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Proposition 1B: Goods Movement Emission Reduction Program

Truck Stop Electrification (TSE) Emissions Benefits Calculator Directions and Methodology

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California Environmental Protection Agency

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To: User

This document includes directions for using the Truck Stop Electrification (TSE) Emissions Benefit Calculator to estimate the emission reductions and cost effectiveness of TSE projects identified in the Proposition 1B: Goods Movement Emission Reduction Program "Final 2013 Guidelines for Implementation". If you are interested in a project that is not included in this calculator or one of the other posted calculators, please contact us for guidance at the Goods Movement Hotline (916-444-6637). We recommend you print this document in color.

Background

The Proposition 1B Goods Movement Emission Reduction Program (Prop. 1B) provides incentives that help owners upgrade or replace diesel equipment and reduce emissions of particulate matter (PM), nitrogen oxides (NOx) and other air pollutants. For truck stops, distribution centers and warehouses, Prop. 1B funds can be used to upgrade facilities with connections for grid-based electrical power or connections for cabin comfort (e.g., heating and air conditioning). These upgrades reduce emissions by allowing trucks to plug into the grid or use a truck cabin window adapter, rather than running diesel engines to provide electricity or cabin comfort.

The Proposition 1B Truck Stop Electrification Emissions Benefit Calculator (TSE Calculator) allows a user to estimate the weighted emission reduction benefits of a proposed project. This document provides directions for using the TSE Calculator and describes the methodology to determine both emissions reductions and cost-effectiveness.

The TSE Calculator only yields emissions benefits for truck electrification infrastructure projects that are eligible for funding under the 2013 Proposition 1B Guidelines[1], including the following:

- Truck stops that provide only cabin comfort;
- Truck stops that provide both cabin comfort and connections for transport refrigeration units (TRUs or Reefers); and
- Distribution Centers/Intermodal Facilities that provide only TRU connections

Emissions reductions are estimated for both NOx and PM10 (particulate matter with an aerodynamic diameter less than or equal to a nominal 10 microns).

[1] Air Resources Board, "*Proposition 1B: Goods Movement Emission Reduction Program, Final 2013 Guidelines for Implementation*", January 2013, available at http://www.arb.ca.gov/gmbond/ .

Calculator Tabs

The TSE Calculator contains the following tabs. Each tab will be described in greater detail below.

Table 1: Summary of all the worksheets in the calculator

Worksheet Tab	Description
Directions	Provides directions on using the calculator to calculate emission reductions for various project options.
Benefits Summary	Contains a summary of the PM10 and NOx emission reductions, weighted emission reductions, and cost-effectiveness (CE) for each project. It also provides a summary of the total reductions and overall CE for all projects.
User Input Data	The applicant or the local agency inputs data on this tab for each project. These data are required for the emissions benefit estimation.
Conv Power Use to Occupancy	Converts annual power usage in Truck Stop Area or Distribution Center into the annual percent occupancy required by the TSE Calculator.
Examples	Contains sample projects with sample inputs.

"Directions" Tab

This tab provides directions on using the calculator to calculate emission reductions for various project options. Shown below are the available data fields, descriptions, and valid entries. Please note the following general directions:

- **ONLY INPUT DATA IN THE "INPUT DATA" TAB.**

Table 2: Data Fields and Descriptions

Data Field	Description
Project ID	Provide project a unique identification.
Calendar Year when operational	Choose from dropdown menu year when project will become operational.
Type of project	Only choose option from dropdown menu: • Truck stop area only cabin comfort • Truck stop area cabin comfort and TRU connection • Distribution Center/Intermodal Facility with only TRU connection
EXISTING CONDITIONS	**Number of Existing Parking Spaces**	Indicate total number of available parking spaces at truck stop area.
	Average daily time a parking space is used (hours)	Indicate average daily hours a parking space at the truck stop area is used by trucks.
	Average daily time a TRU operates while parked (hours)	Indicate average daily hours a parking space is used OR the average hours a TRU operates while loading/unloading at distribution center.

Table 3: Data Fields and Descriptions (continued)

	Data Field			Description
PROPOSED NEW PROJECT	**Number of Spaces to be Electrified**			Indicate number of spaces to be electrified.
	Projected Space Usage	**Annual percent occupancy for each year of project life**	**1**	**a) Truck stop area only cabin comfort:** Columns H-Q: provide the projected annual percent occupancy of trucks. **b) Truck stop area cabin comfort and TRU connection:** Columns H-Q: provide the projected annual percent occupancy of trucks. **c) Distribution Center/Intermodal Facility with only TRU connection:** Columns H-Q: no values should be enter for this option. Any value in these columns will be ignored.
			2	
			3	
			5	
			6	
			7	
			8	
			9	
			10	
	PROJECTED USAGE BY TRUs THAT CAN CONNECT TO GRID	**Annual percent occupancy for each year of project life**	**1**	**a) Truck stop area only cabin comfort** Columns R-AA: No values should be enter for this option. Any value in these columns will be ignored. **b) Truck stop area cabin comfort and TRU connection:** Columns R-AA: provide annual percent occupancy of TRUs that can use the electric grid. **c) Distribution Center/Intermodal Facility with only TRU connection:** Columns R-AA: provide annual percent occupancy of TRUs while loading/unloading at dock.
			2	
			3	
			5	
			6	
			7	
			8	
			9	
			10	

PROJECT COST	**Total Project Cost**	Enter total project eligible costs.
	Program Funds Requested	Total program funds requested.
	Other State Funds	Other State funding to be applied. For example, any funds from the $2 surcharge on vehicle registration under AB 923.

WARNINGS	Displays a message if requested funding or cost-effectiveness does not meet Program Guidelines.

"User Input Data" Tab

To estimate the emission reduction benefits for a proposed project, the user must enter information on the "User Input Data" tab of the TSE Calculator as shown below. This is the only tab where the user can enter data. If there is a potential problem regarding the input data, the last column "Warnings" will contain a note. Data fields and descriptions are described above in Table 2. The first three rows contain example data for each of the three project types.

Input Data for Equipment Projects

		Project Type Instructions
		For projects at truck rest stop areas that will only provide for driver cabin comfort, choose "Truck stop area only cabin comfort"
		For projects at truck rest stop areas with technology to provide cabin comfort for driver and electrical power (plug-in) TRU choose "Truck stop area cabin comfort and TRU connection"
		For projects at distribution centers/intermodal facilities projects that will only provide electrical power to operate TRUs at the docks choose "Distribution Center/Intermodal Facility with only TRU connection"
		For a project where the intention is to provide electrical power for TRUs at the docks and also to provide electrical power at a nearby parking area for TRUs (and potentially to trucks), must enter as two projects on separate rows in calculator. On one row choose "Distribution Center/Intermodal Facility with only TRU connection" and on the next row enter "Truck stop area cabin comfort and TRU connection". Enter the required information for each project in the corresponding row.
Project ID	**Calendar Year when operational**	**Type of project**
CC008	2014	Truck stop area only cabin comfort
CT008	2014	Truck stop area cabin comfort and TRU connection
BI008	2014	Distribution Center/Intermodal Facility with only TRU connection

EXISTING CONDITIONS		
Number of Existing Parking Spaces	**Average daily time a parking space is used (hours)**	**Average daily time a TRU operates while parked (hours)**
40	24	16
40	24	16
12		8.4

PROPOSED NEW PROJECT										
Number of Spaces to be Electrified	Projected Space Usage Annual percent occupancy for each year of project life									
	1	2	3	4	5	6	7	8	9	10
30	5%	5%	5%	5%	5%	10%	10%	10%	10%	10%
30	5%	5%	5%	5%	5%	10%	10%	10%	10%	10%
12										

PROPOSED NEW PROJECT									
PROJECTED USAGE BY TRUs THAT CAN CONNECT TO GRID Annual percent occupancy for each year of project life									
1	2	3	4	5	6	7	8	9	10
1%	1%	1%	1%	1%	2%	2%	2%	2%	2%
20%	40%	60%	80%	90%	90%	90%	90%	90%	90%

PROJECT COST			
Total Project Cost ($)	Program Funds Requested ($)	Other State Funds ($)	WARNINGS
$540,000.00	$15,000.00		
$1,200,000.00	$15,000.00		
$1,800,000.00	$85,000.00		

"Benefits Summary" Tab

The "Benefits Summary" tab contains an automatically updated table of the PM10 and NOx emission reduction benefits and cost-effectiveness by project name, project year, project type, and state investment for the entire contract life of that project. A summary of total emission reductions and overall cost-effectiveness for all projects is also provided at the top of this tab.

Emission Benefits Summary

This tab provides the emissions benefits (PM10 and NOx) for each proposed project. If "FALSE" or "N/A" or "#VALUE" or "0" appears in the table there is an invalid project entry.

Project ID	Calendar Year when operational	Type of project
CC008	2014	Truck stop area only cabin comfort
CT008	2014	Truck stop area cabin comfort and TRU connection
BI008	2014	Distribution Center/Intermodal Facility with only TRU connection

EXISTING CONDITIONS		
Number of Existing Parking Spaces	**Average daily time a parking space is used (hours)**	**Average daily time an operating TRU is parked (hours)**
40	24	16
40	24	16
12		8.4

PROPOSED NEW PROJECT										
Number of Spaces to be Electrified	PROJECTED SPACE USAGE									
	Annual percent occupancy for each year of project life									
	1	2	3	4	5	6	7	8	9	10
30	5%	5%	5%	5%	5%	10%	10%	10%	10%	10%
30	5%	5%	5%	5%	5%	10%	10%	10%	10%	10%
12										

PROPOSED NEW PROJECT									
PROJECTED USAGE BY TRUs THAT CAN CONNECT TO GRID									
Annual percent occupancy for each year of project life									
1	2	3	4	5	6	7	8	9	10
1%	1%	1%	1%	1%	2%	2%	2%	2%	2%
20%	40%	60%	80%	90%	90%	90%	90%	90%	90%

PROJECT COST			
Total Project Cost ($)	Program Funds Requested ($)	Other State Funds ($)	WARNINGS
$540,000.00	$15,000.00		
$1,200,000.00	$15,000.00		
$1,800,000.00	$85,000.00		

Baseline Emissions for Project life		Future Emissions for Project life		Emissions Reduced for Project Life		Weighted Emissions	Cost Effectiveness
NOx (lb)	PM (lb)	NOx (lb)	PM (lb)	NOx (lb)	PM (lb)	NOx+20*PM (lb)	(lb/$)
9,213.85	92.73	388.97	17.46	8,824.88	75.27	10,330.27	0.69
12,286.38	142.52	453.90	24.64	11,832.48	117.88	14,190.15	0.95
30,998.13	554.16	3,392.53	98.97	27,605.60	455.20	36,709.54	0.43
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Projected Annual Performance										Total
1 (hr)	2 (hr)	3 (hr)	4 (hr)	5 (hr)	6 (hr)	7 (hr)	8 (hr)	9 (hr)	10 (hr)	(hr)
13,140.0	13,140.0	13,140.0	13,140.0	13,140.0	26,280.0	26,280.0	26,280.0	26,280.0	26,280.0	197,100.0
13,140.0	13,140.0	13,140.0	13,140.0	13,140.0	26,280.0	26,280.0	26,280.0	26,280.0	26,280.0	197,100.0
7,358.4	14,716.8	22,075.2	29,433.6	33,112.8	33,112.8	33,112.8	33,112.8	33,112.8	33,112.8	272,260.8

Methodology

Accounting for Regulatory Requirements

The Prop. 1B Program funds projects that can achieve early or extra emission reductions which are not otherwise required by law or regulation. "Early" reductions are those that occur before a regulatory deadline takes effect and "extra" reductions are those that occur because the technology is cleaner than required by regulatory emission standards. The 2013 TSE Calculator has been designed to account for the following regulatory requirements and it only shows reductions that qualify as early or extra (i.e., "with rule").

- ARB's "Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling (Idling Rule)"[2], which was fully effective by January 2008.
- ARB's "Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate (TRU Rule)"[3], under which in-use performance standards are phased in from December 2009 to 2019.
- "Hours of Service of Drivers" under the Federal Motor Carrier Safety Regulations with updates that became effective in July 2013[4].

In California, the Idling Rule requires heavy-duty trucks to shut down after 5 minutes of idling. This requirement applies to all diesel-fueled commercial motor vehicles over 10,000 GVWR and licensed to operate on the highways, including non-California based vehicles [*Section §2485(c)(1)(A)*]. However, the rule allows a vehicle that is more than 100 feet away from a restricted area to be exempt from the 5-minute idling limit, if the primary diesel engine meets an optional NOx emission standard while idling [*Section §2485(d)(1)(A)*]. Alternative technologies, such as diesel-fueled auxiliary power systems, are also required to meet emission standards if operating past the 5-minute idling limit, to ensure that the exhaust emissions are not exceeding the emissions of a primary engine at idle [*Section §2485(c)(3)*]. Due to the requirements of the Idling Rule, the TSE Calculator assumes that the primary diesel engine will be shut down after 5 minutes of idling, unless the truck has an engine that meets the emission standards (model year 2008 or newer). The Calculator also assumes the truck will only idle for 5 minutes when the driver is preparing to leave.

Transport refrigerated units (TRUs or reefers) are not subject to the 5-minute idling limit, so they can continue running the TRU engine to preserve perishable goods while

[2] California Code of Regulations, Title 13, Division 3, Chapter 10, Section §2485.
http://www.arb.ca.gov/msprog/truck-idling/truck-idling.htm ;
http://www.arb.ca.gov/msprog/truck-idling/2485.pdf
[3] California Code of Regulations, Title 13, Division 3, Chapter 9, Section 2477.
http://www.arb.ca.gov/diesel/tru/tru.htm ;
http://www.arb.ca.gov/diesel/tru/documents/fro_10-16-12.pdf
[4] Code of Federal Regulations, Chapter 49, Subchapter B, Part 395.
http://www.fmcsa.dot.gov/rules-regulations/rules-regulations.htm

parked at truck stops or while loading/unloading at distribution centers/warehouses. However, ARB's TRU Rule requires existing and new TRU diesel engines to comply with emission performance standards based on the model year and calendar year. As these standards are being phased in, TRU engines get cleaner and the TSE Calculator reflects this by using emission factors that decline over time. The Calculator estimates emission reduction benefits by determining the difference between the baseline TRUs that run on diesel engines and TRUs that are equipped to plug into grid power at truck stops/distribution centers.

In addition to ARB regulations, the TSE Calculator also reflects the requirements contained in the Federal Hours of Service regulations which require drivers to be off-duty 10 consecutive hours after 11-14 hours continuous on-duty travel. The Calculator uses these time limits to estimate how long trucks will be connected to grid power.

Calculation Method and Equations

To estimate the emission reductions from a Prop. 1B project, the TSE Calculator determines the PM10 and NOx emissions during each year of the project for baseline operations with existing trucks/TRUs and future operations after the trucks/TRUs can plug into grid power. The difference between the baseline and future operations is the emissions reduction for each year and the annual reductions are summed up by pollutant to provide the total reductions over the full project life. To calculate the project's weighted emissions reduction benefit, the TSE Calculator uses the Carl Moyer Program protocol of weighting combustion PM emissions (essentially diesel PM) by a factor of 20, relative to NOx, to account for the greater health impacts of diesel PM. This protocol helps target incentive funding to the projects that will achieve the greatest reduction in health risk - a key focus of the Prop. 1B Program.

Provided below are basic equations being used in the TSE Calculator. Example calculations are provided in the Appendix.

(1) [Activity, hrs/day] =
[# of Parking spaces] x [Amt. of time parking space is used, hr/day] x [% of trucks/TRUs that plug into grid]

(2) [Emissions, lbs] = [Activity, hrs/day] x [Emission Factor, g/hr] x [1 lb/453.6 g]
(3) [Emissions reduction, lbs] = [Baseline Emissions, lbs] - [Future Emissions, lbs]
(4) [Total emissions reduction, lbs] = Σ [Emissions reduction, lbs] over the entire life of the project
(5) [Weighted emission reduction, lbs] = [Total NOx reduction, lbs] + [Total PM reduction x 20, lbs]
(6) [Cost-effectiveness, lbs/$] = [Weighted emission reduction, lbs] / [Total applicable State funding, $]

The TSE Calculator does not estimate any emission reductions from diesel-powered auxiliary power units (APUs). It is assumed that trucks equipped with compliant diesel APUs would continue to run them, rather than plug into grid power, and no emission reductions would be achieved.

Provided below are assumptions and detailed equations for each of the three project types.

- Truck stops that provide only cabin comfort;
- Truck stops that provide both cabin comfort and connections for transport refrigeration units (TRUs or Reefers); and
- Distribution Centers/Intermodal Facilities that provide only TRU connections

1. Truck stops that provide only cabin comfort

Under ARB's Idling Rule, the only trucks that can continue idling their primary diesel engines beyond 5 minutes are those with a MY2008 or newer engine that meets the emission performance standards. Therefore, these MY2008 or newer engines are the only ones that can provide "early or extra" emission reductions when they plug into grid power. The TSE Calculator uses the following assumptions to estimate emission reductions.

- Truck parks in space and idles for 5 minutes.
- After 5 minutes of idling:
    - Trucks with an engine older than MY2008 will shut down primary engine.
    - Trucks with engine MY2008 or newer can continue idling during their stay at the truck stop or plug into grid power.
- Truck remains in the parking space for at least 10 continuous hours to comply with the Federal Hours of Service regulation. The TSE Calculator allows the user to input times greater than 10 hours.
- Before leaving the parking space, truck will idle another 5 minutes.
- Baseline emissions assume that a MY2008 or newer diesel engine runs for 10 minutes (idling) plus 10 hours minus 10 minutes (during rest period).
- Future emissions assume that a MY2008 or newer diesel engine runs for 10 minutes (idling) then plugs into the grid for at least 10 hours minus 10 minutes (during rest period with emissions only from the generation of grid electricity).
- For the 10 minutes of idling, both Baseline and Future emissions use the exact same assumptions and generate the same emissions which cancel each other out. Since there are no emission reductions associated with the 10-minute idling period, the TSE Calculator does not include them in the emission reduction calculations.

Detailed equations are provided below.

1. Truck stops that provide only cabin comfort (contd.)

H =	the total hours that a parking space is occupied each day
$H,_{HOS}$ =	the hours spent during a trucker's rest period to comply with the Federal Hours of Service regulation (default is 10 hours)
[$H/H,_{HOS}$] =	the number of times that a parking space can be used each day (if [$H/H,_{HOS}$] < 1, this factor is replaced by 1)
N =	the number of parking spaces being electrified
$F,_{use}$ =	percentage occupancy for grid connections (% of trucks that will plug into grid power)
$P,_{MY2008}$	percentage of heavy heavy-duty trucks that will have a MY2008 or newer engine that meets the idling emission standards
$EF,_{MY2008}$ =	emission factor for MY2008 or newer diesel engines that meet the optional NOx standard in the Idling Rule, grams/hour
P,cabin	grid power requirement to provide cabin comfort, kW
EF,grid =	emission factor for grid electricity, grams/kW-hour

[Time period when emissions occur, hrs/space/day] = [Total time space is occupied] - [Time spent idling]
or [H] – {[$H/H,_{HOS}$] x [10 min idling / 60 min/hr]}

Baseline Emissions during rest period (diesel engine):

[Baseline emissions, lb/yr] =
[Time period, hrs/space/day] x [N] x [$F,_{use}$] x [$P,_{MY2008}$] x [$EF,_{MY2008}$ g/hr] x [1 lb/454 grams]x [365 days/yr]

Future emissions during rest period (electric grid):

[Future emissions, lb/yr] =
[Time period, hrs/space/day] x [N] x [$F,_{use}$] x [$P,_{MY2008}$] x [$P,_{cabin}$, kW] x [$EF,_{grid}$ g/kW-hr] x [1 lb/454 grams] x [365 days/yr]

[Emission Reductions, lb/yr] = [Baseline Emissions] – [Future Emissions]

2. Truck stops that provide both cabin comfort and TRU connections

- Truck parks in space. Both the primary diesel engine and the TRU diesel engine idle for 5 minutes.
- After 5 minutes of idling:
    - Trucks with an engine older than MY2008 will shut down primary engine.
    - Trucks with engine MY2008 or newer can continue idling during their stay at the truck stop or plug into grid power.
    - TRUs shut down their diesel engine if they are equipped to plug into grid power.
- Truck remains in the parking space for at least 10 continuous hours to comply with the Federal Hours of Service regulation. The TSE Calculator allows the user to input times greater than 10 hours.
- Before leaving the parking space, both the primary diesel engine and the TRU diesel engine idle for another 5 minutes.
- Baseline emissions assume that a MY2008 or newer primary diesel engine and a TRU diesel engine both run for 10 minutes (idling) plus at least 10 hours minus 10 minutes (during rest period).
- Future emissions assume that a MY2008 or newer primary diesel engine and a TRU diesel engine both run for 10 minutes (idling) then both plug into the grid for at least 10 hours minus 10 minutes (during rest period with emissions only from the generation of grid electricity).
- For the 10 minutes of idling, both Baseline and Future emissions use the exact same assumptions and generate the same emissions which cancel each other out. Since there are no emission reductions associated with the 10-minute idling period, the TSE Calculator does not include them in the emission reduction calculations.

Detailed equations are provided below.

2. Truck stops that provide both cabin comfort and TRU connections (contd.)

H =	the total hours that a parking space is occupied each day
$H,_{HOS}$ =	the hours spent during a trucker's rest period to comply with the Federal Hours of Service regulation (default is 10 hours)
[$H/H,_{HOS}$] =	the number of times that a parking space can be used each day (if [$H/H,_{HOS}$] < 1, this factor is replaced by 1)
N =	the number of parking spaces being electrified
$F,_{use}$ =	percentage occupancy for grid connections (i.e., % of trucks that will plug into grid power)
$F,_{TRU\text{-}use}$ =	percentage occupancy for TRU grid connections (i.e., % of TRUs that will plug into grid power)
$P,_{MY2008}$	percentage of heavy heavy-duty trucks that will have a MY2008 or newer engine that meets the idling emission standards
$EF,_{MY2008}$ =	emission factor for MY2008 or newer diesel engines that meet the optional NOx standard in the Idling Rule, grams/hour
$EF,_{TRU}$ =	emission factor for diesel TRUs, grams/hour
P,cabin	grid power requirement to provide cabin comfort, kW
P,TRU	grid power requirement to run TRU, kW
EF,grid =	emission factor for grid electricity, grams/kW-hour

[Time period when emissions occur, hrs/space/day] = [Total time space is occupied] - [Time spent idling]
or [H] – {[H/H,$_{HOS}$] x [10 min idling / 60 min/hr]}

Baseline Emissions during rest period (diesel engine):

[Baseline emissions, lb/yr] =
[Time period-Truck, hrs/space/day]x[N]x[1 lb/454 grams]x[365 days/yr]x[F,$_{use}$]x[P,$_{MY2008}$] x [EF,$_{MY2008}$ g/hr] +
[Time period-TRU, hrs/space/day] x [N]x[1 lb/454 grams]x[365 days/yr]x[F,$_{TRU\text{-}use}$] x [EF,$_{TRU}$ g/hr]

Future emissions during rest period (electric grid):

[Future emissions, lb/yr] =
[Time period-Truck, hrs/space/day] x [N] x [1 lb/454 grams] x [365 days/yr] x [F,$_{use}$] x [P,$_{MY2008}$] x [P,$_{cabin}$, kW] x [EF,$_{grid}$ g/kW-hr] +
[Time period-TRU, hrs/space/day] x [N] x [1 lb/454 grams] x [365 days/yr] x [F,$_{TRU\text{-}use}$] x [P,$_{TRU}$, kW] x [EF,$_{grid}$ g/kW-hr]

[Emission Reductions, lb/yr] = [Baseline Emissions] – [Future Emissions]

3. Distribution Centers/Intermodal Facilities that provide only TRU connections

- Truck parks at the distribution center. Both the primary diesel engine and the TRU diesel engine idle for 5 minutes.
- After 5 minutes of idling:
  - All trucks shut down the primary engine, regardless of engine model year. No grid power is available for cabin comfort.
  - TRUs shut down their diesel engine if they are equipped to plug into grid power.
- Truck remains parked at the distribution center for at least 2.4 hours which is the total estimated amount of time for loading/unloading[5].
- Before leaving the distribution center, both the primary diesel engine and the TRU diesel engine idle for another 5 minutes.
- Baseline emissions assume that all primary diesel engines run for only 10 minutes (idling) while the TRU diesel engine runs for 10 minutes (idling) plus at least 2.4 hours minus 10 minutes (during loading/unloading).
- Future emissions assume that all primary diesel engines run for only 10 minutes (idling); the TRU diesel engine runs for 10 minutes (idling), then plugs into the grid for at least 2.4 hours minus 10 minutes (during loading/unloading with emissions only from the generation of grid electricity).
- For the 10 minutes of idling, both Baseline and Future emissions use the exact same assumptions and generate the same emissions which cancel each other out. Since there are no emission reductions associated with the 10-minute idling period, the TSE Calculator does not include them in the emission reduction calculations.

Detailed equations are provided below.

[5] Air Resources Board. "Staff Report: Initial Statement of Reasons for Proposed Rulemaking, 2011 Amendments for the Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities where TRUs Operate"; August 2011; Appendix B, Table B-2, page B-4. http://www.arb.ca.gov/regact/2011/tru2011/truisor.pdf

3. Distribution Centers/Intermodal Facilities that provide only TRU connections (contd.)

H =	the total hours that a parking space is occupied each day
$H_{,TRU\ load}$ =	the hours spent during loading/unloading at a distribution center (default is 2.4 hours)
[$H/H_{,TRU\ load}$] =	the number of times that a parking space can be used each day (if [$H/H_{,TRU\ load}$] < 1, this factor is replaced by 1)
N =	the number of parking spaces being electrified
$F_{,TRU\text{-}use}$ =	percentage occupancy for TRU grid connections (i.e., % of TRUs that will plug into grid power)
$EF_{,TRU}$ =	emission factor for diesel TRUs, grams/hour
P,TRU	grid power requirement to run TRU, kW
$EF,grid$ =	emission factor for grid electricity, grams/kW-hour

[Time period for emissions estimate, hrs/space/day] = [Total time space is occupied] - [Time spent idling]
or [H] – {[$H/H_{,TRU\ load}$] x [10 min idling / 60 min/hr]}

Baseline Emissions during loading/unloading (diesel engine):

[Baseline emissions, lb/yr] =
[Time period, hrs/space/day] x [N] x [$F_{,TRU\text{-}use}$] x [$EF_{,TRU}$ g/hr] x [1 lb/454 grams] x [365 days/yr]

Future Emissions during loading/unloading (electric grid):

[Future emissions, lb/yr] =
[Time period, hrs/space/day] x [N] x [$F_{,TRU\text{-}use}$] x [$P_{,TRU}$, kW] x [$EF_{,grid}$ g/kW-hr] x [1 lb/454 grams] x [365 days/yr]

[Emission Reductions, lb/yr] = [Baseline Emissions] – [Future Emissions]

Data References and Assumptions

1. Emission Rates for Diesel Engines that Meet Optional NOx Standards – Under ARB's Idling Rule, engines that meet the optional NOx emission standard may continue idling after 5 minutes. These engines are assumed to be model year 2008 (MY2008) or newer and it is expected that they would normally be operated at high idle while parked at a truck stop *.

For NOx, the idling emission rate is equivalent to the emission standard of 30 grams NOx/hour. For PM10, the idling emission rate was obtained from ARB's EMFAC2011-HD model which estimates emissions for heavy duty vehicles[6]. The PM10 emission rate is a composite based on annual average high-idle emissions for heavy heavy-duty diesel trucks (T7 or Class 8) with engine model years of 2008 or newer.

To convert emission rates between Total PM, PM10 and PM2.5 we used ARB's PM Speciation Profile Code #425 [7]:

[PM10] = [Total PM] * 1.00
[PM2.5] = [Total PM] * 0.92

** Please note that these idling emission rates are only used to estimate baseline emissions for truck stops where MY2008 or newer engines continue idling after 5 minutes. For distribution centers, it is assumed that the facility owner will require all primary diesel engines to shut down after idling for 5 minutes - regardless of engine model year – to protect workers from exposure to diesel exhaust.*

2. Percentage of Diesel Engines that Meet Optional NOx Standards – Only a portion of trucks that visit truck stops will have MY2008 or newer engines which meet the optional NOx standard and allow them to continue idling after 5 minutes. To determine the percentage of trucks with MY2008 or newer engines, we used statewide population data from ARB's EMFAC2011-HD model[8] and the following equation:

$$\%\ \text{of Trucks with MY2008 or newer engine} = \frac{\text{Population of T7/Class 8 trucks with MY2008 or newer engine}}{\text{Total population of T7/Class 8 trucks}}$$

The results range from 28% in 2014, increasing to 100% by 2023. The TSE Calculator applies the appropriate percentage during each year of the 10-year project life.

[6] Idling emission rates by model year were obtained July 2013 from "EMFAC2011 Idling Emission Rates": http://www.arb.ca.gov/msei/modeling.htm#emfac2011_web_based_data

[7] ARB speciation Profiles are available at: http://www.arb.ca.gov/ei/speciate/speciate.htm . The reference document for Speciation Profile Code #425 is available at: http://www.arb.ca.gov/ei/speciate/r01t20/rf20doc/refnum20.htm .

[8] Truck population data was obtained February 2013 from "EMFAC2011 Emissions and Emission Rates (updated January 2013)": http://www.arb.ca.gov/msei/modeling.htm#emfac2011_web_based_data

3. Emission Rates for TRUs – Two sets of emission rates are used for transport refrigeration units (TRUs) – one for TRUs that stay at truck stops and one for those that visit distribution centers for loading/unloading. The emission rates are fleet averages based on the inventory developed for ARB's 2011 amendments for the TRU Rule and they reflect the Rule's benefits[9].

It is assumed that out-of-state trucks would be used for the long-haul (interstate) transport of refrigerated goods, so it's expected that the vast majority of TRUs at truck stops would be from out-of-state. Therefore, TRU emission rates for truck stop projects are based on out-of-state TRUs only. For distribution centers, it is assumed that all of the TRU categories shown below would be represented. In both cases, the emission rates were determined based on the California share of the total emissions as documented in the 2011 inventory.

Table 3. TRU Categories and Bins[10]

Truck Stops*	Distr. Ctrs.*	Category	Horsepower Bin	Principal Application or Use	CA Share
	X	CA- based TRU	25 - 50	Trailers based in California.	78%
	X		11 - 25	Refrigerated trucks used in California	100%
	X		<11	Refrigerated trucks and vans used in California	100%
X	X	Out-of-State TRU	25 - 50	Trailers used for long-haul or interstate commerce.	12%
	X	Generator sets	25 - 50	Trailers or containers based in California (generator sets provide electrical power to a non-integrated refrigeration unit)	78%
	X	Out-of-State Generator sets	25 - 50	Trailers or containers used for long-haul, interstate or international commerce.	12%

** An "X" indicates which TRU categories were included when determining emission rates for the TSE Calculator.*

[9] Emissions and activity data were obtained in February 2013 from the 2011 Transport Refrigeration Unit (TRU) Regulation - Background Materials on Air Emissions; 2011 Emissions Inventory (zip file); Scenario: Statewide by Equipment Type, Proposed Amendments: http://www.arb.ca.gov/msei/categories.htm#tru_category

[10] ARB; "Staff Report: Initial Statement of Reasons for Proposed Rulemaking, 2011 Amendments for the Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate"; August 2011; Table 2; http://www.arb.ca.gov/regact/2011/tru2011/truisor.pdf

4. Emission Rates for Grid Electricity – After trucks/TRUs shut down their engines and plug into grid power, we estimate emissions from the generation of grid electricity to provide that power. ARB staff determined incremental emission rates for grid electricity, based primarily on natural gas plants using an average between high load and low load. The estimated emission rates include adjustments for the phase-in of California's Renewable Portfolio Standard which requires 33% renewable energy by 2020.

Table 4: Estimated Incremental Emission Rates for Grid Electricity

Pollutant	Emission Rates (grams/Megawatt-hour)
PM2.5	13.319
PM10	14.477
NOx	27.429

5. Power Requirements for Trucks/TRUs that Plug Into Grid Electricity – To estimate the amount of grid power needed to provide cabin comfort and/or run a TRU, the TSE Calculator uses the following average values:

- For cabin comfort, trucks need 3.8 kW or 0.0038 MW [11]
- TRUs need 7.7 kW or 0.0077 MW [12]

[11] Antares Group Inc.; "Summary of Operations: Truck Stop Electrification Facilities on the New York State Thruway"; January 2005; prepared for the New York State Energy Research and Development Authority. Available at: http://www.nyserda.ny.gov/Publications/Research-and-Development-Technical-Reports/-/media/Files/Publications/Research/Transportation/i-90tsedemonstrationreportjan05.ashx

[12] Shurepower LLC; "Electric-Powered Trailer Refrigeration Unit Demonstration", page 4-9; December 20, 2007; prepared for the New York State Energy Research and Development Authority and the U.S. EPA Smartway Transportation Partnership. Available at http://www.shorepower.com/adeq-nyserda-final-report.pdf

Appendix

Example Calculations and Sample Inputs for the

Truck Stop Electrification Calculator

Appendix – Example Calculations and Sample Inputs

- Truck stops that provide only cabin comfort;
- Truck stops that provide both cabin comfort and connections for transport refrigeration units (TRUs or Reefers); and
- Distribution Centers/Intermodal Facilities that provide only TRU connections

Example Calculation #1: Truck Stop - Cabin Comfort Only

The proposed project would install electrification infrastructure in 30 parking spaces at a truck stop to provide cabin comfort only. It is expected that each space would be occupied 24 hours per day, but only 5% to 10% of the trucks would actually plug into grid power during their stay. The full project life is ten years – during years 1 to 5 assume 5% of trucks will plug in, then assume this will increase to 10% during years 6 to 10. The total project cost is $540,000 and the applicant is requesting Proposition 1B funding of $50,000.

Emission Rates

	Baseline (diesel engine)	Future (grid power)
PM2.5	0.0867 g/hr	0.0133 g/kW-hr
NOx	30 g/hr	0.0274 g/kW-hr

Percentage of Trucks with MY2008 or Newer Engines (by calendar year)

2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*
27.7%	37.8%	51.8%	56.8%	61.5%	65.2%	74.1%	85.4%	96.7%	100%

[Time period when emissions occur, hrs/space/day] = [Total time space is occupied] - [Time spent idling]
or [H] – {[H/H,$_{HOS}$] x [10 min idling / 60 min/hr]}

= [24 hr] – { [24 hr/10 hr] x [10 min idling / 60 min/hr] } = **23.6** hrs/space/day

(Note: If [H/H,$_{HOS}$] < 1, this factor is replaced by 1)

Baseline Emissions during rest period (diesel engine):

[Baseline emissions in 2014, lb/yr] =
[Time period, hrs/space/day] x [N] x [F,$_{use}$] x [P,$_{MY2008}$] x [EF,$_{MY2008}$ g/hr] x [1 lb/454 grams]x [365 days/yr]

[23.6 hrs/space/day] x [30 spaces] x [5%] x [27.7%] x [30 g/hr NOx] x [1 lb/454 g] x [365 days/yr] = **236.5** lbs/yr NOx

Future emissions during rest period (electric grid):

[Future emissions in 2014, lb/yr] =
[Time period, hrs/space/day] x [N] x [F,$_{use}$] x [P,$_{MY2008}$] x [P,$_{cabin}$, kW] x [EF,$_{grid}$ g/kW-hr] x [1 lb/454 grams] x [365 days/yr]

[23.6 hrs/space/day] x [30 spaces] x [5%] x [27.7%] x [3.8 kW] x [0.0274 g/kW-hr] x [1 lb/454 g] x [365 days/yr]
= **0.8** lb/yr NOx

[Emission Reductions] = [Baseline Emissions] – [Future Emissions] = 236.5 – 0.8 = **235.7** lbs/yr NOx

This process is repeated for the next nine years (project life is 10 years). Total NOx emission reductions are calculated by summing reductions for each of the ten years starting in 2014. The same process is repeated for PM2.5 emissions.

[Total NOx reduction, 2014-2023] =

[235.7 + 321.8 + 440.9 + 483.3 + 523.0 + 1108.8 + 1260.7 + 1452.8 + 1645.0 + 1701.7 lbs] = 9174 lbs NOx

[Total PM2.5 reduction, 2014-2023] =

[0.3 + 0.4 + 0.5 + 0.6 + 0.6 + 1.3 + 1.5 + 1.8 + 2.0 + 2.1 lbs] = 11.1 lbs PM2.5

[Weighted emission reduction, lbs] = [9174 lbs NOx] + [11.1 lbs PM2.5 x 20] = 9174 +222 =

9396 lbs or 4.7 tons over project life

Cost-effectiveness of each project is calculated by computing the total weighted emission reductions (NOx + 20*PM) over the project life and then dividing by the State contribution.

[Cost-effectiveness, lbs/$] = [9396 lbs] / [$50,000] = 0.19 lbs/$

The following would be the correct inputs for this project:

Project ID	Calendar Year when operational	Type of project
CC008	2014	Truck stop area only cabin comfort

EXISTING CONDITIONS		
Number of Existing Parking Spaces	Average daily time a parking space is used (hours)	Average daily time a TRU operates while parked (hours)
40	24	16

PROPOSED NEW PROJECT										
Number of Spaces to be Electrified	Projected Space Usage Annual percent occupancy for each year of project life									
	1	2	3	4	5	6	7	8	9	10
30	5%	5%	5%	5%	5%	10%	10%	10%	10%	10%

PROPOSED NEW PROJECT									
PROJECTED USAGE BY TRUs THAT CAN CONNECT TO GRID									
Annual percent occupancy for each year of project life									
1	2	3	4	5	6	7	8	9	10

PROJECT COST			
Total Project Cost ($)	Program Funds Requested ($)	Other State Funds ($)	WARNINGS
$540,000.00	$50,000.00		

Example Calculation #2: Truck Stop - Cabin Comfort & TRU

The proposed project would install electrification infrastructure in 30 parking spaces at a truck stop to provide both cabin comfort and connections for TRUs. It is expected that each space would be occupied 24 hours per day, but only 5% to 10% of the trucks would actually plug into grid power during their stay. For TRUs, it is assumed that only 1% to 2% will plug into grid power. The full project life is ten years – during years 1 to 5 assume 5% of trucks and 1% of TRUs will plug in, then assume this will increase to 10% (trucks) and 2% (TRUs) during years 6 to 10. The total project cost is and the applicant is requesting Proposition 1B funding of $15,000.

Emission Rates

	Baseline (diesel engine)	Baseline (diesel TRU)	Future (grid power)
PM2.5	0.0867 g/hr	from 2.84 to 0.23 g/hr*	0.0133 g/kW-hr
NOx	30 g/hr	from 69.70 to 49.44 g/hr*	0.0274 g/kW-hr

** Baseline emission rates for diesel TRUs at truck stops decline each year as the rule is implemented and the equipment becomes cleaner over time.*

Percentage of Trucks with MY2008 or Newer Engines (by calendar year)

2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*
27.7%	37.8%	51.8%	56.8%	61.5%	65.2%	74.1%	85.4%	96.7%	100%

[Time period when emissions occur, hrs/space/day] = [Total time space is occupied] - [Time spent idling]
or [H] – {[H/H,$_{HOS}$] x [10 min idling / 60 min/hr]}

= [24 hr] – { [24 hr/10 hr] x [10 min idling / 60 min/hr] } = **23.6** hrs/space/day for Truck
= [16 hr] – { [16 hr/10 hr] x [10 min idling / 60 min/hr] } = **15.7** hrs/space/day for TRU

(Note: If [H/H,$_{HOS}$] < 1, this factor is replaced by 1)

Baseline Emissions during rest period (diesel engine):

[Baseline emissions in 2014, lb/yr] =
[Time period-Truck, hrs/space/day] x [N] x [1 lb/454 grams] x [365 days/yr] x [F,$_{use}$] x [P,$_{MY2008}$] x [EF,$_{MY2008}$ g/hr] +
[Time period-TRU, hrs/space/day] x [N] x[1 lb/454 grams] x [365 days/yr] x [F,$_{TRU\text{-}use}$] x [EF,$_{TRU}$ g/hr]

[23.6 hrs/space/day] x [30 spaces] x [1 lb/454 grams] x [365 days/yr] x [5%] x [27.7%] x [30 g/hr NOx] +
[15.7 hrs/space/day] x [30 spaces] x [1 lb/454 grams] x [365 days/yr] x [1%] x [69.7 g/hr NOx] = **500.4** lbs/yr NOx

Future emissions during rest period (electric grid):

[Future emissions, lb/yr] =
[Time period-Truck, hrs/space/day] x [N] x [1 lb/454 grams] x [365 days/yr] x [F,$_{use}$] x [P,$_{MY2008}$] x [P,$_{cabin}$, kW] x [EF,$_{grid}$ g/kW-hr] +
[Time period-TRU, hrs/space/day] x [N] x [1 lb/454 grams] x [365 days/yr] x [F,$_{TRU\text{-}use}$] x [P,$_{TRU}$, kW] x [EF,$_{grid}$ g/kW-hr]

[23.6 hrs/space/day] x [30 spaces] x [1 lb/454 grams] x [365 days/yr] x [5%] x [27.7%] x [3.8 kW] x [0.0274 g/kW-hr] +
[15.7 hrs/space/day] x [30 spaces] x [1 lb/454 grams] x [365 days/yr] x [1%] x [7.7 kW] x [0.0274 g/kW-hr] = **1.6** lbs/yr NOx

[Emission Reductions, lb/yr] = [Baseline Emissions]–[Future Emissions] = 500.4–1.6 = **498.8** lbs/yr NOx

This process is repeated for the next nine years (project life is 10 years). Total NOx emission reductions are calculated by summing reductions for each of the ten years starting in 2014. The same process is repeated for PM2.5 emissions.

[Total NOx reduction, 2014-2023] = 12183 lbs NOx

[Total PM2.5 reduction, 2014-2023] = 50 lbs PM2.5

[Weighted emission reduction, lbs] = [12183 lbs NOx] + [50 lbs PM2.5 x 20] = 12183 +1000 = 13183 lbs or 6.6 tons over project life

Cost-effectiveness of each project is calculated by computing the total weighted emission reductions (NOx + 20*PM) over the project life and then dividing by the State contribution.

[Cost-effectiveness, lbs/$] = [13183 lbs] / [$15,000] = 0.88 lbs/$

The following would be the correct inputs for this project:

Project ID	Calendar Year when operational	Type of project
CT008	2014	Truck stop area cabin comfort and TRU connection

EXISTING CONDITIONS		
Number of Existing Parking Spaces	Average daily time a parking space is used (hours)	Average daily time a TRU operates while parked (hours)
40	24	16

PROPOSED NEW PROJECT										
Number of Spaces to be Electrified	Projected Space Usage Annual percent occupancy for each year of project life									
	1	2	3	4	5	6	7	8	9	10
30	5%	5%	5%	5%	5%	10%	10%	10%	10%	10%

PROPOSED NEW PROJECT									
PROJECTED USAGE BY TRUs THAT CAN CONNECT TO GRID									
Annual percent occupancy for each year of project life									
1	2	3	4	5	6	7	8	9	10
1%	1%	1%	1%	1%	2%	2%	2%	2%	2%

PROJECT COST			
Total Project Cost ($)	Program Funds Requested ($)	Other State Funds ($)	WARNINGS
$1,200,000.00	$15,000.00		

Example Calculation #3: Distribution Center – TRU Only

The proposed project would install electrification infrastructure in 12 parking spaces at a distribution center to provide connections for TRUs only. It is expected that each space would be occupied 8.4 hours per day, but the percentage of TRUs that would actually plug into grid power would range from 20% to 90% in years 5 to 10. The full project life is ten years – during years 1 to 4 assume 20%/40%/60%/80% of TRUs will plug in, then assume the percentage will be 90% during years 5 to 10. The total project cost is $1,800,000 and the applicant is requesting Proposition 1B funding of $85,000.

Emission Rates

	Baseline (diesel TRU)	Future (grid power)
PM2.5	from 2.82 to 0.35 g/hr*	0.0133 g/kW-hr
NOx	from 62.97 to 46.54 g/hr*	0.0274 g/kW-hr

** Baseline emission rates for diesel TRUs at distribution centers decline each year as the rule is implemented and the equipment becomes cleaner over time.*

[Time period for emissions estimate, hrs/space/day] = [Total time space is occupied] - [Time spent idling]
or [H] – {[H/H,$_{TRU\ load}$] x [10 min idling / 60 min/hr]}

= [8.4 hr] – { [8.4 hr/2.4 hr] x [10 min idling / 60 min/hr] } = **7.8** hrs/space/day for TRU

(Note: If [H/H,$_{TRU\ load}$] < 1, this factor is replaced by 1)

Baseline Emissions during loading/unloading (diesel engine):

[Baseline emissions in 2014, lb/yr] =
[7.8 hrs/space/day] x [12 spaces] x [20%] x [62.97 g/hr] x [1 lb/454 grams] x [365 days/yr] = **947.7** lb/yr NOx

Future Emissions during loading/unloading (electric grid):

[Future emissions, lb/yr] =
[Time period, hrs/space/day] x [N] x [F,$_{TRU\text{-}use}$] x [P,$_{TRU}$, kW] x [EF,$_{grid}$ g/kW-hr] x [1 lb/454 grams] x [365 days/yr]

[7.8 hrs/space/day] x [12 spaces] x [20%] x [7.7 kW] x [0.0274 g/kW-hr] x [1 lb/454 grams] x [365 days/yr] = **3.2** lb/yr NOx

[Emission Reductions, lb/yr] = [Baseline Emissions]–[Future Emissions] = 947.7–3.2 = **944.5** lbs/yr NOx

This process is repeated for the next nine years (project life is 10 years). Total NOx emission reductions are calculated by summing reductions for each of the ten years starting in 2014. The same process is repeated for PM2.5 emissions.

[Total NOx reduction, 2014-2023] = 27200 lbs NOx

[Total PM2.5 reduction, 2014-2023] = 413 lbs PM2.5

[Weighted emission reduction, lbs] = [27200 lbs NOx] + [413 lbs PM2.5 x 20] = 27200 +8260 = 35460 lbs or 17.7 tons over project life

Cost-effectiveness of each project is calculated by computing the total weighted emission reductions (NOx + 20*PM) over the project life and then dividing by the State contribution.

[Cost-effectiveness, lbs/$] = [35460 lbs] / [$85,000] = 0.42 lbs/$

The following would be the correct inputs for this project:

Project ID	Calendar Year when operational	Type of project
BI008	2014	Distribution Center/Intermodal Facility with only TRU connection

EXISTING CONDITIONS		
Number of Existing Parking Spaces	Average daily time a parking space is used (hours)	Average daily time a TRU operates while parked (hours)
12		8.4

PROPOSED NEW PROJECT										
Number of Spaces to be Electrified	Projected Space Usage Annual percent occupancy for each year of project life									
	1	2	3	4	5	6	7	8	9	10
12										

PROPOSED NEW PROJECT									
PROJECTED USAGE BY TRUs THAT CAN CONNECT TO GRID									
Annual percent occupancy for each year of project life									
1	2	3	4	5	6	7	8	9	10
20%	40%	60%	80%	90%	90%	90%	90%	90%	90%

PROJECT COST			
Total Project Cost ($)	Program Funds Requested ($)	Other State Funds ($)	WARNINGS
$1,800,000.00	$85,000.00		