMMS may use the shortest in-traffic travel route as the SOBT route for the baseline scenario for the corresponding carpool trip. Note that the SOBT route is determined every time a carpool trip is made and may be different from time to time. This puts additional scalability requirement on CMMS and additional cost for the project proponent to subscribe to use some services. Results of such queries must be stored as part of the carpool trip data for review and data integrity checks.

DOCUMENT HISTORY

Version	Date	Comment
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