Modeling Truck Idling Emissions in Central Texas

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ABSTRACT

The Capital Area Council of Governments (CAPCOG) represents 10 counties in Central Texas that include the counties that make up the Austin-Round Rock Metropolitan Statistical Area (MSA). CAPCOG has completed several research projects on truck idling in recent years in order to estimate the extent of idling activity and the effectiveness of idling restrictions and technologies in reducing emissions. In 2011 and 2012, CAPCOG collected over 200 hours of field observational data on both extended and short-term idling within the region, and conducted interviews with 118 truck drivers on idling activities and behavior. Analysis of the observational data, combined with extensive review of data collected from previous studies, enabled CAPCOG to develop updated idling profiles to model emissions from this activity within the region. Driver interviews provided data on market penetration of various idle reduction devices and CARB-certified low-nitrogen oxides (NO_X) idle engines. The driver interviews also indicated that drivers typically idle at a lower engine speed than MOVES2010 or MOVES2014 assume. The survey results provided data on levels of awareness and willingness to comply with idling restrictions and drivers' willingness to use idle reduction infrastructure. These survey results can be used to model the control effectiveness of idling reduction control measures.

INTRODUCTION

This study provides estimates of both extended and short-term truck idling activity and emissions estimates for an average 2012 ozone season weekday in an 11-county region of Central Texas that include Bastrop, Blanco, Burnet, Caldwell, Fayette, Hays, Lee, Llano, Milam, Travis, and Williamson Counties. Bastrop, Caldwell, Hays, Travis, and Williamson Counties make up the Austin-Round Rock Metropolitan Statistical Area (MSA). CAPCOG's estimates are based on extensive data collection, literature review, and analysis that CAPCOG undertook from 2011-2013 as part of three separate reports (CAPCOG 2013a, CAPCOG 2013b, CAPCOG 2013c). The first of these reports used observational data obtained in 2011 to develop extended idling emissions activity data for the 11-county region for 2006, 2008, and 2011 (CAPCOG 2013c). This report also included results and analysis of driver surveys conducted at local truck stops in 2011. The second report used new emissions inventory data obtained after 2011 to bring these extended idling estimates forward to 2012 and project them out to 2018 (CAPCOG 2013b). The third report used observational data collected by CAPCOG in conjunction with observational data collected in several prior studies in order to develop estimates on short-term idling activity at several different business types in the Austin-Round Rock MSA for 2005, 2007, 2015, 2025, and 2035 (CAPCOG 2013a).

The current paper summarizes the basic approaches CAPCOG used in prior studies and applies these approaches, along with new data and updated analysis, to obtain new estimates of 2012 ozone season day activity and emissions for the region. For the extended idling activity estimates, CAPCOG reviewed the extended idling locations for 2012, and subsequently adjusted the estimated extended idling surrogate data for a few counties. Since MOVES2014 takes a somewhat different approach to modeling extended idling activity and emissions than MOVES2010, this paper also includes estimates of diesel auxiliary power unit (APU) usage to better reflect the approach used in MOVES2014. For the short-term truck idling estimates, which use employment statistics as an activity surrogate in several key North American Industrial Classification (NAICS) industry codes, CAPCOG obtained 2012 employment data in order to develop contemporaneous short-term truck idling activity estimates. For extended idling emission rates, CAPCOG used emissions inventory data developed by the Texas Transportation Institute (TTI) for all 254 counties in Texas for 2006, 2012, and 2018 (TTI 2014). For short-term idling emissions rates, CAPCOG used a MOVES2010 sensitivity study (TTI 2011). This report presents these emissions inventory data, along with a summary of the main insights developed from the driver survey conducted in 2011. For this project, the driver survey was not directly used to calculate the truck idling activity data or emissions estimates. However, it did provide a quality check on several assumptions that the U.S. Environmental Protection Agency (EPA) uses for the MOVES model that strongly suggests that additional research on this activity type could be valuable in order to improve the accuracy and precision of estimating idling activity and emissions. This paper includes estimates for carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_X), fine particulate matter ($PM_{2.5}$), coarse particulate matter (PM_{10}), and volatile organic compounds (VOC).

LOCAL IDLING RESTRICTIONS

One of the main reasons that CAPCOG undertook these research projects was to provide local elected officials with locally representative data of idling activity and emissions in order to support regional air quality planning efforts. In 2012, all five of the county governments and a number of city governments in the Austin-Round Rock MSA enforced idling restrictions under the Texas Administrative Code (TAC) or local ordinances. EPA has incorporated 30 TAC, Part 1, Chapter 114, Subchapter J, Division 2: Locally Enforced Motor Vehicle Idling Limitations, into Texas's State Implementation Plan (SIP). Under these restrictions, vehicles with gross vehicle weight ratings of 14,001 pounds or more are not allowed to idle for more than five consecutive minutes, although a number of important exemptions applied. These include:

- Use of an idling to power a heater or air conditioner while a driver is using a sleeper berth for a government-mandated rest period if the truck is not within two miles of a facility that offers external heating and air conditioning (except from September 2009 – mid-August 2011);
- Use of engine for heating/cooling while employee is performing an essential job function related to roadway construction or maintenance;
- Use of a vehicle's engine to provide mechanical power (such as to power-take-off device) and/or passenger compartment heating or air conditioning;
- Armored vehicles; and
- Military, national guard, reserve forces, law enforcement, and emergency vehicles.

For conducting an inventory of idling activity in the region, it is valuable to understand both the total extent of "off-network" idling (occurs off of the roadway network and distinct from idling that occurs when a vehicle is temporarily stopped at an intersection or in heavy traffic) and the portion of that idling that could theoretically be reduced through compliance with the region's idling restrictions. Improved compliance with these restrictions or deployment of idle reduction technologies can be used in transportation planning efforts to meet transportation conformity budgets or as emission reduction measures for a SIP if the region is ever designated nonattainment for ozone. Since the exemption for extended idling only applies if there are not heating/cooling hook-ups available within two miles, it is useful to also assess the extent to which this activity could be reduced through technological solutions.

EPA'S APPROACH TO ESTIMATING EXTENDED IDLING EMISSIONS

In the past 11 years, EPA's approach to modeling truck idling emissions has become increasingly detailed, and it has updated its on-road emissions models accordingly.

EPA's 2004 Guidance

EPA's 2004 *Guidance for Quantifying and Using Long Duration Truck Idling Emission Reductions in State Implementation Plans and Transportation Conformity* outlined a set of steps and assumptions that states could use to estimate truck idling emissions using MOBILE6 (EPA 2004a). As EPA describes in the guidance document, "some fraction of long duration truck idling emissions are included in emissions inventories based on MOBILE6 estimates through the model's use of conversion factors, but these emissions are not a distinct and separate category." In this guidance document, EPA identified two different types of idling:

1) Idling by long-haul drivers in their sleeper compartment that can occur for hours at a time (extended idling); and
2) Idling that occurs when truck drivers wait in a queue at a border crossing or port, or while waiting to load or unload their truck (short-term idling).

To some extent, EPA's 2004 guidance document covered both of these types of idling. "Long duration idling" is simply defined as as "the operation of a truck's propulsion engine when not engaged in gear for a period greater than 15 consecutive minutes, except when associated with routine stoppages due to traffic movement or congestion," regardless of whether it is for mandatory rest periods or while waiting for a delivery or in a queue. EPA reviewed fuel consumption data for different truck types, and estimated that long-duration idling accounted for no more than 3.4% of total emissions from Class 8 trucks (trucks with gross vehicle weight ratings of over 33,000 pounds) for any criteria pollutant or precursor. EPA used emissions rates of 135 grams per hour for NO_x and 0.33 - 3.68 grams per hour for PM, depending on the modeled year. This guidance document did not, however, include any direction for estimating idling emissions for other types of heavy duty trucks other than Class 8 trucks.

Another guidance document EPA issued later in 2004 (EPA 2004b) does identify an approach that can be used to estimate idling emissions rates for any vehicle type included in an emissions model. "MOBILE6.2 does not directly model idle emission rates…however, as with MOBILE5, idling emission rates (in grams per hour) are assumed to be the same as for driving at 2.5 mph." The equation EPA provided for this estimation was as follows:

Equation (1): Idling emission rate = Emissions at 2.5 mph * Average speed (2.5 mph)

EPA points out that in some cases, idle emissions rates calculated using this method might include effects from engine starts, but also indicated that the effects of an engine start on exhaust emissions quickly diminish, and will disappear within two minutes from start time for most vehicles. This general approach remains the best method for estimating the emissions rate for short-term idling in MOVES2010 and MOVES2014.

Idling in MOVES2010

EPA's MOVES2010 model provided a much more direct and detailed method for estimating long-duration idling activity and emissions. EPA incorporated extended idling emission rates into MOVES2010 that were directly based on extended truck idling activity. Appendix A.3 of EPA's *Development of Emission Rates for Heavy-Duty Vehicles in the Motor Vehicle Emissions Simulator*

MOVES 2010, provides data summaries for these emissions rates (EPA 2012). Factors that EPA identified as influencing truck idling emissions rates included model year, the use of accessories, and engine idle speed.

As described in EPA's *MOVES2010 Highway Vehicle Population and Activity Data*, EPA assumed a ratio of 5.9 hours of extended idling for every 10 hours of long-haul truck driving (EPA 2010). EPA points out that "no sources exist that directly measure extended idling in order to geographically allocate the hours of extended idling estimated for heavy-duty trucks. However, extended idling (or hoteling) occurs primarily on long-haul trips across multiple states, which suggests that travel on urban and rural interstates would best represent long-haul trips." The allocation factor was based on state-level "parking" demand and county-level Class 8 diesel truck vehicle miles traveled (VMT) on rural and urban interstates. The allocation factors EPA used were calculated as follows, with "i" indicating the state, and "j" indicating the county:

Equation (2): StateAllocation(i) = StateParkingDemand(i) / Sum(StateParkingDemand(i))

Equation (3): IdleAllocFactor(i) = StateAllocation(i) * (CountyVMT(j)) / Sum(CountyVMT(j))

Users could also provide alternative inputs based on local data. Extended idling activity was an "off-network" activity that was assumed to only occur for combination long-haul trucks.

Idling in MOVES2014

EPA's guidance on developing on-road emissions inventories using MOVES2014 defines extended idling as follows: "Extended Idle is defined as long-duration idling with more load than standard idle and a different idle speed. It is used to account for emissions during hotelling operation when a truck's engine is used to support loads such as heaters, air conditioners, microwave ovens, etc" (EPA 2015).

MOVES2014 included a number of adjustments to handle emissions from hoteling by combination long-haul trucks. First, hoteling activity in MOVES2014 is divided into four different types of activity:

1) Extended idling hours: hours spent idling the engine used by the truck for propulsion;
2) Diesel APU hours: hours spent using an on-board diesel-powered APU to power a truck's accessories;
3) Battery APU hours: hours spent using an on-board battery-powered APU to power a truck's accessories; and
4) Engine off hours: hours spent hoteling in which the truck is using power from on-site truck stop infrastructure.

MOVES2014 assumes that 100% of hoteling hours for model years 2009 and earlier are allocated to extended idling, while hoteling hours for trucks 2010 and newer are split, 70% extended idling and 30% diesel APU. Users may adjust the fractions for these four types of hoteling hours based on local data.

The other major change in 2014 is that, whereas in MOVES2010, hoteling activity was allocated to each county based on class 8 truck VMT on urban and rural interstate highways, MOVES2014 allocates hoteling activity only based on rural restricted roadway VMT, assuming that extended idling does not occur in urban settings.

EPA states that, in most cases, users of MOVES2014 should rely on default MOVES-generated hoteling hours, but it does allow for an optional input for hoteling hours: "This input can be used if users have detailed local information on total hoteling hours by hour of day, day type, month, and vehicle model year." Similarly, for the distribution of hoteling to various types of activity, users should rely on the default operation mode fractions, but users can provide inputs if they have local hoteling data (EPA 2014).

TEXAS APPROACH TO ESTIMATING EXTENDED IDLINGACTIVITY AND EMISSIONS

The approach used by the Texas Commission on Environmental Quality (TCEQ) and the Texas Transportation Institute (TTI) to developing county-level hoteling activity and emissions estimates relies on a bottom-up approach that relates hoteling activity in a given county to the estimated truck stop and rest area parking capacity that can be used by long-haul trucks for such activity. These estimates are based on a statewide study conducted by Eastern Research Group, Inc. (ERG) in 2004 that developed county-level parking capacities and idling activity rates, expressed as idling hours per truck parking space (Baker et al. 2004). These base year activity estimates are then projected to a given analysis year based on the ratio of combination long-haul VMT in the analysis year relative to 2004. For new inventories developed using MOVES2014 for analysis years 2010 and later, the default 70%-30% split between extended idling and diesel APU usage is applied to hoteling hours estimated for model years 2010 and later. Once emissions estimates are generated using MOVES, a post-processing adjustment is made in order to reflect the emission reduction impact of the use of Texas Low-Emission Diesel (TxLED) in the eastern portion of the state. TxLED achieves a 6.2% reduction in NO_X emissions for 2001 and earlier model years and a 4.8% reduction in NO_X emissions for model years 2002 and later. TTI has recently produced new emissions inventories for all 254 counties in Texas using MOVES2014 for 2006, 2012, and 2018.

CAPCOG APPROACH TO ESTIMATING EXTENDED IDLING ACTIVITY AND EMISSIONS

CAPCOG has used the basic methodology used by ERG in its 2004 study (Baker et al. 2004) in order to estimate the hoteling activity in the region, using an updated inventory of local truck parking locations and new observations of truck idling patterns at a number of these locations.

Description of Observational Data Collection at Local Truck Stops

CAPCOG's starting point for developing the 2006, 2008, and 2011 extended idling activity data was the 2004 ERG study (Baker et al. 2004) and a TTI study completed the prior year (Zietsman and Perkinson 2003). CAPCOG augmented this list by conducting internet searches for any additional truck stops within the region. This review produced a list of truck stops and rest areas across the 11-county region.

In 2011, CAPCOG hired TTI to conduct data collection for this project. Their initial task involved conducting an initial visual survey of a number of the locations CAPCOG had identified in its preliminary list. TTI visited 16 potential locations in Bastrop, Caldwell, Fayette, Hays, Travis, and Williamson Counties in June 2011. TTI then reported back to CAPCOG on each location. Data collected included the operational status of the location, whether it was being used by trucks for hoteling activity, and what the estimated parking capacity for the location was. This review confirmed that several of the locations that had been operational or used for idling in 2004 were no longer operational or used for idling, and that there were also several new facilities used for idling that had not been operational in 2004.

CAPCOG and TTI then developed a data collection plan for collecting on-site observations at seven total locations between July and August 2011. This data collection plan was based to a large degree on analyses conducted by ERG in its 2004 study (Baker et al. 2004). This study found significant variation in idling patterns by the time of day, with much higher rates of idling per truck parking space during nighttime than during the day. ERG's 2004 study did not identify any statistically significant differences in idling rates by day type, but the study also did not include many observations on Fridays and didn't include any observations on Saturdays or Sundays. In order to test for and control these variables, the data collection plan involved TTI researchers visiting the seven chosen truck stops in Caldwell, Hays, Travis, and Williamson Counties and collect data on the total number of trucks parked and total number of trucks idling at different times of day on different day types.

Six of the seven facilities observed were located along interstate highway (IH) 35, which runs north-south from Laredo on the U.S.-Mexico border, through San Antonio and Austin up to the Dallas-Fort Worth area and then north up to the U.S.-Canada border in Minnesota. IH-35 is the only interstate highway that runs through Austin. Four of the truck stops observed were located on IH-35 north of Austin and two were located on IH-35 south of Austin. The seventh location was located close to the Caldwell -Travis County border along U.S. Highway 183 and State Highway 130 (SH 130) at the intersection with SH 21. SH 130 is a new toll road that runs from Georgetown in Williamson County down through eastern Travis County and Caldwell County to IH-10, and is intended as a way to bypass traffic on IH-35 in Austin, one of the most congested roadways in the state. At the time data collection efforts were undertaken in 2011, the segment of SH 130 that was adjacent to the truck stop TTI observed was still under construction. Observations were collected in three rounds of data collection between July 11, 2011, and August 13, 2011.

Summary of Truck Stop Observations by Facility, Time of Day, and Day Type

Tables 1, 2, and 3, below, show the distribution of observations by facility, time of day, and day type. Between 19 and 31 hourly observations were collected at each facility, ensuring that no one facility's data skewed the results. Hourly observations were collected at various times of the day and night, ensuring a full representation of the cycle of idling activity: 28% of observations were collected from 12 am – 8 am, 33% were collected from 8 am – 4 pm, and 39% were collected from 4 pm – 12 am. Similarly, sufficient observations were collected on Fridays and Saturdays in order to assess the extent to which differences in on-road VMT for these day types compared to Monday-Thursday might also be reflected in idling activity. A total of 55% of the observations were collected on the "weekday" (Monday-Thursday) day type, while 21% were collected on Fridays, and 24% were collected on Saturdays.

Table 1. Number of truck stop idling observations by facility.

Facility	County	Adjacent Roadway	Spaces (2011)	Hourly Observations
Flying J	Williamson	IH 35 (northbound)	110	23
Texas Star	Williamson	IH 35 (southbound)	45	22
Mustang Ridge	Caldwell	SH 130 (northbound)	40	28
San Marcos Truck Stop	Hays	IH 35 (southbound)	29	28
Conoco Tex-Best	Hays	IH 35 (northbound)	20	31
Texaco Speedy Stop	Travis	IH 35 (northbound)	20	19
Berry Creek	Williamson	IH 35 (northbound)	10	19
TOTAL	**n/a**	**n/a**	**276**	**170**

Table 2. Number of truck stop idling observations by time of day.

Time of Day	Hourly Observations
12 am – 1 am	8
1 am – 2 am	2
2 am – 3 am	2
3 am – 4 am	0
4 am – 5 am	0
5 am – 6 am	13
6 am – 7 am	13
7 am -8 am	10
8 am – 9 am	12
9 am – 10 am	12
10 am – 11 am	6
11 am – 12 pm	4
12 pm – 1 pm	5
1 pm – 2 pm	5
2 pm – 3 pm	7
3 pm – 4 pm	5
4 pm – 5 pm-	3
5 pm – 6 pm	4
6 pm – 7 pm	5
7 pm – 8 pm	1
8 pm – 9 pm	6
9 pm – 10 pm	14
10 pm – 11 pm	16
11 pm – 12 am	17
Total	**170**

Table 3. Number of truck stop idling observations by day type.

Day Type	Hourly Observations
Monday	0
Tuesday	9
Wednesday	27
Thursday	57
Friday	36
Saturday	41
Sunday	0
Total	**170**

Results from Truck Stop Observations and Data Analysis

Once the data was collected and entered into spreadsheets, TTI submitted the data to CAPCOG. CAPCOG reviewed the data in order to calculate the percentage of spaces occupied by trucks and the percentage of trucks observed to be idling. Table 4, below, shows a basic summary of these data.

Table 4. Summary statistics from truck stop observations.

Data Point	Value
Facilities Observed	7
Hourly Observations	170
Parking Space-Hours Observed (total spaces observed * hours)	6,632
Parked Truck-Hours Observed	3,837
Idling Truck Hours Observed	2,102
Average Occupancy Rate (unweighted)	56%
Average Occupancy Rate (weighted)	56%
Average % of Trucks Idling (unweighted)	54%
Average % of Trucks Idling (weighted)	55%
% of Parking Spaces Occupied by an Idling Truck (unweighted)	30%
% of Parking Spaces Occupied by an Idling Truck (weighted)	32%

CAPCOG performed various statistical analyses of the data in order to assess the extent to which the hourly percentages of parking spaces occupied by an idling truck was impacted by observation location, time of day, and day of the week. These analyses yielded the following insights:

- There were four distinct hourly observation groupings that had statistically significantly distinct idling characteristics:
  - Late night: 12 am – 6 am;
  - Morning: 6 am – 8 am;
  - Day: 8 am – 8 pm; and
  - Evening/Night: 8 pm – 12am;
- There were statistically significant differences between the Tuesday-Thursday observations and the Friday and Saturday observations; and
- The Mustang Ridge truck stop along SH 130 exhibited statistically significantly different patterns than the other six truck stops.

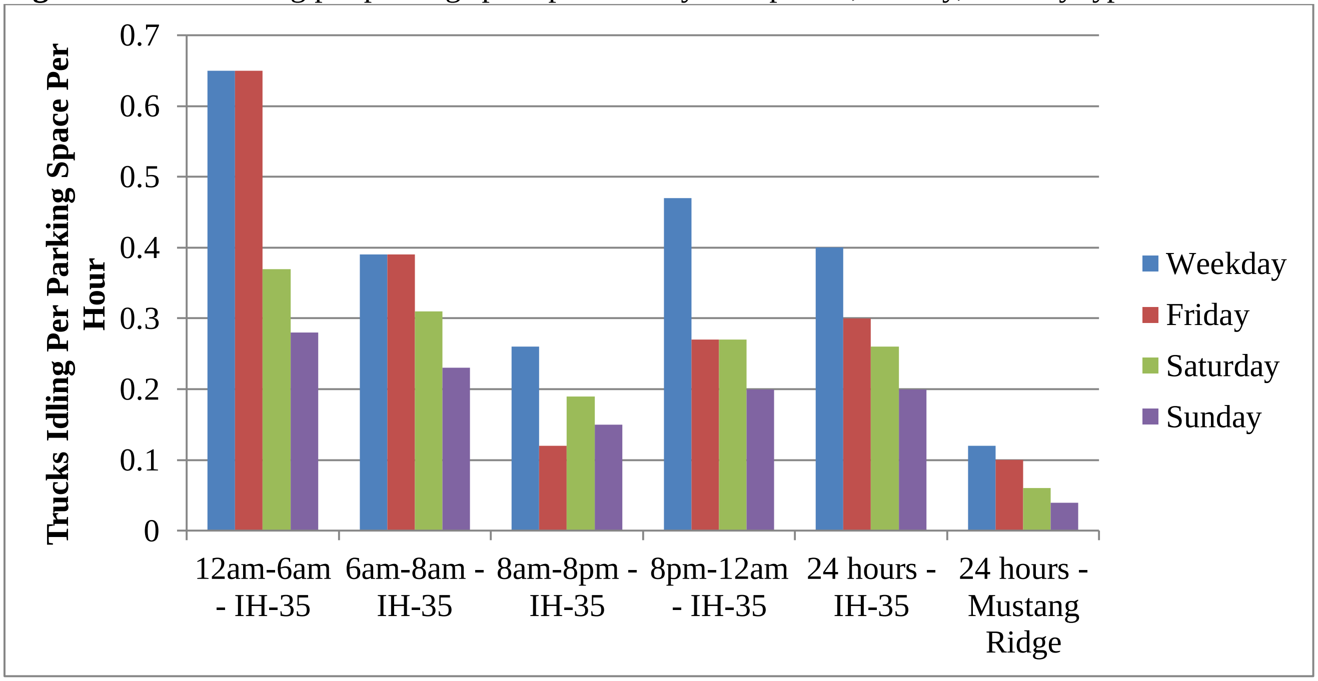
A regression analysis of the data using weekday, daytime observations at the six truck stops along IH-35 as the reference point had an adjusted R-squared value of 0.57 with the p value of the model F statistic of less than 0.1%. Table 5 shows the p-values and coefficients for each of the independent variables tested for a 95% confidence level.

Table 5. Truck stop regression analysis results.

Independent Variable	Coefficient	P-Value
Intercept (Tue-Thu, 8 am- 8 pm, IH-35 facilities)	0.297	<0.1%
Late Night (12 am – 6 am)	0.278	<0.1%
Morning (6 am – 8 am)	0.125	<0.1%
Late Night (8 pm – 12 am)	0.183	0.2%
Friday	-0.171	<0.1%
Saturday	-0.118	<0.1%
Facility = Mustang Ridge (1 = yes)	-0.267	<0.1%

Using these results, CAPCOG constructed idling profiles for the six IH-35 facilities and for Mustang Ridge for Monday-Thursday, Friday, Saturday, and Sunday. Since observations were not collected on Sunday CAPCOG used the ratio of combination long-haul truck VMT on Sundays relative to Saturdays in order to estimate the Sunday idling profile. Figure 1 show the idling rates (expressed as idling trucks per parking space per hour) developed using these data.

Figure 1. Trucks idling per parking space per hour by time period, facility, and day type.



Follow Up Observations Conducted at Other Locations in October 2011

TTI conducted another round of data collection in October 2011 in order to investigate idling activity in several locations that had not been in the initial list of idling locations. These were locations where CAPCOG staff had anecdotally witnessed idling activity occurring in the course of regional travel. These included several Wal-Marts in the region, along the frontage roads of IH-35, a large dirt parking area across the road from the Texaco Speedy Stop in Pflugerville (northern Travis County), and a Spirit gas station in San Marcos (Hays County).

While these data collection efforts were not as comprehensive as the data collection efforts conducted in July and August 2011, they did lead to the following changes in CAPCOG's estimated idling in the region:

1) Inclusion of extended idling along frontage roads as a distinctive type of extended idling activity;
2) Inclusion of Wal-Marts and estimation of parking capacities as truck parking facilities; and
3) Adjustment in the estimated parking capacity of the Texaco Speedy Stop in Pflugerville.

For the frontage road observations, TTI drove along the frontage roads for IH-35 from 11:00 pm on Tuesday, October 11, 2011, to 2:15 am on Wednesday, October 12, 2011, from the southernmost border of Hays County, to the northernmost border of Williamson County, and back again, counting the number of trucks pulled onto the side of the road engaged in idling. It is possible to distinguish parked trucks with the engine off from parked trucks with the engine on based both on audible sound and by whether the truck's yellow fog lights around the base of the truck are on. TTI observed a total of 16 trucks parked along the frontage roads in this manner, 8 of which were idling. The observations were conducted along approximately 120 miles of frontage road. Dividing the number of idling trucks by the number of miles of frontage road yields a ratio of 0.07 trucks idling per mile of frontage road for this time period. Since these observations occurred during the time period with the highest idling rates at truck stops, CAPCOG estimated the idling rates for other day types and time periods using the ratios between weekday late night truck stop idling rates to the other day type/time period combinations. The results of these calculations are shown in Table 6.

Table 6. Hours idling per mile of frontage road by time period.

Time Period	Hours in Time Period	Weekday	Friday	Saturday	Sunday
Late Night (12 am – 6 am)	6	0.40	0.30	0.19	0.09
Morning (6 am – 8 am)	2	0.08	0.06	0.04	0.02
Day (8 am – 8 pm)	12	0.32	0.24	0.15	0.07
Evening (8 pm – 12 am)	4	0.24	0.18	0.11	0.06
24 Hours	**24**	**1.04**	**0.77**	**0.67**	**0.51**

The inclusion of Wal-Marts in the list of truck idling locations and adjustment of the parking capacity of the Pflugerville Texaco Speedy Stop were a direct result of TTI researchers confirming that truck idling was in fact occurring in these locations.

Refinement of List of Idling Locations and Parking Capacity Estimates

Prior to calculating the estimated idling hours for each idling location, CAPCOG further refined the list of idling locations in the region. This investigation yielded several types of adjustments to the master list of idling locations and the corresponding surrogate data (either parking capacity or frontage road miles).

1) Addition of parking lot capacity at all Wal-Marts in the region that could conceivably accommodate truck parking;
2) Addition of other smaller facilities that had not been originally included in the list that were subsequently identified either through anecdotal evidence or through analysis of aerial imagery along major highways in the region;
3) Estimation of parking capacities at all facilities where TTI personnel did not personally visit using aerial imagery;
4) Refinement of TTI parking capacity estimates for 2011 where the precise number of spaces was ambiguous using aerial imagery;
5) Estimation of the dates when idling locations that were present in 2011 but not in ERG's 2004 study were built;
6) Estimation of the dates when idling locations that were present in 2004 but not in 2011 were closed; and
7) Addition of locations or capacity that were present in 2012 but not present in 2011.

While for some facilities, it may be relatively easy to estimate the number of truck parking spaces because they are relatively clearly identified on pavement with paint, trucks will often park in unmarked parts of the lot or will park off of the lot on the grass along an adjacent road. Wal-Marts provide another type of challenge, since trucks are usually parking across multiple spaces marked for cars, but are rarely using more than a small fraction of the lot for idling activities. In some cases, their physical layout prevents idling in certain locations, while in others, it is possible to accommodate a truck but it is not clear from aerial imagery whether trucks are parking there or not. CAPCOG spent considerable time for each facility using the standard dimensions of a combination long-haul truck carrying a trailer in order to refine the capacity estimates for each facility. These estimates are very accurate, but not necessarily very precise, since – at any given time, the position of the trucks parked there could lead to significantly different useful capacities.

Aside from parking capacities, the other surrogate data CAPCOG used for modeling truck activity were interstate frontage road miles by county. CAPCOG reviewed aerial imagery for Hays, Travis, and Williamson Counties along IH-35 in order to estimate the total miles of frontage road in each county. While observations were not collected along IH-10 in Caldwell and Fayette County, CAPCOG also reviewed the imagery of the frontage roads in those two counties in order to evaluate whether they were suitable for truck idling. CAPCOG determined that, while the frontage roads in Caldwell County were usable for truck idling, it was not clear that the configuration of the frontage roads in Fayette County would be conducive for such activity.

Table 7, below, shows a summary of the parking space capacity and IH frontage miles for each county in region.

Table 7. Extended idling activity surrogates by county, 2012.

County	Truck Parking Locations	Parking Space Capacity	IH Frontage Miles
Bastrop	4	39	0
Blanco	2	93	0
Burnet	2	16	0
Caldwell	3	64	9
Fayette	4	68	0
Hays	4	62	50
Lee	2	23	0
Llano	0	0	0
Milam	2	45	0
Travis	10	90	55
Williamson	9	262	55
Total	**42**	**762**	**169**

Calculation of Extended Idling Activity for 2012

After obtaining 2012 surrogate data, CAPCOG applied the related idling rates to each county's surrogates for truck parking facilities and IH frontage roads. While in 2011, the observations at the Mustang Ridge truck stop along SH-130 were statistically significantly different from other locations, the completion of construction on SH-130 adjacent to the truck stop that year likely changed the characteristics of the trucks stopping at the facility significantly – from trucks being used to haul construction material for the roadway to trucks being used to haul other types of cargo. ERG's 2004 study (Baker et al. 2004) did not find significant differences in idling rates by the average annual daily traffic (AADT) of nearby roadways, so CAPCOG believes that the 2011 Mustang Ridge observations may have been unique to that specific time frame. Therefore, CAPCOG used the rates for the six IH-35 parking facilities for all parking facilities in the region for 2012.

Table 8 shows the number of idling hours on an ozone season (summer) weekday for each county by parking location type.

Table 8. 2012 Ozone season weekday extended idling hours by location type.

County	Parking Facilities	Frontage Roads	Total
Bastrop	377	0	377
Blanco	899	0	899
Burnet	155	0	155
Caldwell	619	10	629
Fayette	658	0	658
Hays	600	51	651
Lee	222	0	222
Llano	0	0	0
Milam	435	0	435
Travis	870	58	928
Williamson	2,534	57	2,591
Total	**7,369**	**176**	**7,545**

Since these estimates are based on direct observations of extended idling activity – actual use of truck engines for extended idling – it would not be appropriate to assume that these estimates are broadly "hoteling" such that they could be split into extended idling, diesel APU, battery APU, and engine off hours, as done in MOVES2014. Instead, the ratio of total diesel APU hours to extended idling hours for 2012 from TTI's MOVES2014 inventory (TTI 2014) should be multiplied by the estimates above in order to calculate the diesel APU hours for 2012. Alternatively, CAPCOG's data from the driver surveys (shown in Table 24) could be used as the basis for calculating diesel APU and battery APU hours. TTI's 2012 inventories for the region indicate that there are 4.2 diesel APU hours for every hundred hours of extended idling. Using this ratio, there should be approximately 319 hours of diesel APU hours per day for ozone season weekdays.

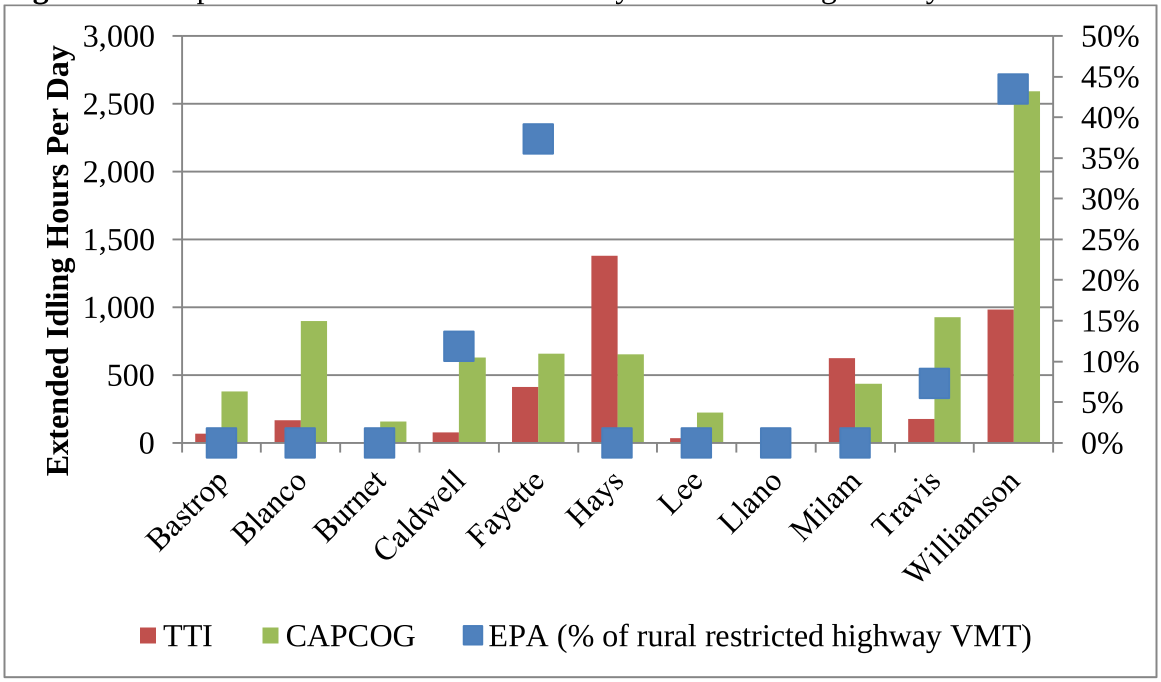
Comparison of CAPCOG Activity Estimates to TCEQ and EPA Assumptions

CAPCOG's estimates of extended idling activity in 2012 are substantially different from the activity estimates in TTI's most recent 2012 emissions inventories developed using MOVES2014. Overall, CAPCOG estimates that there were a total of 7,545 extended idling hours per day on summer weekdays (Monday – Thursday) across the 11-county region, 92% higher than TTI's estimate of 3,920 idling hours per weekday, based on the projection of ERG's 2004 estimates.

Most of this difference can be attributed to having a more comprehensive inventory of idling locations and a more extensive review of the capacities at these locations. ERG's 2004 estimates only accounted for 20 facilities in the region with a combined parking capacity of 467 spaces. CAPCOG's 2012 estimates, on the other hand, cover 42 facilities with a combined parking capacity of 762 spaces. This 63% increase in parking capacity estimates between ERG's 2004 study and CAPCOG's 2012 estimate is well beyond the growth in long-haul truck VMT over that period. CAPCOG's idling rates are also approximately 15% higher for weekdays than ERG's idling rates were. CAPCOG estimated 9.67 truck idling hours per parking space per day compared to ERG's estimate of 8.3 truck idling hours per parking space for truck stops in areas other than San Antonio. Finally, the allocation of hoteling time to diesel APU hours starting in 2010 results in a 4.2% reduction in the 2012 projections compared to a scenario in which 100% of the hoteling hours were allocated to extended idling.

CAPCOG's activity estimates are generally higher for each of the counties in the 11-county region, except for Hays, Llano, and Milam Counties. The reduced estimates for Hays and Milam Counties reflects the closure of a large truck stop in each county. The Llano County activity estimate remained the same, at zero hours. Despite thorough reviews of aerial imagery in Llano County, there is no obvious place along any of the major roads where trucks might pass through for them to idle. In absence of any specific evidence of extended idling in this very rural county, CAPCOG will retain the estimate of zero extended idling hours there. Figure 2 shows the comparison of the summer weekday extended idling hour estimates for each county, as well as the % of rural restricted highway combination long-haul truck VMT for each county, which EPA uses as the surrogate for allocating extended idling activity.

Figure 2. Comparison of 2012 summer weekday extended idling activity estimates.



Emissions Rates

CAPCOG used emissions rates derived from inventories developed by TTI for TCEQ using MOVES2014 (TTI 2014). Combination long-haul truck age distributions were based on statewide age distributions as of July 1, 2012. Emission rates varied somewhat by county based on the meteorological and fuel inputs for the county's corresponding Texas Department of Transportation (TxDOT) district and fuel regulations. Table 9 summarizes these variations and the emissions rates derived from TTI's 2012 inventories for these 11 counties. The emission rates below consolidate the crankcase and exhaust rates. Since Burnet County and Llano County were not estimated to have any idling in TTI's inventories, the assigned rates correspond to Blanco County's rates.

Table 9. Summer 2012 extended idling emissions rates extended idling.

County	TxDOT District	TxLED?	CO Rate (lbs/hr)	NO_X Rate (lbs/hr)	VOC Rate (lbs/hr)	CO_2 Rate (lbs/hr)	PM_{10} Rate (lbs/hr)	$PM_{2.5}$ Rate (lbs/hr)
Bastrop	Austin	Yes	0.19781	0.42108	0.11354	20.16552	0.01025	0.00943
Blanco	Austin	No	0.19781	0.44583	0.11354	20.16552	0.01025	0.00943
Burnet	Austin	No	0.19781	0.44583	0.11354	20.16552	0.01025	0.00943
Caldwell	Austin	Yes	0.19781	0.42110	0.11354	20.16552	0.01025	0.00943
Fayette	Yoakum	Yes	0.19781	0.38453	0.11354	20.16552	0.01023	0.00941
Hays	Austin	Yes	0.19781	0.42105	0.11354	20.16552	0.01025	0.00943

County	TxDOT District	TxLED?	CO Rate (lbs/hr)	NO_X Rate (lbs/hr)	VOC Rate (lbs/hr)	CO_2 Rate (lbs/hr)	PM_{10} Rate (lbs/hr)	$PM_{2.5}$ Rate (lbs/hr)
Lee	Austin	Yes	0.19781	0.42111	0.11354	20.16552	0.01025	0.00943
Llano	Austin	No	0.19781	0.44583	0.11354	20.16552	0.01025	0.00943
Milam	Bryan	Yes	0.19781	0.39702	0.11354	20.16552	0.01025	0.00943
Travis	Austin	Yes	0.19781	0.42111	0.11354	20.16552	0.01025	0.00943
Williamson	Austin	Yes	0.19781	0.42114	0.11354	20.16552	0.01025	0.00943

Emissions Estimates

The Table 10 shows the weekday (Monday-Thursday) emissions for each county, calculated by multiplying the applicable rates by the idling hours.

Table 10. 2012 Summer weekday extended idling emissions, 2012 (tons per day).

County	CO	NO_X	VOC	CO_2	PM_{10}	$PM_{2.5}$
Bastrop	0.0373	0.0794	0.0214	3.8012	0.0019	0.0018
Blanco	0.0889	0.2004	0.0510	9.0644	0.0046	0.0042
Burnet	0.0153	0.0346	0.0088	1.5628	0.0008	0.0007
Caldwell	0.0622	0.1324	0.0357	6.3421	0.0032	0.0030
Fayette	0.0651	0.1265	0.0374	6.6345	0.0034	0.0031
Hays	0.0644	0.1371	0.0370	6.5639	0.0033	0.0031
Lee	0.0220	0.0467	0.0126	2.2384	0.0011	0.0010
Llano	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Milam	0.0430	0.0864	0.0247	4.3860	0.0022	0.0021
Travis	0.0918	0.1954	0.0527	9.3568	0.0048	0.0044
Williamson	0.2563	0.5456	0.1471	26.1244	0.0133	0.0122
TOTAL	**0.7462**	**1.5844**	**0.4283**	**76.0744**	**0.0386**	**0.0356**

These estimates are 92-95% higher region-wide compared to the existing TTI estimates for 2012.

ESTIMATION OF SHORT-TERM TRUCK IDLING FOR SELECTED INDUSTRIES

Unlike extended idling, the kind of short-term idling that EPA described in its 2004 guidance that occurs when trucks wait in queues or to pick up or drop off goods is not explicitly modeled in MOVES2014, and the emissions from such idling do not appear to be accounted for anywhere in the inventories produced using MOVES2014. The primary goal of CAPCOG's short-term idling inventory research was to fill that gap by estimating the idling activity by heavy-duty trucks that would be subject to the region's 5-minute idling restrictions. In 2013, CAPCOG produced estimates of the idling activity associated with quarrying (NAICS Code 211), manufacturing (NAICS Codes 31-33), wholesale trade (NAICS Code 42), and retail trade (NAICS Code 44-45) in the 5-county Metropolitan Statistical Area (MSA), Bastrop, Caldwell, Hays, Travis, and Williamson Counties, for 2005, 2007, 2015, 2025, and 2035. For this report, CAPCOG is applying employee-based idling activity ratios to 2012 County Business Patterns (CBP) employment data in order to generate short-term idling estimates for trucks making trips to or from these business types. CAPCOG used emissions rates generated by TTI in 2011 using MOVES2010 at 2.5 mph for 2006 and 2018, in conjunction with TTI's 2012 emissions inventories generated using MOVES2014, in order to approximate the emissions rates for short-term idling emission rates for summer 2012.

This portion of the study provides estimates for truck idling during pickup and delivery of freight at selected business types known to have significant trucking activity and extended idling by combination-long-haul trucks. For the purpose of this study, “idling” is any time spent in an off-network setting when a truck’s engine is on but is not being used to propel the truck. “Heavy-duty trucks” include any vehicle with a gross vehicle weight rating (GVWR) of 14,001 pounds or more (Class 4 or higher) other than buses and motor homes. Short-term idling is distinguished from extended idling in that extended idling is assumed to coincide with government-mandated rest periods for long-haul trucks. This activity is currently exempt from idling restrictions. This project is not necessarily intended to provide a comprehensive estimate of off-network, short-term truck idling for the Austin-Round Rock MSA, but was is intended to characterize a substantial portion of idling activity.

CAPCOG’s idling estimates are further broken down into the vehicle source use types used in the MOVES emissions model – single unit short-haul, single unit long-haul, combination short-haul, and combination long-haul trucks. CAPCOG’s estimates are available by North American Industrial Classification System (NAICS) codes down to the 2-digit level for retail, 3-digit level for mining/quarrying and manufacturing, and 4-digit level for wholesale trade. CAPCOG also calculated idling at the entry points for wholesale trade establishments (NAICS Code 493).

For this project, CAPCOG selected five different general business types for which to estimate truck trip generation rates:

- Mining/Quarrying (NAICS Code 212),
- Manufacturing (NAICS Code 31-33),
- Wholesale Trade (NAICS Code 42),
- Warehousing (NAICS Code 493), and
- Retail (NAICS Code 44-45).

Based on an initial literature review, CAPCOG determined that these would be the business types most likely to account for a large majority of any “restricted” idling in the region. While trucks visit other establishments, the initial literature review indicated that truck activity was likely to be much higher at these business types within the Austin-Round Rock MSA than at other business types. This study does not account for any idling that occurs at farms (NAICS Code 11), oil and gas production facilities (NAICS Code 21), utility establishments (NAICS Code 22), construction projects (NAICS Code 23), or any service-type businesses. CAPCOG determined that insufficient information would be available to adequately characterize trucking activity associated with these business types. For construction in particular, which CAPCOG believes is associated with a very large amount of trucking activity, two exemptions (use of an engine for mechanical power and use of air conditioning/heating while performing essential road construction work) would make it much more difficult to develop a defensible estimate without extensive data collection.

Description of Short-Term Idling in MOVES Documentation

EPA’s *Development of Emission Rates for Heavy-Duty Vehicles in the Motor Vehicle Emissions Simulator MOVES 2010* (EPA 2012) distinguishes between the treatment of extended idling and short-term idling in the model as follows: “Extended idling does not include vehicle idle operation which occurs during normal road operation, such as the idle operation which a vehicle experiences while waiting at a traffic signal **or during a relatively short stop, such as idle operation during a delivery**. Although frequent stops and idling can contribute to overall emissions, these modes are already included in the normal vehicle hours of operation. Extended idling is characterized by idling periods that last hours, rather than minutes" (emphasis added).

While MOVES2014 does account for idling that occurs when a vehicle is not moving while on-road, such as when it is at a traffic light or stop sign, it is not clear from CAPCOG's review of the MOVES model that emissions from idling that occurs off-network that would occur during a delivery or pick-up are actually included in emissions estimates generated by the MOVES model. Based on the descriptions of the processes in the MOVES model, it appears that any time spent idling off-network would not be accounted for under the emissions associated with the number of vehicle hours accounted for in the model.

Summary of CAPCOG Methodology to Estimate Short-Term Idling

CAPCOG's method for estimating short-term truck idling at the various business types listed above is based on methods developed by TTI that involve estimating short-term idling based on observations and the employment levels at a given facility (TTI 2008, TTI 2009). CAPCOG conducted its own idling observations at a number of local businesses and adapted TTI's approach, augmenting it with other data sources and research.

Trip Generation Rates

CAPCOG developed employment-based trip generation estimates for each business type using a 2009 Freight Study commissioned by CAMPO (MACTEC 2009), and the 2007 Commodity Flow Survey (Census Bureau 2010, Census Bureau 2011a, and Census Bureau 2011b). Retail locations were assumed to have combination and single-unit truck trip generation rates listed in the 2009 Freight Study. Trip generation rates (truck trips generated per employee) for mining, manufacturing, and wholesale trade establishments were based on the industry-specific tonnage shipped by truck as reported in the 2007 CFS. Table 11 shows the trip generation rates for each industry covered in this study.

Table 11. Trip generation rates by NAICS code (trucks trips per employee per day).

NAICS	Description	Single Unit	Combination	Heavy Duty Total
212	Mining (except oil and gas)	2.6196	2.1965	4.8161
311	Food manufacturing	0.0398	0.0168	0.0566
312	Beverage and tobacco product manufacturing	0.3954	0.1990	0.5944
313	Textile mills	0.0422	0.0098	0.0520
314	Textile product mills	0.0520	0.0078	0.0598
315	Apparel manufacturing	0.0070	0.0006	0.0076
316	Leather and allied product manufacturing	0.0106	0.0010	0.0116
321	Wood product manufacturing	0.1386	0.0766	0.2152
322	Paper manufacturing	0.1942	0.0628	0.2570
323	Printing and related support activities	0.0026	0.0004	0.0030
324	Petroleum and coal products manufacturing	2.8854	2.1509	5.0363
325	Chemical manufacturing	0.0404	0.0184	0.0588
326	Plastics and rubber products manufacturing	0.0974	0.0108	0.1082
327	Nonmetallic mineral product manufacturing	0.7489	0.4761	1.2249
331	Primary metal manufacturing	0.1254	0.0664	0.1918
332	Fabricated metal product manufacturing	0.0268	0.0052	0.0320

NAICS	Description	Single Unit	Combination	Heavy Duty Total
333	Machinery manufacturing	0.0314	0.0052	0.0366
334	Computer and electronic product manufacturing	0.0044	0.0004	0.0048
335	Electrical equipment, appliance, and component manufacturing	0.0654	0.0120	0.0774
336	Transportation equipment manufacturing	0.0010	0.0002	0.0012
337	Furniture and related product manufacturing	0.0512	0.0038	0.0550
339	Miscellaneous manufacturing	0.0050	0.0006	0.0056
4231	Motor vehicle and motor vehicle parts and supplies merchant wholesalers	0.0480	0.0064	0.0544
4232	Furniture and home furnishing merchant wholesalers	0.0700	0.0042	0.0742
4233	Lumber and other construction materials merchant wholesalers	0.3440	0.1294	0.4734
4234	Professional and commercial equipment and supplies merchant wholesalers	0.0138	0.0004	0.0142
4235	Metal and mineral (except petroleum) merchant wholesalers	0.2678	0.0484	0.3162
4236	Electrical and electronic goods merchant wholesalers	0.0182	0.0012	0.0194
4237	Hardware, plumbing and heating equipment and supplies merchant wholesalers	0.0278	0.0012	0.0290
4238	Machinery, equipment, and supplies merchant wholesalers	0.0278	0.0040	0.0318
4239	Miscellaneous durable goods merchant wholesalers	0.0786	0.0574	0.1360
4241	Paper and paper product merchant wholesalers	0.2182	0.0152	0.2334
4242	Drugs and druggists' sundries merchant wholesalers	0.1034	0.0092	0.1126
4243	Apparel, piece goods, and notions merchant wholesalers	0.0390	0.0040	0.0430
4244	Grocery and related product merchant wholesalers	0.2410	0.0222	0.2632
4245	Farm product raw material merchant wholesalers	0.8084	0.8100	1.6184
4246	Chemical and allied products merchant wholesalers	0.5648	0.1172	0.6820
4247	Petroleum and petroleum products merchant wholesalers	1.4417	0.7225	2.1642
4248	Beer, wine, and distilled alcoholic beverage merchant wholesalers	0.4422	0.0100	0.4522
4249	Miscellaneous nondurable goods merchant wholesalers	0.0018	0.0006	0.0024
44-45	Retail Trade	0.1330	0.0370	0.1700

Using data at this level of detail shows the extent to which singly using travel demand model trip generation rates, as done in the MOVES model which groups mining, manufacturing, and wholesale trade together under the general “basic” employment category results in a loss of detail about the variations in truck activity rates within the “basic” employment group that is important to emissions estimation. Certain industry types, primarily those that deal with large masses of raw goods, such as mining and mineral product manufacturing have much higher ratios of tonnage shipped by truck per employee (24,940 tons per employee per year for mining, 3,775 tons per employee for mineral product manufacturing) than others, such as food manufacturing (247 tons per employee) and computer and electronic product manufacturing (3 tons per employee) (See CAPCOG 2013a) These ratios also reflect the differences in the types of trucks that might pick up or drop off goods at a given location.

Average Idling Duration Per Truck Trip

CAPCOG used observational data collected across multiple studies in order to calculate the average time spent idling off-network per truck trip. Table 12 summarizes the data used for these estimated idling activity ratios. A more detailed description of these efforts can be found in CAPCOG's original short-term idling report for CAMPO (CAPCOG 2013a).

Table 12. Data used for average idling duration per truck trip.

Data Source	Business Type	Locations	Truck Trips	Total Minutes Idling	Minutes Idling per Truck
CAPCOG 2013a	Retail	6	73	770	10.55
TTI 2009	Retail	16	64	264	4.13
Retail Subtotal	***Retail***	***22***	***137***	***1,034***	***7.55***
CAPCOG 2013a	Basic	9	65	594	9.14
CLEAN AIR Force	Basic	8	670	6,587	9.83
TTI 2009	Basic	3	59	2,205	37.37
Zietsman and Perkinson 2003	Basic	22	341	18,640	54.66
Basic Subtotal	***Basic***	***42***	***1,135***	***28,026***	***24.69***

Estimated Total Short-Term Truck Idling Hours by Industry

CAPCOG calculated the average estimated daily truck trips associated with the selected industries for 2012 using County Business Patterns employment data for 2012. Where the precise level of employment was withheld, CAPCOG used the midpoint of the range provided. CAPCOG multiplied these employment estimates by the trip generation rates in order to obtain the total single-unit and combination truck trips generated for each industry. CAPCOG then summed these into the "retail" and "basic" employment categories and multiplied the number of trips by the average duration of idling per truck trip using the rates calculated above. Table 13 below shows the estimated total short-term idling hours per day associated with the selected industries.

Table 13. Estimated average daily short-term truck idling hours for selected industries, 2012.

Duration	Single Unit Trucks	Combination Trucks	Total
All	4,085	1,873	5,958
> 5 Minutes	3,825	1,756	5,581

Allocation of Short-Term Idling Activity to Source Use Types

CAPCOG allocated the idling activity to each MOVES source use type relative to each source use type's share of the corresponding truck type's total vehicle starts. The Table 14 below shows these allocations.

Table 14. Allocation of idling hours to MOVES source use types.

Fuel Type	Short Haul or Long Haul	Single Unit	Combination
Gas	Short Haul	23.9%	5.0%
Diesel	Short Haul	69.9%	52.9%
Gas	Long Haul	1.6%	0.0%
Diesel	Long Haul	4.6%	42.1%

Emissions Rates

The only existing emissions data the CAPCOG could identify that would indicate emission rates at 2.5 mph were in TTI's 2011 MOVES Sensitivity Study (TTI 2011). CAPCOG averaged the 2006 and 2018 emission rates for trucks at 2.5 mph in order to obtain an approximate rate for 2012 (although, in reality, it should be a bit lower, since a larger reduction in rates will occur between 2006 and 2012 than between 2012 and 2018. Since the rates were expressed in grams per hour, CAPCOG multiplied the rates by 2.5 miles per hour in order to obtain rates expressed in grams per hour. Table 15 shows these calculated rates. While a specific 2012 run would provide a more accurate representation of the actual rate for that year, this approximation allows an overall assessment of the scale of this type of idling.

Table 15. Estimated 2012 short-term emissions rates (g/hour).

SUT	CO	NO_X	VOC	CO_2	PM_{10}	$PM_{2.5}$
Single Unit Short Haul Truck - Gas	199.258	31.503	16.834	17313.965	0.068	0.063
Single Unit Short Haul Truck - Diesel	26.504	71.612	9.830	21791.443	3.666	3.557
Single Unit Long Haul Truck - Gas	194.130	29.751	16.405	16481.219	0.072	0.066
Single Unit Short Haul Truck - Diesel	26.666	71.438	10.026	21304.703	3.663	3.553
Combination Short Haul Truck - Gas	515.579	59.711	35.316	25288.436	0.137	0.126
Combination Short Haul Truck - Diesel	50.306	125.769	11.969	28178.757	6.546	6.349
Combination Long Haul Truck - Gas	n/a	n/a	n/a	n/a	n/a	n/a
Combination Short Haul Truck - Diesel	57.852	140.405	12.237	28585.681	7.367	7.146

Emissions Estimates

CAPCOG calculated the emissions estimates by multiplying the aggregate hours per day of short-term idling activity by the emissions factors listed above. Table 16 below shows the results.

Table 16. Emissions estimates for short-term idling for selected industries, 2012 (tons per day).

SUT	Hours	CO	NO_X	VOC	CO_2	PM_{10}	$PM_{2.5}$
Single Unit Short Haul Truck - Gas	978	0.2147	0.0339	0.0181	18.6560	0.0001	0.0001
Single Unit Short Haul Truck - Diesel	2,857	0.0835	0.2256	0.0310	68.6352	0.0115	0.0112
Single Unit Long Haul Truck - Gas	64	0.0136	0.0021	0.0012	1.1572	0.0000	0.0000
Single Unit Short Haul Truck - Diesel	186	0.0055	0.0147	0.0021	4.3797	0.0008	0.0007
Combination Short Haul Truck - Gas	94	0.0536	0.0062	0.0037	2.6292	0.0000	0.0000
Combination Short Haul Truck - Diesel	991	0.0549	0.1373	0.0131	30.7689	0.0071	0.0069
Combination Long Haul Truck - Gas	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Combination Short Haul Truck - Diesel	788	0.0503	0.1220	0.0106	24.8336	0.0064	0.0062
TOTAL	**5,958**	**0.4761**	**0.5418**	**0.0797**	**151.0598**	**0.0259**	**0.0252**

TRUCKER SURVEYS

As part of CAPCOG's 2011 data collection efforts, TTI collected surveys from 118 truck drivers at two truck stops along IH-35: the Texas Star truck stop in Williamson County and the San Marcos Truck Stop in Hays County. This survey was conducted simultaneously to the extended idling data collection in 2011 referenced earlier in this report. At this time, extended idling was not exempt from the local idling restrictions. Data collected from these interviews shed light on a number of aspects of idling behavior that are important for correctly characterizing extended idling, including:

- Frequency and duration of idling;
- Engine speed settings during extended idling;
- Market penetration of California Air Resources Board (CARB) low-NO_X certified trucks;
- Presence and usage of on-board idle reduction technologies;
- Awareness of local idle restrictions; and
- Willingness to comply with idling restrictions.

Data Collection

Interviews were conducted at Texas Star on Friday, July 15, 2011, and Friday, August 12, 2011. Interviews were conducted at San Marcos Truck Stop on Friday, July 22, 2011. All interviews were conducted between 6 am and 2 pm. Drivers were offered a $5 in-store gift certificate for participating in the survey. A copy of the survey instrument can be found in the original (CAPCOG 2013c). The high and low hourly temperatures recorded at an air monitoring station in Travis County, which is situated between the two truck stops, are shown in Table 17, below. CAPCOG believes that any idling that occurred during this period would have involve operating an air conditioner, given the high temperatures.

Table 17. High and low temperatures recorded on days when survey was conducted.

Temperature Type	July 15, 2011	July 22, 2011	August 12, 2011
Low	78.5	78.7	80.1
High	100.4	98.9	98.0

Responses

A total of 118 drivers participated in the survey. Of these, 83 of the responses were collected at the Texas Star Truck Stop, and 35 responses were collected at the San Marcos Truck Stop. Most of the survey respondents had sleeper cabins, while the rest had day cabins. This distinction was used by CAPCOG to delineate which trucks would be most likely to fit into the "combination long-haul" truck category. With one exception, all of the day cab respondents indicated that they were conducting trips within Texas, most of which were between the Dallas-Fort Worth area to the north along IH-35 and the San Antonio area to the south along IH-35. Table 18 shows the sample size and associated margins of error.

Table 18. Responses by cab type.

Cab Type	Associated MOVES Source Use Type	Sample Size	Margin of Error
Sleeper Cab	Combination Long-Haul Trucks	71	+/- 12%
Day Cab	Combination Short-Haul Trucks	46	+/- 14%

TTI asked drivers the ages of the trucks they were driving. Responses to this question were helpful both as a quality check on other responses, since the age distribution could be compared to general truck age distribution data sets, and because certain on-board technologies would be expected to be more prevalent on more recently manufactured trucks. CAPCOG performed chi-squared tests on the age distributions for the sleeper cabs, comparing them to July 1, 2012 statewide age distributions for combination long-haul trucks, and for day cabs, comparing them to July 1, 2012 local age distributions for combination short-haul trucks. These analyses did not show any statistically significant differences in the age distributions between this survey and overall vehicle registrations.

Idling Prevalence and Duration

CAPCOG's survey asked drivers how long their stay at the truck stop would be, if they planned to idle their truck during their stay, and if so, for how long. Table 19 shows the prevalence of idling behavior at the truck stop among the survey respondents.

Table 19. Respondents reporting whether they planned to idle during their stay.

Cab Type	No Idling	Idling < 1 Hr	Idling 1+ Hr
Sleeper	22 (31%)	27 (38%)	22 (31%)
Day	26 (57%)	19 (41%)	1 (2%)

EPA assumes that extended idling occurs for 8 hours at a time. For estimating the emission rates for 2007 and newer trucks, this assumption becomes increasingly important, since the emission rate is adjusted based on pollution control devices on these newer model year vehicles for the first hour of idling. Then the average rate for the entire period of idling is adjusted to reflect the lower emissions rate from that first hour of idling (see EPA 2012) .. If actual idling behavior were occurring for less than 8 hours at a time, the effect of the lower emissions in this first hour would be spread out over fewer hours of activity, causing a lower average emissions rate, and likewise – if the actual period of idling was longer than 8 hours, the impact of lower emissions in the first hour would be somewhat diminished.

Table 20 shows the average durations of idling reported for trucks staying for an hour or more and for trucks staying less than an hour. The average duration of trucks reporting idling for an hour or more was 8.39 hours, with a confidence interval of 6.47 to 10.31 hours, indicating consistency with EPA's assumption of 8 hours of idling. For shorter-term idling behavior, the average duration was 12 minutes +/- 2 minutes.

Table 20. Average duration of extended and short-term idling reported by drivers.

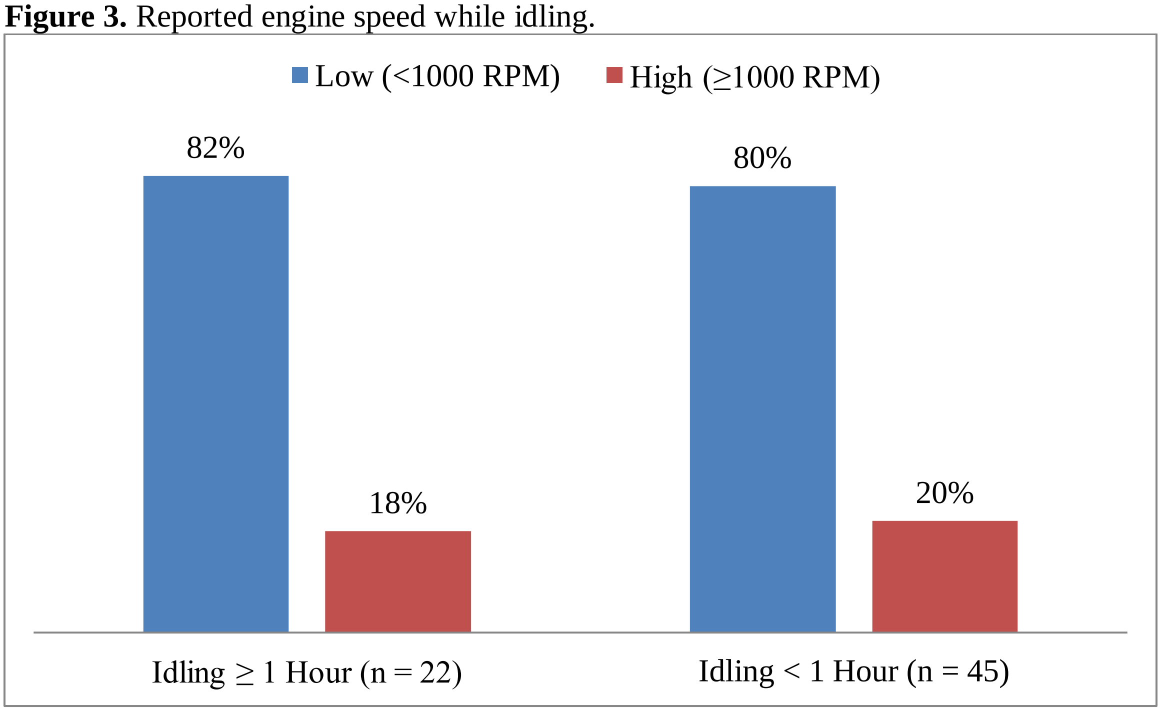
Idling Duration Reported	Average Duration (hours)	95% Confidence Interval (hours)
Idling ≥ 1 Hour	8.39	(6.47 – 10.31)
Idling < 1 Hour	0.20	(0.17 – 0.23)

Analysis of Data on Idling Engine Speed

In EPA's documentation for the heavy-duty truck emissions rates in the MOVES model, EPA identifies engine speed while idling as an important factor in determining the appropriate emissions rate to apply to an idling truck (EPA 2012). EPA states that the measured impact of accessory use and engine idle speed, "makes the behavior of truck operators very important in estimating the emissions rates to assign to periods of extended idling." One of those behaviors is the selection of an engine idling speed. In the MOVES model, EPA assumes that extended idling occurs at a high engine speed, represented in revolutions per minute (RPM), and are using air conditioning (A/C) or heating, thereby increasing the engine load. EPA explains this assumption by stating that there is a tendency to increase idle speed during long idle periods for engine durability, but does not present any specific data supporting this assumption.

As part of CAPCOG's survey, TTI asked drivers whether they engaged in "high" RPM idling or "low" RPM idling in the ranges defined by EPA: high RPM idling is 1,000 RPM or greater, while low RPM idling is less than 1,000 RPM. Figure 3 shows the results for drivers reporting idling an hour or more and for drivers who reported idling for less than an hour.

Figure 3. Reported engine speed while idling.



These results contradict EPA's assumption that extended idling primarily occurs at a high RPM setting. The fact that truck drivers were four times as likely to report idling their engine at a low RPM setting than an high RPM setting, even during one of the hottest summers on record for Central Texas, also challenges that EPA's assumption that accessory use significantly increases the likelihood that an engine will need to idle at a higher speed.

These surprising results prompted CAPCOG to conduct an extensive literature review to both identify any other data that might shed light on this aspect of idling behavior and the potential impact that this assumption has on EPA's default MOVES emissions rates. CAPCOG found a number of studies that present data on typical driver engine RPM settings while engaged in extended idling, and all of them support the conclusion that extended idling typically occurs at a lower engine RPM setting than EPA assumes (Brodrick et al. 2001, Irick and Wilson 2002, Lutsey et al. 2004, Zietsman and Perkinson 2003). Table 21 below shows the summary of the engine RPM data from these studies that CAPCOG evaluated. The average extended idling engine speed across the 764 trucks covered by these studies was 886 RPM.

Table 21. Average RPM settings reported in prior extended idling literature.

Study	Sample Size	Average RPM
Brodrick et al 2001	233	850
Irick and Wilson 2002 (Drivers)	100	965
Irick and Wilson 2002 (Fleet Operators)	100	964
Lutsey et al. 2004	315	866
Zietsman and Perkinson 2003	16	838
TOTAL	**764**	**886**

CAPCOG's reviews of the studies EPA used to determine the emissions rates for idling showed that the average engine speed setting for the "high speed idle/AC" engine tests for NO_X conducted on model years 1991-2006 trucks was 1050 RPM (Broderick 2001, Calcagno 2005, Lim. 2002, Storey et al. 2003). These studies also showed the emissions for "low RPM/Accessory Use" situations. CAPCOG's review of the data sources used by EPA to calculate the idling emissions rates also enabled CAPCOG to more precisely estimate the average engine RPM settings that are associated with the "average high RPM/Accessory Use" emissions rates used by EPA in the MOVES model. As Table 22 below shows, these average rates for 1991-2006 trucks with high idle speed/AC range from 1028 RPM to 1150 RPM, depending on the pollutant.

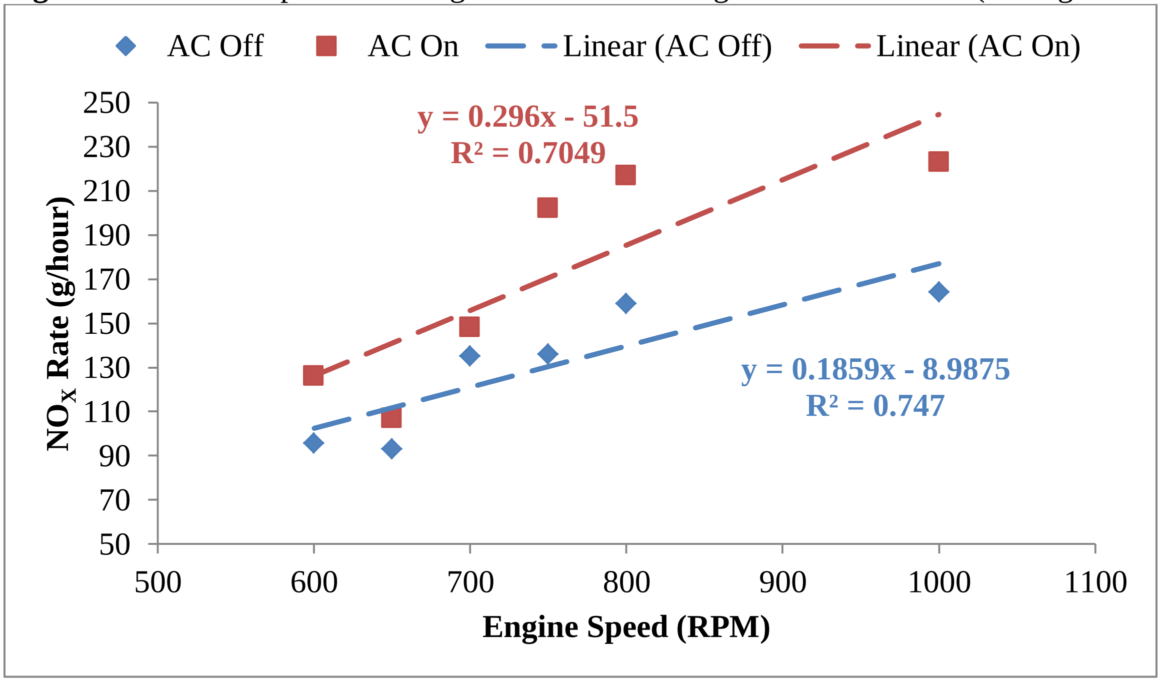
Table 22. Average RPM settings for 1991-2006 idling engine tests: high speed idle/AC.

Source	Trucks	Average RPM	Pollutants
Broderick et al. 2001a	1	1050	HC, CO, NO_X
Calcagno 2005	21	1000	CO, NO_X, PM
Lim 2002	5	1158	NO_X
Storey et al. 2003	4	1175	HC, CO, NO_X, PM
Subtotal – HC	5	1150	HC
Subtotal – CO	26	1029	CO
Subtotal – NO_X	31	1050	NO_X
Subtotal – PM	25	1028	PM

CAPCOG's data review showed that there is a fairly strong positive correlation between engine speed and exhaust emissions. The Figure 4 shows the relationship between NO_X emissions and engine

RPM setting in the Calcagno study, which included the largest number of trucks and engine RPM settings. There may not necessarily be a strictly linear relationship between engine RPM and idling emissions rates – the emissions rates at 800 RPM and 1000 RPM are very similar in this figure – but a linear relationship would explain 70-75% of the variation in these test data between 600 – 1000 RPM.

Figure 4. Relationship between engine idle RPM setting & NO_X emissions (Calcagno 2005).



The survey findings and literature review suggest that existing emission rates used for extended idling may not be representative of typical idling behavior as it pertains to engine idle speed.

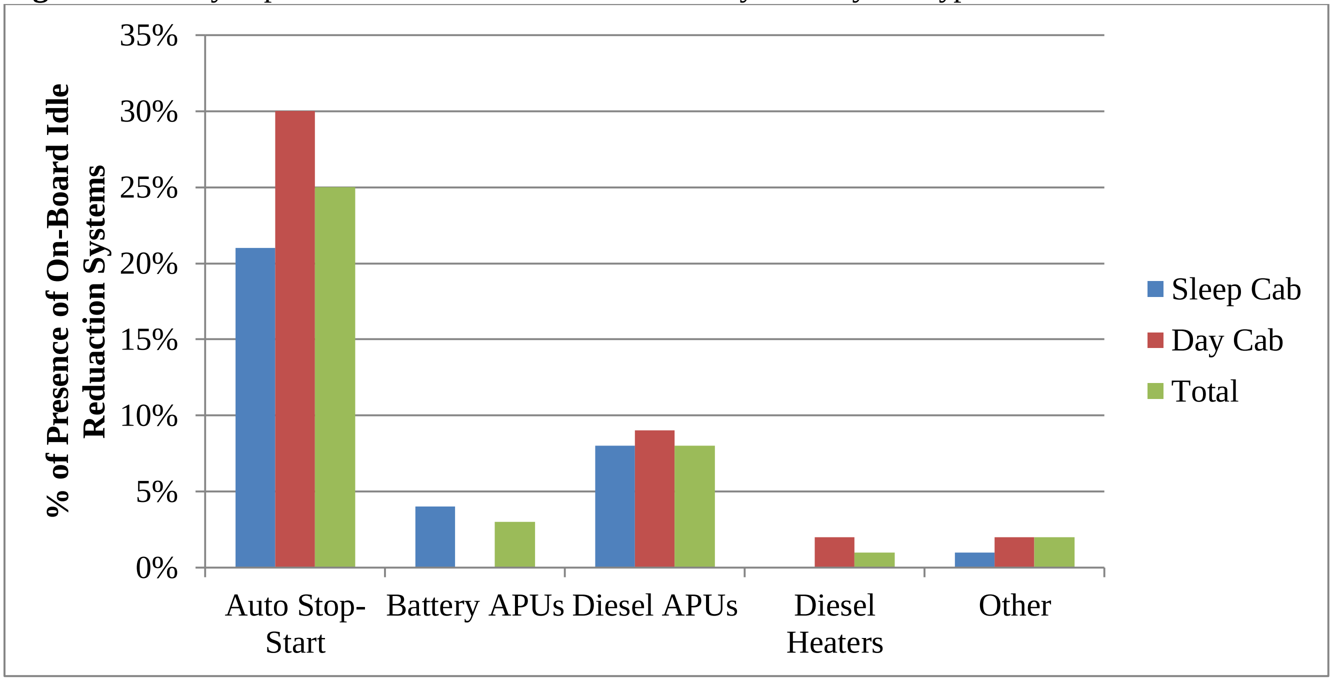
<u>Analysis of Data on On-Board Idling Technologies</u>

Drivers were asked if their truck was equipped with an idle reduction system, and if the driver responded, "Yes," they were asked to identify the type of system. The options identified were:

- Diesel Gen-Set / Diesel APUs;
- Diesel Heater (Direct Fire Heater);
- Automatic Stop-Stop Controls;
- Battery-Powered APUs;
- Thermal Storage Cooling;
- Engine Coolant Heaters; and
- Other.

Drivers were then asked if they intended to use the systems during their stay at the truck stop, and if so, for how long. Among other things, these responses can be used to develop empirically-based allocation factors for hoteling activity for combination long-haul trucks. Figure 5 below shows the percentages of drivers who reported the presence of an on-board idle reduction system on trucks equipped with sleeper cabs and day cabs.

Figure 5. Surveyed presence of on-board idle reduction systems by cab type.



The MOVES2014 model assumes that for model year 2010 and later trucks, 30% of hoteling hours are spent using a diesel APU, rather than idling. Since the CARB low-NO_X idle certification started in 2008, CAPCOG also analyzed these data based on model year. Table 23 shows the numbers and percentages of truck drivers reporting each type of on-board idle reduction system.

Table 23. Presence of on-board idle reduction systems by cab type.

Activity	MY 2008+	% Equipped MY 2008+	< MY 2007	% Equipped < MY 2008
Automatic Stop-Start Controls	6	35%	21	22%
Battery-Powered APU	1	6%	2	2%
Diesel APU	3	18%	7	7%
Diesel Heater	0	0%	1	1%
Other	0	0%	2	2%
None	7	41%	62	65%
TOTAL	**17**	**100%**	**95**	**100%**

These data suggest that on-board idle reduction technology is indeed more prevalent on later model year vehicles, but much of it appears to be in the form of automatic stop-start controls. Combined, battery-powered and diesel-powered APUs for model years 2008 and newer made up 24% of the trucks surveyed. However, 12% of trucks 2007 or older had some kind of idle reduction technology other than automatic stop-start controls, which is not currently accounted for in the MOVES model.

For respondents who indicated that they were planning on spending more than 5 minutes at the location, CAPCOG analyzed the data in order to obtain estimates of the allocation of that time into truck idling, diesel APU, battery APU, and engine off activity. Table 24 shows these allocations for short-duration idling (less than an hour) and extended idling. These data indicate a ratio of 2.8 hours of APU usage per 100 hours of extended idling – about two-thirds of the ratio in TTI's 2012 inventory, but the survey also showed that a significant share of trucks with model years earlier than 2010 also had APUs, which MOVES2014's default allocations of hoteling time do not account for.

Table 24. Calculated Allocation of Hoteling Time From Driver Surveys.

Activity	Total Hours if Stay greater than 1 hr (n = 24)	% of Time if Stay ≥ 1 hr	Total Hours if Stay less than 1 hr (n = 85)	% of Time if Stay less than1 hr
Truck Idling	178	76%	18.1	90%
Diesel APU	5	2%	1.0	5%
Battery APU	0	0%	0.0	0%
Engine Off	51	22%	1.1	5%
TOTAL	**234**	**100%**	**20.2**	**100%**

The survey also asked drivers whether or not their truck was certified to meet the California Air Resources Board's low-NO_X-idle standards that began applying to any trucks model year 2008 or newer. Table 25 shows the distribution of responses for drivers with trucks in each of these model year groups.

Table 25. Percent of respondents indicating their truck was low-NO_X-idle certified by CARB.

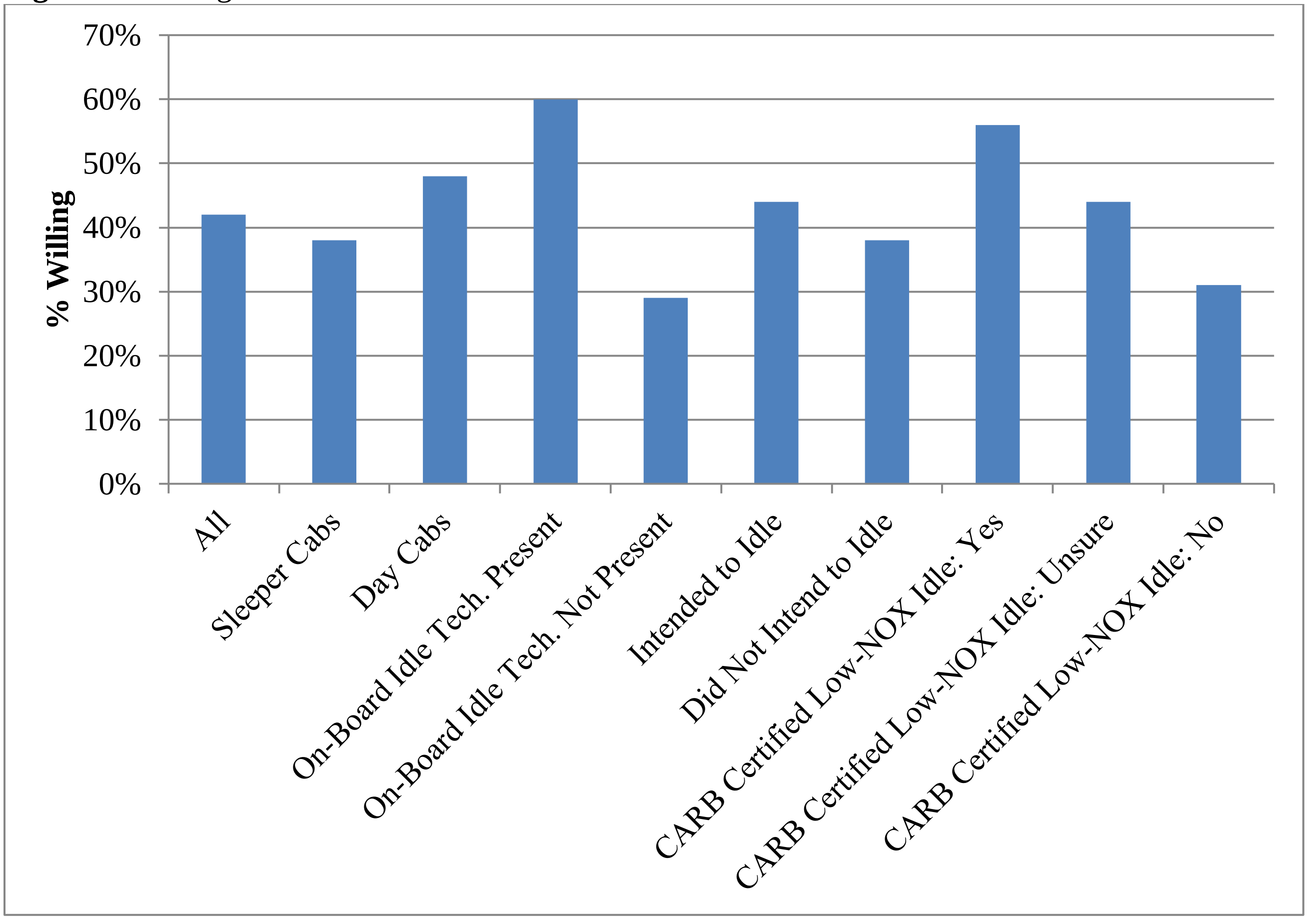
Model Years	Yes	No	Don't Know
2008+	70.6%	5.9%	23.5%
<2008	24.2%	48.4%	27.4%

The fact that 24% of respondents with trucks with model years 2008 and older responded "yes" to this question may mean that a certain percentage of truckers misunderstood the question, perhaps thinking the researcher was asking whether the truck was CARB-certified or that it met national emissions standards. Assuming a similar % of respondents with trucks 2008 and newer may have made the same mistake, CAPCOG subtracted this "false positive" percentage from the percentage of positive respondents with 2008 model year and newer trucks in order to calculate the estimated 46% of 2008 and newer vehicles that were CARB low-NO_X idle certified. Seven of these 17 respondents reported the presence of on-board idle reduction technology (41%).

Analysis of Data on Idling Reduction Infrastructure

Truckers were also asked about their willingness to use idle reduction infrastructure if it was available. Figure 6 shows the driver's answer to this yes/no question across various categories.

Figure 6. Willing to use on-site idle reduction infrastructure if available.



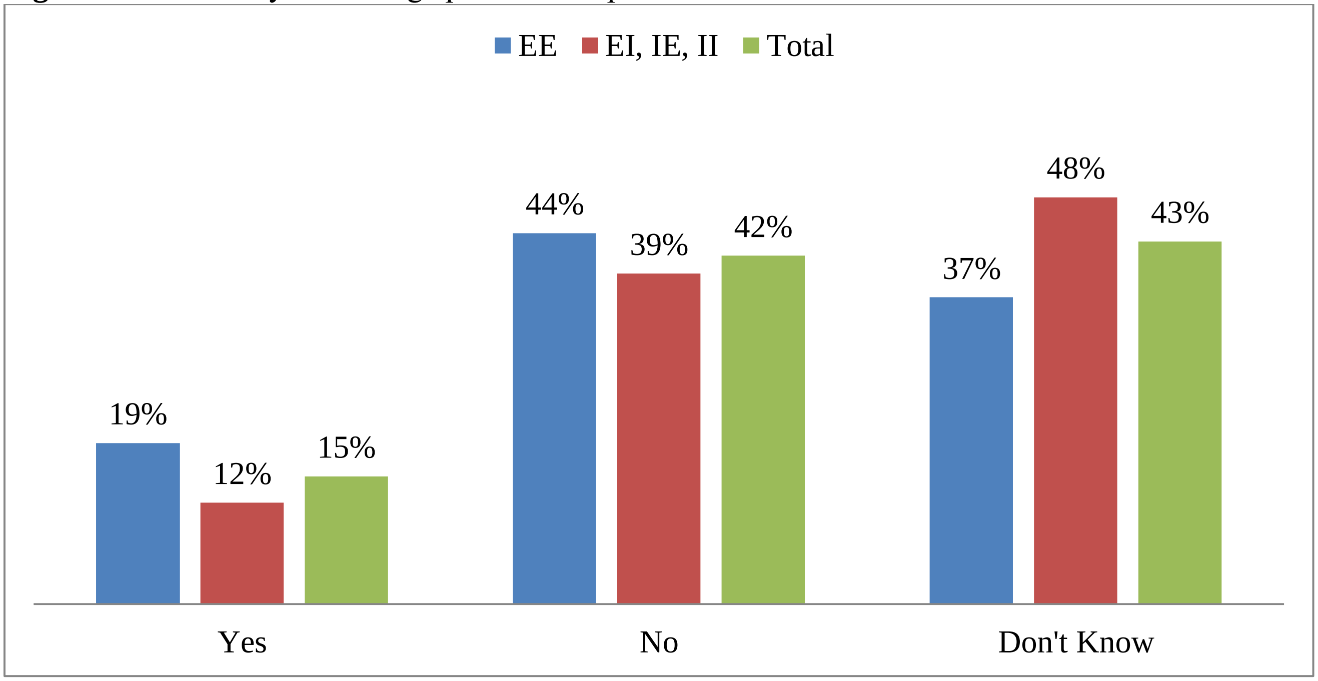
These results highlight one of the challenge for using on-site idle reduction infrastructure as an idle reduction strategy – the truckers most willing to use it are those that already have on-board technology or report being CARB low-NO_X idle certified, and the ones least likely to report being willing to use it are those with no on-board technology or report definitely not being CARB low-NO_X idle certified.

Another important note found from this study: as air quality planners consider how to calculate the emission reduction benefits from truck stop electrification efforts, these results should point to the need to avoid double-counting emission reductions from reduced idling resulting from truckers who are using the on-site infrastructure in lieu of using an APU, rather than in lieu of idling. Failing to account for this could result in double-counting emission reductions.

Analysis of Data on Awareness of and Attitudes Toward Idling Restrictions

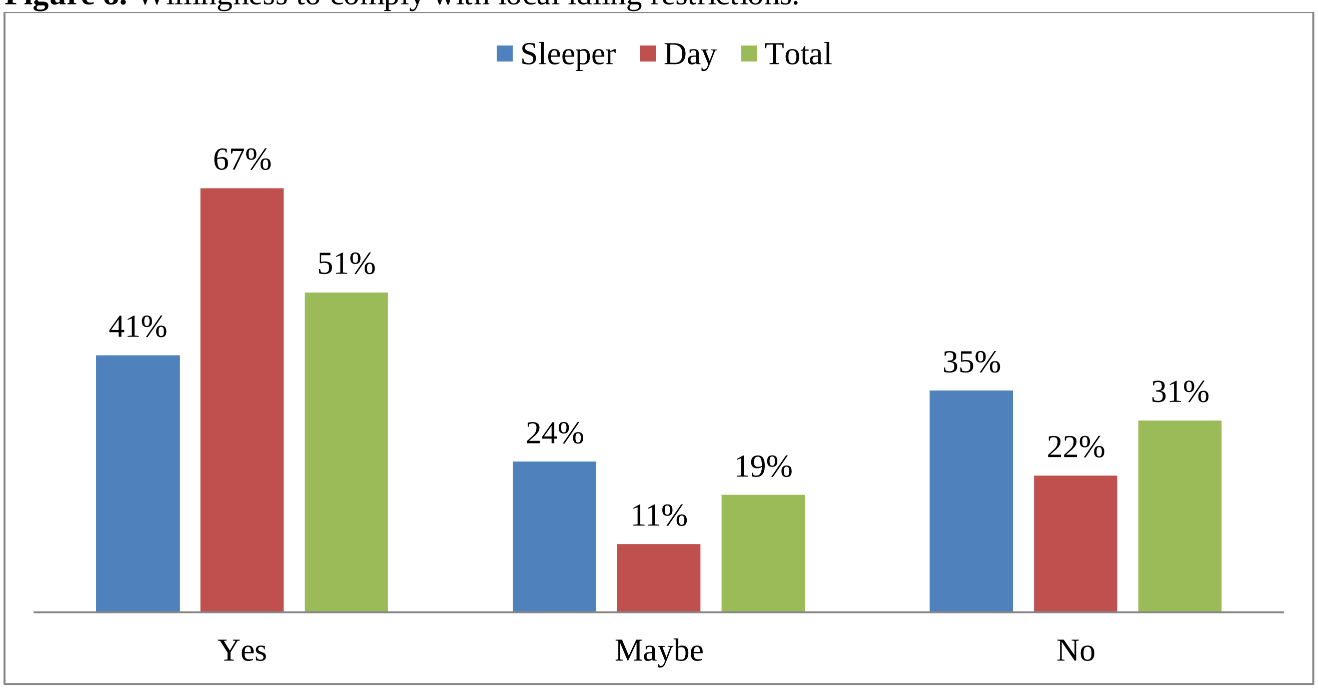
Finally, the results that were probably of most interest to local policy-makers were the extent to which truckers were aware of and willing to comply with local idling restrictions. Truck drivers were asked, "Is there any 'no-idling' provision in place in this location?" Very few truck drivers were aware of the idling restrictions that were in place, even those who were engaged in "internal-internal" truck trips within the Austin-Round Rock MSA. Figure 7 shows the responses by trip type. "I" refers to an origin or destination within the Austin-Round Rock MSA and "E" refers to an origin or destination outside of the Austin-Round Rock MSA. An "I-E" trip type has an origin within the MSA and a destination outside of the MSA.

Figure 7. Is there any "no-idling" provision in place in this location?



Regardless of how a truck driver responded to the question regarding whether idling restrictions in place or not, the drivers were then asked, "If there was such a 'no-idling' provision, would you intend to adhere to it?" Figure 8 shows the responses to this question by cab type.

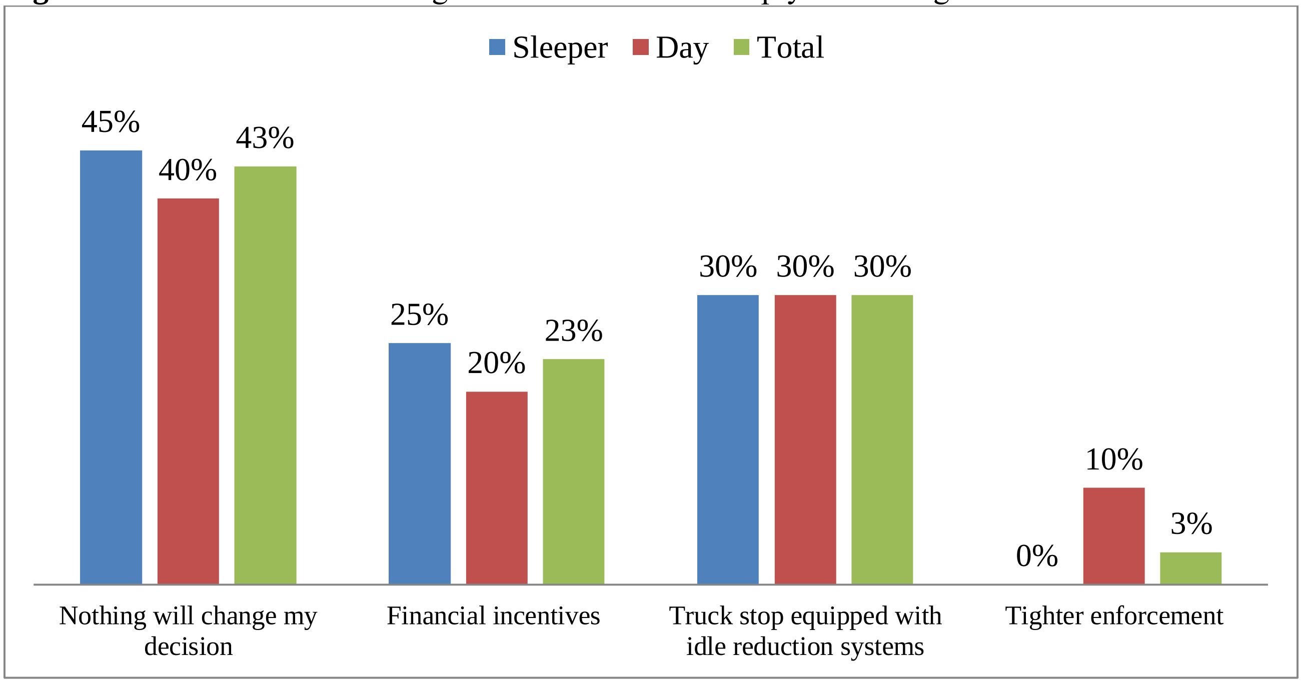
Figure 8. Willingness to comply with local idling restrictions.



The significantly higher percentage of day cab drivers responding "yes" may reflect the fact that they are more likely to be based locally and would be less likely to avoid paying a ticket, or might simply be more respectful of local rules than pass-through drivers might be.

Drivers who responded that they would not intend to comply with local idling restrictions were asked a follow-up question to determine what, if anything might change their mind to comply with local idling restrictions. Figure 9 shows those results. There were a total of 20 drivers with sleeper cabs and 10 drivers with day cabs who responded to this question.

Figure 9. Factors that could change a driver's mind to comply with idling restrictions.



Taking all of these results into account, it is evident that lack of awareness of idling restrictions limited the emissions reductions impact that these rules could have achieved. Even if high levels of awareness were achieved, there would remain large hurdles to ensuring high levels of compliance. This survey was conducted simultaneously to the extended idling data collection in 2011 referenced earlier in this report. At this time, extended idling was not exempt from the local idling restrictions. Given these results, CAPCOG believes that the idling restrictions were only achieving approximately an 8-12% rule effectiveness, based on the equations below.

Equation (4): % Aware of Rule * % Willing to Comply With Rule = Rule Effectiveness %

Equation (5): 19% Awareness * 41% (Yes) = 8% Rule Effectiveness (Min.)

Equation (6): 19% Awareness * 65% (Yes + Maybe) = 12% Rule Effectiveness (Max)

These results also suggest that there are about 15% of sleeper cab drivers who would not reduce idling behavior even under the best circumstances – they reported not being willing to comply with the rule and indicated that nothing would change their minds.

CONCLUSION

Relative Importance of Extended Idling v. Short-Term Idling

Table 26 shows the estimated extended and short-term idling emissions estimates for 2012 for the Austin-Round Rock MSA.

Table 26. Truck idling emissions estimates, 2012 ozone season weekdays (tons per day).

Idling Type	Hours	CO	NO_X	VOC	CO_2	PM_{10}	$PM_{2.5}$
Short-Term Idling	5,958	0.4761	0.5418	0.0797	151.0598	0.0259	0.0252
Extended Idling	5,176	0.5119	1.0898	0.2938	52.1884	0.0265	0.0244
Combined	**11,134**	**0.9880**	**1.6316**	**0.3735**	**203.2482**	**0.0524**	**0.0496**

Despite short-term idling making up a larger share of the total number of hours spent idling, it makes up a smaller share of CO, NO_X, and VOC emissions. Short-term idling accounts for approximately the same amount of PM_{10}, and $PM_{2.5}$ emissions, and a significantly larger share of CO_2 emissions. These differences in the relative share of idling-related CO, NO_X, and VOC emissions compared to CO_2 emissions can be explained by the impacts of pollution control devices that will continue to operate efficiently during a short-term idling situation but will diminish for extended idling.

Recommend Re-Evaluating MOVES Extended Idling Emissions Rates in Light of RPM Findings

One of the more important implications of the trucker surveys and the extensive literature review was that the assumption that truckers primarily use high-RPM engine speeds while engaged in extended idling is not supported by the available empirical evidence. CAPCOG's review indicated that truck drivers typically idle their engines at about 886 RPM, as opposed to the 1028-1150 RPM averages for the engine test data EPA used for their extended idling emission rates for 1991-2006 model years and – with exhaust control effects factored in for the first hour of idling – 2007 model years and beyond. These findings warrant a re-analysis of the data sources EPA used for the MOVES extended idling emission rates presented in *Development of Emission Rates for Heavy-Duty Vehicles in the Motor Vehicle Emissions Simulator MOVES 2010*, A3 (EPA 2012). Many of those same studies include emissions data for extended idling emissions at lower RPM settings consistent with CAPCOG's survey and literature review with accessory loads added. CAPCOG expects that this re-analysis will show that lower exhaust emissions rates consistent with these low RPM/AC settings would be more representative of typical extended idling behavior.

Recommended Future Research

For future MOVES model development, CAPCOG believes that use of a surrogate other than rural restricted highway VMT should be used to allocate idling activity to the county level. CAPCOG's research indicates that this is not a reliable indicator for a county's extended idling activity. Extended idling occurs along roadways other than interstate highways, and the fact that a segment carries a large amount of truck VMT does not mean that it also has adequate nearby truck parking capacity. National-scale options include development of a national database of truck stops and rest areas or allocating the activity to each county based on total combination truck VMT on all roadway types.

The driver surveys strongly suggested that additional data collection on the prevalence and use of on-board idle reduction technologies could be valuable. The high degree of market penetration of CARB low-NO_X-idle-certified trucks in an area outside of California in this survey suggests that emissions rates for trucks model year 2008 and newer may need to be reevaluated to account for the spillover effects of these standards. Additional collection of sales data and trip characteristics of such vehicles would be valuable to gaining a more precise estimate for these impacts.

Bottom-Up Versus Top-Down Methods

This report provides bottom-up estimates of extended and short-term idling behavior in Central Texas. The relative value of bottom-up approaches compared to top-down approaches depends largely on a user's intended application of the data. For CAPCOG's purposes, bottom-up inventories were important in order to accurately represent each county's idling activity and identify the key areas where idling would be expected to occur. However, these were quite labor-intensive processes and, especially for the extended idling location inventory, were very sensitive to anecdotal evidence and year-to-year changes in the estimated idling activity in a given county. The existence of local idling restrictions made it important to have this kind of county-level and location-level accuracy and precision, and that could only be developed through bottom-up research. However, if a state or region does not intend to include idling reduction strategies as part of an air pollution control strategy, , a top-down approach may be preferable. Top-down methods have an advantage over bottom-up methods in that they involve uniform application across many geographies and ensure more or less complete accounting of the activity at a high geographic scale.

However – as this paper shows, bottom-up research does provide a good check on the assumptions used in top-down applications. The geographic distribution of idling activity within Central Texas suggests that EPA's use of rural restricted highway VMT as the basis for allocating hoteling hours is not necessarily a reliable indicator of county-level idling activity. Moreover, CAPCOG's driver survey highlights some important areas where EPA's assumptions about engine idle speed and the prevalence and use of on-board idle reduction technologies may need to be reexamined.

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KEY WORDS

Emission Inventories
Mobile Sources
On-Road
Idling