Reducing Greenhouse Gas Emissions from Transportation

Opportunities in the Northeast and Mid-Atlantic

Technical Appendix

Emission Inventory and Forecast

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Appendix Prepared for Georgetown Climate Center by Cambridge Systematics

CAMBRIDGE SYSTEMATICS

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1.0 Introduction

The objective of the analysis described in this report is to create a bottom-up emissions inventory and forecast (I&F) for the multi-state Transportation and Climate Initiative (TCI) region based on local inputs. The inventory was conducted for 2011 for the on-road, passenger rail and ferry sectors, and for 2012[1] (assumed equivalent to 2011) for the freight rail and intra-region marine sectors. The forecast is developed for 2030 based on a broad set of data and assumptions described herein.

2.0 On-Road Sector

2.1 Introduction

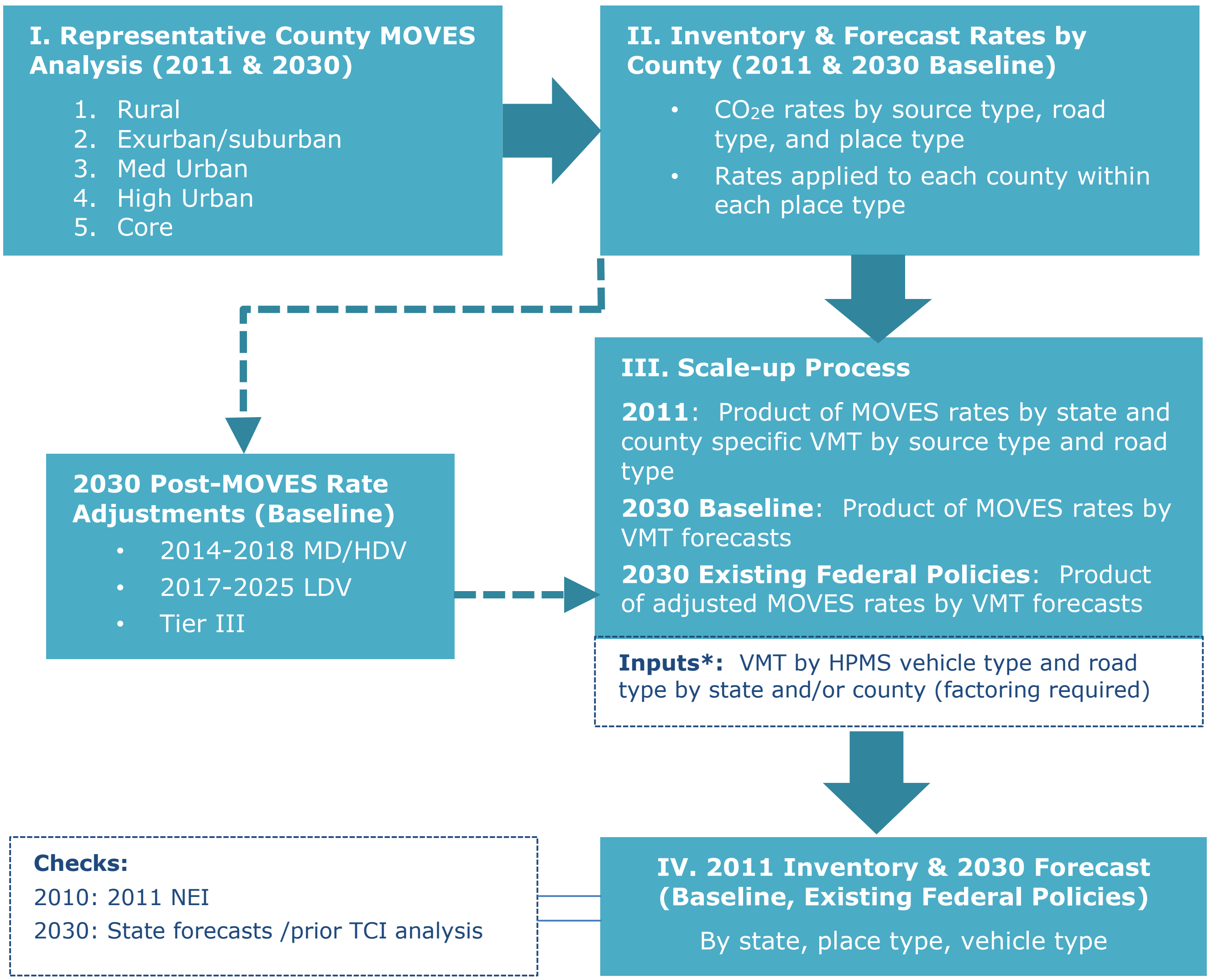
The outcome of the on-road sector I&F is made available to stakeholders as a user-friendly database displaying greenhouse gas (GHG) emissions estimates at the state, place type, and county level, segmented by vehicle type and road type. The on-road I&F also provides a baseline to support the GHG mitigation policy and strategy evaluation described in the main report and the Emission Reduction Strategy Analysis Appendix. The process (see Figure 2.1) for developing the on-road I&F is intended to be transferable and repeatable, enabling recurring updates based on updated tools and data.

Development of the process focused on an approach that met the following goals:

- Data tailored to this region but feasible to collect in the specified timeframe - A representative county approach ensured that unique features of emission profiles by different place type in the region could be captured in the analysis, while not requiring a distinct MOVES analysis for each individual county. As a result, the assessment required limited resources to set up and run MOVES, as well as assembling data and reporting results.
- Every state and the D.C. are assessed similarly - It is recognized that each state and D.C. conduct emissions analysis to support air quality planning through their own unique modeling process. The intent of this analysis is to standardize the approach across the TCI region to enable more relevant comparisons of GHG emissions across jurisdictional boundaries. There is no intent to overwrite or replace existing state-level analysis.
- Applied consistently for any year – The objective is to create a consistent baseline forecast across all states in the TCI region, enabling comparisons where the only independent variables for consideration are place type specific VMT growth rates and a limited set of MOVES input files.

[1] Consistent with data available through the FHWA Freight Analysis Framework.

Figure 2.1 Inventory and Forecast Overview

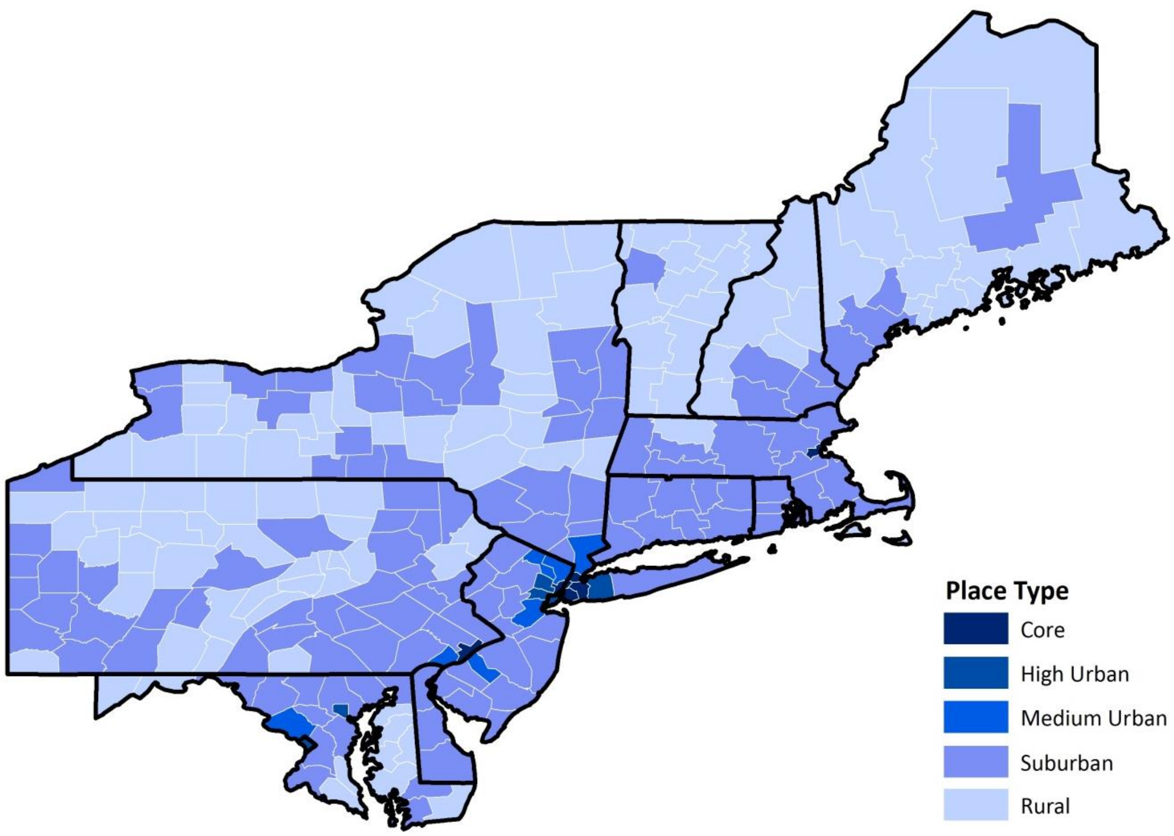


The representative-county MOVES analysis approach is a standard process for reducing the computational burden of running MOVES on every county in a large modeling domain. A number of states use a representative approach to model different regions of the state quickly. The approach is based on a strong assumption that MOVES inputs for neighboring or similar areas are roughly identical. In this case, running MOVES in inventory mode permits the user to develop emissions rates based on the unique characteristics of each representation location, and then assign these emission rates to jurisdiction-specific VMT information.

2.2 Representative County MOVES Analysis

To create a bottom-up emissions I&F for the TCI region for the on-road mobile sector, an approach was employed utilizing the EPA MOVES model (MOVES 2010b)[2] with location specific MOVES inputs to estimate greenhouse gas emission rates (grams CO_2 equivalent, CO_2e, per mile) by vehicle type and road type for five representative place types (two counties for each place type) within the TCI region. The place types were defined based on logical breaks in population density by county within the TCI region. Figure 2.2 presents a map of the place type assignment by county in 2011. There is minimal change in counties by place type in 2030, however as noted in the description of the Inventory & Forecast tool (Section 2.8), users can choose to update assumptions with regard to place type designations by county.

Figure 2.2 TCI Place Types



The intent, rather than just using 2011 National Emissions Inventory (NEI) data, is to apply an analysis approach consistently for both the base year (2011) and future year (2030). The representative-county approach enables development of CO_2e emission rates tailored to the unique characteristics of each place type (specifically speed distribution) along with other MOVES inputs consistent with characteristics of the TCI region. The five place type definitions,

[2] Note, MOVES2014 was released in July 2014, too late for use within this analysis. Adjustments to results from MOVES2010b to reflect new Federal standards are discussed in Section 2.4.

their density ranges, and the representative counties chosen for analysis are presented in Table 2.1. The actual counties selected were intended to bracket the diversity of counties within each place type, while focusing on MOVES inputs received from four states representing the geographic scope of the region – Massachusetts, New York, New Jersey, and Maryland. These four states were selected to help the analysis team represent the geographic diversity of the TCI region and take advantage of available data and expertise within the timeline and budget of the project.

Table 2.1 Place Type/Representative County Approach

Place Type	Density Range	Representative Counties
Rural	<= 500 persons/sq.mi.	Cayuga County, NY; Caroline County, MD
Suburban	> 500 persons/sq.mi. and <=2,000 persons/sq.mi.	Saratoga County, NY; Worcester County, MA
Medium Urban	> 2,000 persons/sq.mi. and <=4,000 persons/sq.mi.	Westchester County, NY; Montgomery County, MD
High Urban	> 4,000 persons/sq.mi. and <=10,000 persons/sq.mi.	Richmond County, NY; Union County, NJ
Core[3]	> 10,000 persons/sq.mi.	Bronx County, NY; Suffolk County, MA

Cambridge Systematics (CS) obtained county-level 2011 MOVES inputs from New York (NEI version 2) and obtained the EPA version 1 NEI data for representative counties from the remainder of TCI states. For 2030 (or the nearest readily available year), CS obtained MOVES inputs for select counties by place type from Connecticut, Delaware, District of Columbia, Maryland, Massachusetts, New Hampshire, New Jersey, New York, and Vermont.

CS conducted a comparative analysis across the range of input files by state to determine the extent to which local MOVES inputs that significantly affect GHG emission rates (speed distribution, age distribution, and source type population) vary by place type. Five New York counties were initially selected. These counties were compared against each other and then compared against five other counties (one per place type) from other states in the region (primarily MD, MA, and NJ).

CS used this analysis to validate the selection of representative counties. The representative county inputs vary most critically on speed distribution profiles and to a lesser extent age distribution and source type population. Meteorology differences have a minimal impact on GHG emission rates, while inputs such as fuel type/technology and fuel supply/formulation are assumed consistent for the entire region. After a thorough review, it was decided to use local inputs (for speed distribution, age distribution, and source type population) for the chosen

[3] Note, for the core place type, MOVES was run, and emission rates applied for each county in 2011: Suffolk, MA; Hudson, NJ; Bronx, NY; Kings, NY; New York, NY; Queens, NY; and Philadelphia, PA.

representative counties as supplied by the states for each place type (refer to Table 2.1) in combination with default MOVES input files in order to model emission rates in MOVES.

2.3 Inventory and Forecast Emission Rates

MOVES was run in inventory mode for the entire year for each representative county, using all county specific inputs provided by the states in 2011 and 2030. In total, MOVES was run for ten counties in 2011 (plus additional runs for the five other core counties) and the same ten counties in 2030. This 2030 forecast is referred to as the "Baseline Scenario."

For each county, total CO_2e by source type and road type as well as composite emission rates (weighted by VMT by speed bin) were output from the MOVES runs. The rates for each county within each place type were compared, and a resulting average rate was identified for each place type. The 2011 and 2030 rates (grams CO_2e/mile) are presented in Table 2.2 and 2.3.

Table 2.2 Running Emission Rates (g CO_2e/mi) by Place Type (2011)

Vehicle Type (MOVES Source ID)	Rural	Suburban	Medium Urban	High Urban	Core
Passenger Car (21)	354	354	370	382	428
Passenger Truck (31)	499	499	515	529	587
Light Commercial Truck (32)	509	510	529	541	598
Transit Bus (42)	1,370	1,373	1,288	1,373	1,425
Single Unit Short-haul Truck (52)	1,005	1,007	1,109	1,150	1,322
Single Unit Long-haul Truck (53)	949	951	1,050	1,095	1,237
Combination Short-haul Truck (61)	2,025	2,028	2,152	2,177	2,387
Combination Long-haul Truck (62)	2,108	2,111	2,244	2,264	2,478

Table 2.3 Running Emission Rates (g CO_2e/mi) by Place Type (2030 BAU)

Vehicle Type (MOVES Source ID)	Rural	Suburban	Medium Urban	High Urban	Core
Passenger Car (21)	265	274	331	367	354
Passenger Truck (31)	340	351	418	458	447
Light Commercial Truck (32)	359	383	452	484	482
Transit Bus (42)	1,244	1,288	1,361	1,482	1,419
Single Unit Short-haul Truck (52)	916	1,017	1,281	1,455	1,374
Single Unit Long-haul Truck (53)	857	961	1,002	1,371	1,306
Combination Short-haul Truck (61)	1,965	2,011	1,077	2,522	2,428
Combination Long-haul Truck (62)	2,049	2,095	2,424	2,614	2,516

Running emissions are those from the tailpipe while the vehicle is in motion and make up the large majority of greenhouse gas emissions in most on-road inventories. Non-running emissions are associated with off-network emissions from vehicle start-up and extended idling for combination long-haul trucks. Running emissions are multiplied by standard factors by place type, based on results from the MOVES model runs, to include non-running emissions after the total inventory is estimated.

2.4 2030 Post-MOVES Rate Adjustments (2030 Federal Policies)

MOVES 2010b does not include the federal GHG standards described below. They are included in MOVES 2014, which was released at the end of July 2014, too late to be used in this analysis. Post-MOVES adjustments were made to reflect these standards since MOVES 2014 was not available in time for this analysis.

- **Final federal rule for MY 2014-2018 medium/heavy duty trucks** – Post-MOVES adjustments are based on percent changes in fuel consumption and greenhouse gas emissions for model year 2018 and later vehicles as provided in the EPA/NHTSA factsheet.[4] These percent changes vary by vehicle type as shown in Table 2.4. Linear interpolation between zero and the 2018 values are used to obtain values for model years 2014-2017. The rule is assumed to impact all model years 2014 and beyond. Based on vehicle age distribution by MOVES source type (vehicle type), the share of vehicles conforming to the standards for 2030 can be estimated. The emission rate adjustment factors in 2030 are summarized in Table 2.6.

Table 2.4 Adjustments for Medium/Heavy Duty MY 2014-2018

	GHG Emission Rate Improvement		
Model Year	**Combination Truck**	**HD Pickups & Vans**	**Vocational**
2014	4.0%	3.0%	2.0%
2015	8.0%	6.0%	4.0%
2016	12.0%	9.0%	6.0%
2017	16.0%	12.0%	8.0%
2018 & later	20.0%	15.0%	10.0%

[4] U.S. Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA). "FACTSHEET: Paving the Way Toward Cleaner, More Efficient Trucks." Available: http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/Factsheet.08092011.pdf

- **Final federal rule for MY 2017-2025 light duty vehicles** – Post-MOVES adjustments are based on new fuel economy estimates for each model year from 2017-2025, which was included in the notice of proposed rulemaking (NPRM).[5] These fuel economy estimates and the corresponding percent improvement in greenhouse gas rates are shown in Table 2.5. The rule is assumed to impact all model years 2017 and beyond. Based on vehicle age distribution by MOVES source type (vehicle type), the share of vehicles conforming to the standards for 2030 can be estimated. The emission rate adjustment factors are summarized in Table 2.6.

Table 2.5 Adjustments for Light Duty MY 2017-2025

	Fuel Economy (mpg)		GHG Rate Improvement	
Model Year	**Passenger Cars**	**Light Trucks**	**Passenger Cars**	**Light Trucks**
2016 base	37.8	28.8		
2017	40.0	29.4	5.82%	2.08%
2018	41.4	30.0	9.52%	4.17%
2019	43.0	30.6	13.76%	6.25%
2020	44.7	31.2	18.25%	8.33%
2021	46.6	33.3	23.28%	15.63%
2022	48.8	34.9	29.10%	21.18%
2023	51.0	36.6	34.92%	27.08%
2024	53.5	38.5	41.53%	33.68%
2025 & later	56.0	40.3	48.15%	39.93%

[5] U.S. Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA). Notice of Proposed Rulemaking (NPRM). 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards. Available: http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/2017-25_CAFE_NPRM.pdf

Table 2.6 2030 Post-MOVES Rate Adjustments

MOVES Source Type	Adjustment Factor by Federal Vehicle Type	Adjustment Factor by MOVES Source Type
Motorcycle (11)	N/A	1
Passenger Car (21)	0.728674 (passenger cars)	0.728674
Passenger Truck (31)	0.787774 (light trucks) 0.881687 (pickups/vans)	0.793409
Light Commercial Truck (32)		0.799832
Intercity Bus (41)	0.921125 (vocational)	0.921125
Transit Bus (42)		0.921125
School Bus (43)		0.921125
Refuse Truck (51)		0.921125
Single Unit Short-haul Truck (52)		0.921125
Single Unit Long-haul Truck (53)		0.921125
Motor Home (54)		0.921125
Combination Short-haul Truck (61)	0.84225 (combination trucks)	0.84225
Combination Long-haul Truck (62)		0.84225

Per the Tier 3 regulatory impact analysis, the reduction in methane (CH_4) from the standard is estimated nationwide at 0.1 mmt CO_2e in 2018 and 0.9 mmt CO_2e in 2030 (less than 0.1 percent of national on-road emissions).[6] The regulatory impact analysis indicates that the Tier 3 standards are not expected to result in any discernible changes in vehicle CO_2e emissions or fuel economy. Emissions of the pollutants that are controlled by the Tier 3 program (NMOG, NO_x, and PM) are not a function of fuel consumed, since manufacturers need to design their emission control systems to reduce these emissions regardless of their engine capacity levels.[7]

2.5 Scale-Up Process

To support the scaling of emissions rates estimated for the five place types using MOVES to the state and regional level, CS obtained from publically available data or directly from state DOT contacts the 2011 Highway Performance Monitoring System (HPMS) VMT data for each county, and 2030 VMT projections from each state. Estimates of 2011 and 2030 VMT were developed for each county in the TCI region, split across MOVES road and source types.

[6] Source: Table 7-53. Tier 3 Regulatory Impact Analysis, February 2014. http://www.epa.gov/otaq/documents/tier3/420r14005.pdf

[7] Source: Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards Final Rule - Regulatory Impact Analysis. US EPA, February 2014. pg 7-131.

The final VMT data for each county used in the I&F was generated using the following steps:

1. Counties were assigned to each of the five place types based on population density;
2. Whenever it was possible to do so, a county-specific split by source and road type was calculated, either from 2011 or projected 2030 VMT received from each state; or
    a. If VMT splits by vehicle type and road type were not available for the specific state or county, for each of the five place types, a representative county with known data was identified (all were in New York), and default shares were calculated for MOVES source type and road type both from overall VMT and from FHWA vehicle type and functional classification;
3. Estimates of VMT in 2011 and 2030 were then generated for each county, source type, and road type; and
4. These estimates were used to calculate an average VMT growth rate by place type across the study area. The average growth rates were then applied to all counties, source and road types to generate consistent estimates of 2030 VMT.

The level of detail in VMT data ranged from ready-made granular VMT for one or both years to only state or county level totals. Consequently, the methodology CS utilized to calculate the road and source type shares and granular VMT estimates varied between states and sometimes between 2011 and 2030 in the same state. Important notes on this process include:

- In general, less detail was available for 2030 forecast VMT than for 2011. Consequently, the New York default 2030 values were used more frequently in the calculation of the 2030 VMT splits by source and road type;
- For states that did not have any detailed (by source or road type) 2030 VMT forecasts available, in some cases total state or county level VMT forecasts were available, while in other cases population growth forecasts were used as replacement for VMT growth;
- For states that provided no specific data, HPMS VMT data for 2011 were split by county according to population and factored by projected county population growth (with the New York default source type split applied); and
- Several states used generalizations of FHWA vehicle types that combined types without documenting the granular data (primarily by summing bus VMT for types 41, 42, and 43). In these cases, the New York default counties were used to calculate a default split that was applied to the total value provided.

Table 2.7 presents 2011 VMT by place type and select source type.

Table 2.7 Annual VMT (billions) by Place Type (2011)

Vehicle Type (MOVES Source ID)	Rural	Suburban	Medium Urban	High Urban	Core
Passenger Car (21)	31,448	187,924	21,847	15,333	15,579
Passenger Truck (31)	18,637	106,370	14,640	10,352	9,947
Light Commercial Truck (32)	5,141	25,436	2,208	1,546	1,308
Transit Bus (42)	377	1,175	99	71	304
Single Unit Short-haul Truck (52)	1,666	4,412	289	472	775
Single Unit Long-haul Truck (53)	183	1,366	434	206	128
Combination Short-haul Truck (61)	613	2,112	236	150	126
Combination Long-haul Truck (62)	525	2,237	137	121	146

The average annual VMT growth rates from 2011 to 2030, applied to the 2011 VMT estimates by place type and source type, are presented in Table 2.8.

Generating an average annual VMT growth rate by place type results in 2030 VMT state total estimates that vary from the VMT forecast data generated by each state. Using place type average VMT growth is overall consistent with the MOVES approach focusing on representative county emission rates by place type.

Table 2.8 Average Annual VMT Growth Rate by Place Type (2011 to 2030)

Vehicle Type (MOVES Source ID)	Rural	Suburban	Medium Urban	High Urban	Core
Passenger Car (21)	0.8%	0.8%	0.6%	0.4%	0.6%
Passenger Truck (31)	0.4%	0.8%	0.7%	0.5%	0.6%
Light Commercial Truck (32)	0.4%	0.7%	0.7%	0.5%	0.5%
Transit Bus (42)	0.6%	0.9%	0.7%	0.9%	0.5%
Single Unit Short-haul Truck (52)	1.0%	1.2%	1.2%	0.6%	0.5%
Single Unit Long-haul Truck (53)	1.1%	2.5%	3.3%	2.9%	1.5%
Combination Short-haul Truck (61)	0.6%	1.9%	2.9%	2.0%	1.6%
Combination Long-haul Truck (62)	0.6%	0.7%	2.1%	1.2%	0.1%

2.6 2011 Inventory and 2030 Forecast Results

VMT by place type, segmented at the county, source type, and road type level is multiplied by the running CO_2e emission rates (g/mile) to estimate total running CO_2e emissions.

The non-running emissions typically make up a small percentage of an on-road GHG inventory (around 5 percent, depending on vehicle type). MOVES emission processes for vehicle starts (type 2) and extended idle (type 90) were reported as part of the MOVES runs for the representative counties. Across each place type, an average share of total emissions was estimated for these two emission processes. These average shares are:

- Core - 5.4 percent
- High Urban – 4.8 percent
- Medium Urban – 5.1 percent
- Suburban – 5.3 percent
- Rural – 5.5 percent

2030 Baseline Scenario emission rates by source type are multiplied by the adjustment factors presented in Table 2.6 in order to estimate 2030 Federal Policies Scenario running emission rates. The same non-running emissions shares are assumed for 2011, the 2030 Baseline Scenario, and 2030 Federal Policies Scenario.

The raw results of this analysis are presented in the Inventory & Forecast tool (Section 2.8) organized as follows:

- In rows organized by county (245 in the TCI region including the District of Columbia), source type (13) and road type (4), totaling 12,740 rows.
- In columns organized by 2011 and 2030 VMT, running emissions rate (2011, 2030 BAU, 2030 Federal Policies), total running emissions (2011, 2030 Baseline, 2030 Federal Policies), and total running and non-running emissions (2011, 2030 Baseline, 2030 Federal Policies), totaling 140,140 unique values.

The design of the table allows for easy filtering, sorting, and development of summary pivot tables within Excel. Note that there are a number of cells with zero values in the raw data table. These cells are in counties where there is zero VMT on one of the four road types. For example a dense urban county may have no roads designated as rural (road types 2 & 3), or a county may have no restricted facilities (road types 2 & 4).

2.6.1 Results

The following tables and figures present example summary statistics from the on-road I&F.

TCI Region Comparison to United States

2011: 20% US population - 17% US VMT - 19% US On-Road CO_2e

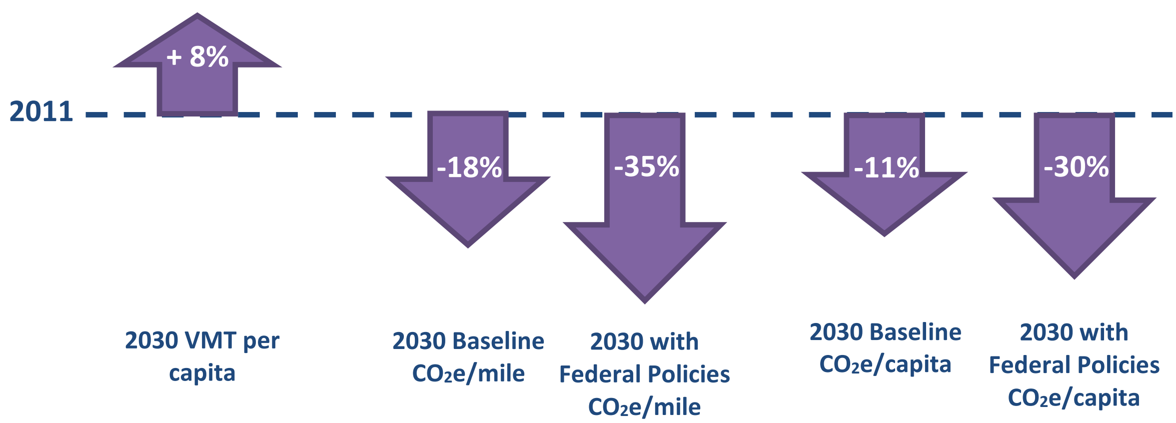
2030: 18% US population - 15% US VMT - 16% US On-Road CO_2e

Note: Proportions based on FHWA Highway Statistics and 2013 Annual Energy Outlook

TCI Region Population, Travel, and On-Road Emissions Statistics

Annual VMT (billions)		Population		Annual mmt CO_2e		
2011	2030	2011	2030	2011	2030 BAU	2030 Federal Policies
497.45	573.91	62,875,018	66,633,704	256.29	242.27	191.44

0.7% annual growth — 0.3% annual growth — -5% — -25%



In prior phases of analysis, estimates of 1990, 2005, and 2008 emissions were developed based on National Emissions Inventory and Annual Energy Outlook data. Figure 2.3 presents a summary of the baseline on-road emissions trend (1990 – 2011) and the outcomes of the 2030 Baseline and 2030 Federal Policies forecast.

The results shown here for 2030 federal policies do not take into account the federal Renewable Fuel Standard (RFS-2), which is not considered in the MOVES model. The Emission Reduction Strategy Analysis does take the RFS into account through a post-processing adjustment, and therefore the figures used in the main report and Emission Reduction Strategy Analysis Appendix are slightly lower.

Figure 2.3 TCI Region On-Road CO_2e Emissions Backcast and Forecast

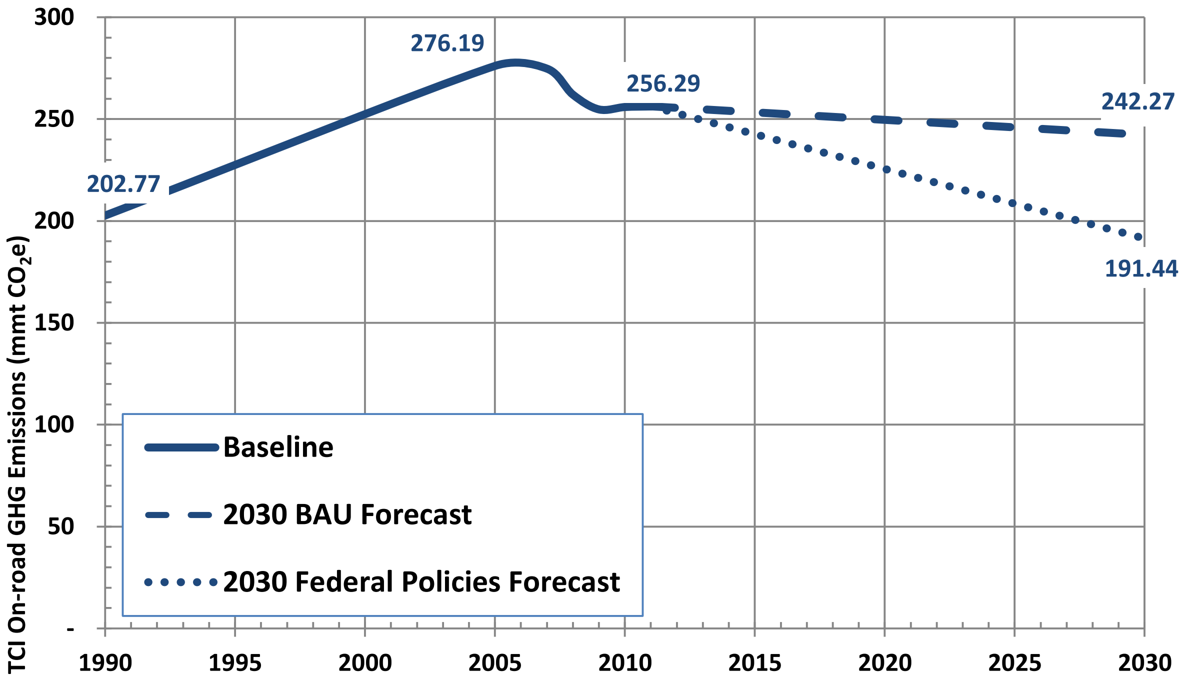


Table 2.9 TCI Region Travel and Emissions Statistics by Vehicle Type

Vehicle Type	Annual VMT (billions) 2011	Annual VMT (billions) 2030	Annual mmt CO_2e 2011	Annual mmt CO_2e 2030 BAU	Annual mmt CO_2e 2030 Federal Policies
Passenger Cars & Trucks	434.99	500.08	194.48	173.31	131.40
Light Commercial Trucks	35.64	40.43	19.64	17.17	13.73
Buses	9.19	10.67	14.75	16.69	15.38
Single-Unit Trucks	11.23	14.59	13.27	17.40	16.03
Combination Trucks	6.40	8.16	14.15	17.70	14.90
Total	**497.45**	**573.91**	**256.29**	**242.27**	**191.44**

As the on-road I&F was developed through a bottom-up process utilizing state-specific data, VMT and GHG emissions can be reported at the state and place type level. Figure 2.4 presents GHG emission estimates by State. Figure 2.5 presents a summary of the 2030 Federal Policies emission difference in each State compared to 2011.

Figure 2.4 TCI Region Emission Estimates by State

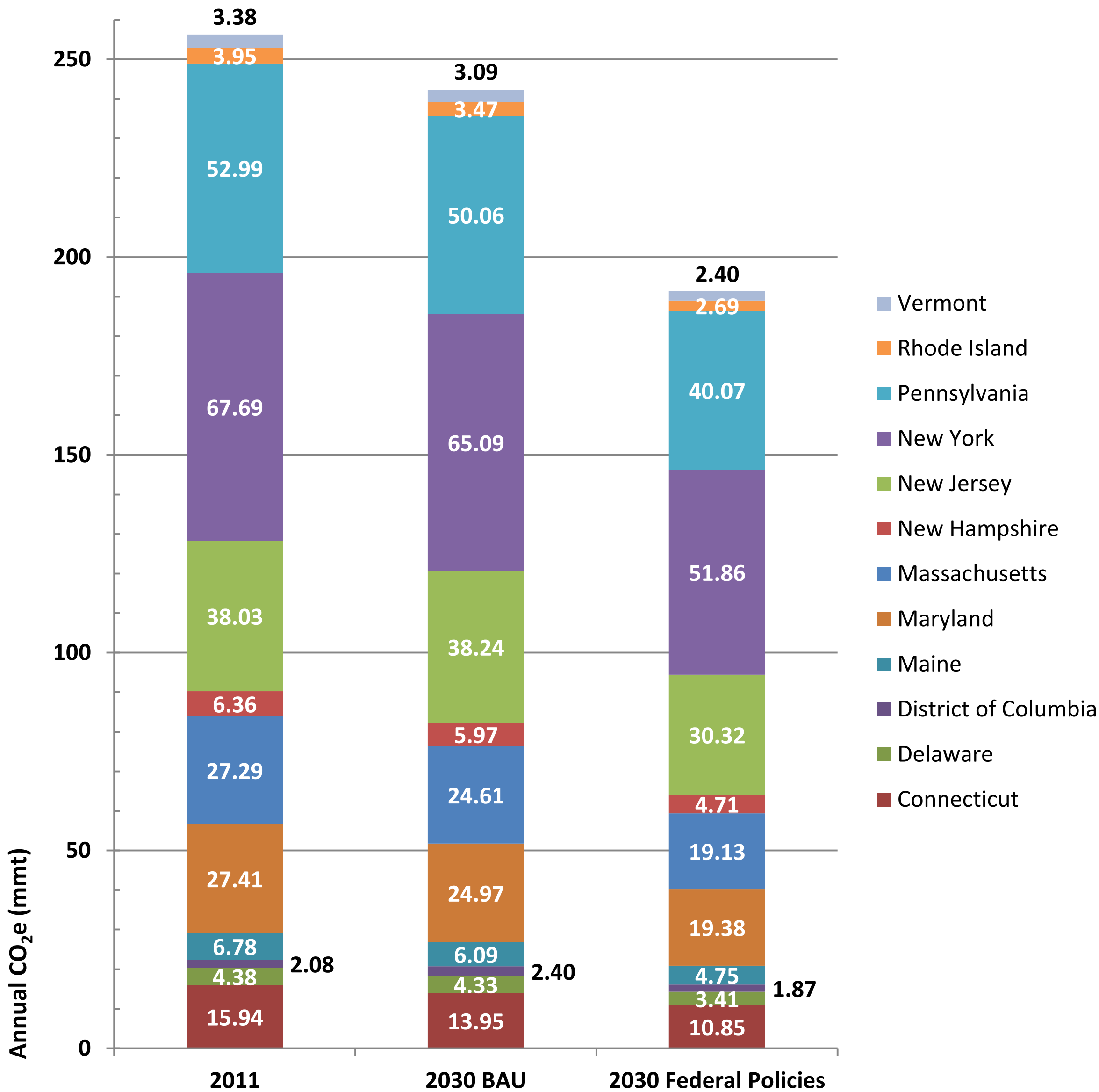
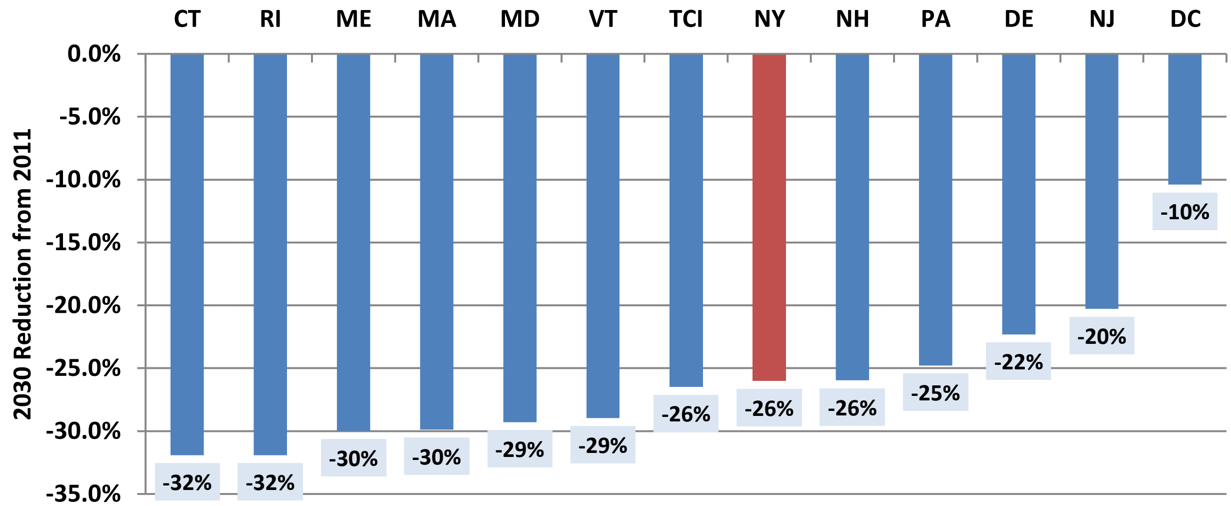


Figure 2.5 2030 Federal Policies Difference Compared to 2011



VMT and GHG emissions by place type are presented in Table 2.10 and Figure 2.6. Average annual VMT per capita increases as density decreases (e.g., VMT per capita is highest in rural locations). Average grams CO_2e/mile is highest in core and urban place types where congestion is more widespread, resulting in less efficient travel.

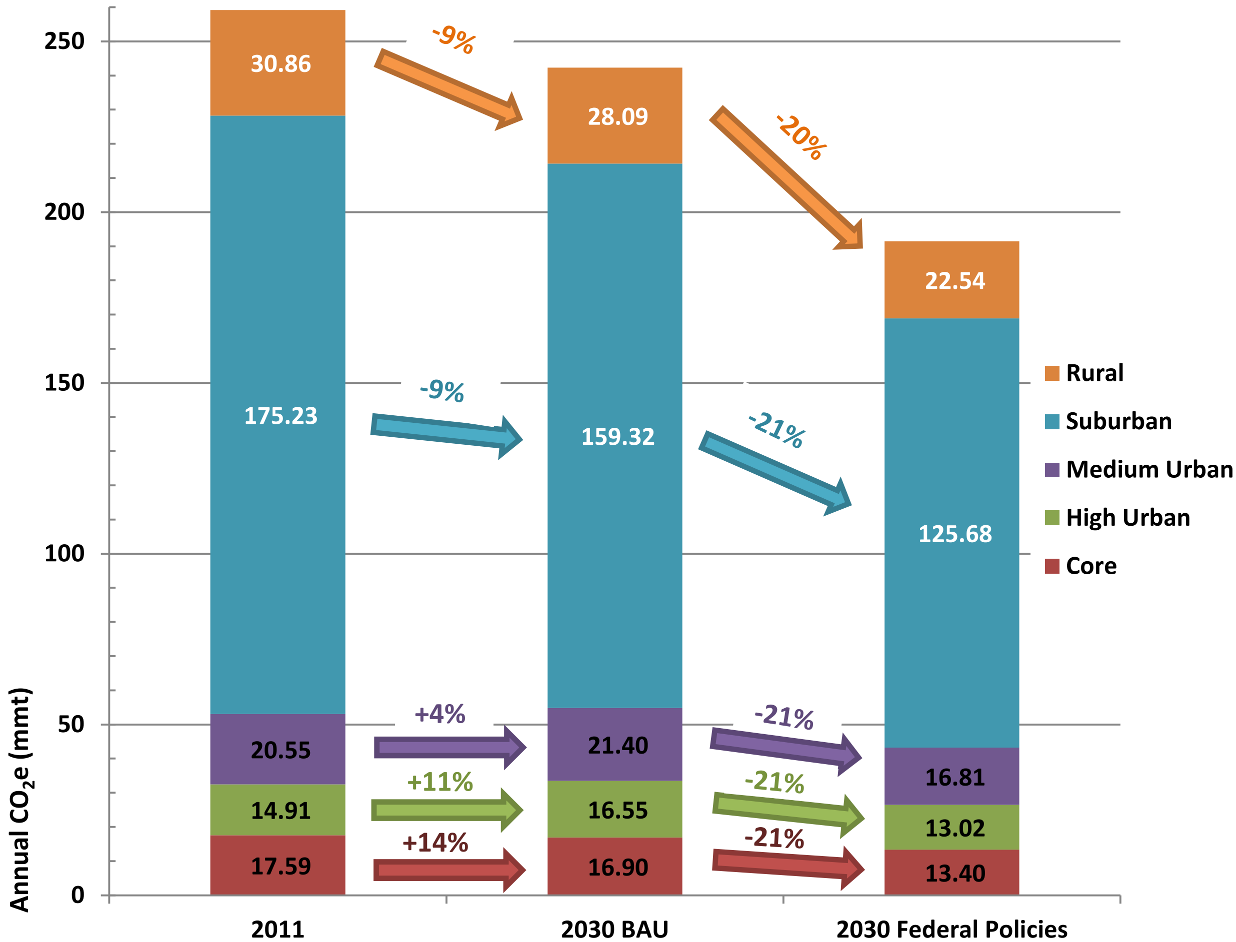
Table 2.10 TCI Region Travel and Emission Statistics by Place Type

Place Type	Density Range persons/square mile, (weighted average)	Annual VMT per capita (miles) 2011	Annual VMT per capita (miles) 2030	Average grams CO_2e/mile 2011	Average grams CO_2e/mile 2030 BAU	Average grams CO_2e/mile 2030 Federal Policies
Core	> 10,000, (25,887)	2,700	2,900	511	524	415
High Urban	4,000 – 10,000, (6,771)	6,500	7,300	521	527	414
Medium Urban	2,000 – 4,000, (2,485)	7,700	8,000	506	461	362
Suburban[1]	500 – 2,000, (530)	9,100	9,900	518	403	318
Rural	<= 500, (80)	11,700	12,900	508	408	328
Region Average	**(1,284)**	**7,900**	**8,600**	**515**	**422**	**334**

VMT growth by place type is highest for suburban place types (0.82% annually) and lowest for core (0.58% annually) and high urban (0.49% annually) compared to the regional average (0.7% annually).

The overall increase (+ 9%) from 2011 to the 2030 BAU across all the urban place types is associated with congestion and VMT growth. Efficiency improvements from federal standards are offset by decreases in average speeds.

Figure 2.6 TCI Region Emissions by Place Type



2.7 I&F Updating Process

This I&F represents a compilation of data and assumptions consistent with the best tools and information available at the time of the analysis. The overall methodology is not data intensive. The analysis could be re-run on a recurring basis to incorporate improved tools and more recent data.

In the next 3 years, reasons for updating the inventory and forecast could include:

- Release of MOVES2014 (July 2014).
- 2014 National Emissions Inventory. Each state will conduct new modeling to support the next NEI (every 3 years), including new emissions model input data and tools (for transportation, presumably MOVES 2014).
- In February 2014, the Administration directed the EPA and the DOT's National Highway Traffic Safety Administration (NHTSA) to develop and issue the next phase of medium- and

heavy-duty vehicle fuel efficiency and greenhouse gas standards by March 2016. Under this timeline, the agencies are expected to issue a Notice of Proposed Rulemaking (NPRM) by March 2015. This second round of fuel efficiency standards will build on the current standards for medium- and heavy-duty vehicles adopted in 2011 and amended in 2013.

The steps to update the process and key inputs are detailed below:

1. Confirm county place type designations based on most recent population data available and population growth forecasts.

2. Identify representative counties.

3. States submit all MOVES2014 inputs for each representative county for the new base year and the horizon year.

4. Run MOVES2014 for each representative county, develop emission rates, and decide on rates by place type to move into "scaling up process".

5. Evaluate need for post-processing adjustments (with MOVES2014 consider how, or will the BAU be defined differently than Federal Policies). If required, develop and document the post-processing methodology.

6. Assemble all state VMT and VMT forecast data for the base and horizon year. Ideally, the data is segmented by county and MOVES source and road type. If not, implement a process to synthesize VMT as presented in Section 2.5.

2.8 Inventory & Forecast Tool

CS has developed a simple spreadsheet tool containing all the emissions and VMT data modeled and compiled at the county, state, and regional level. The tool includes a "Guide" tab that provides information on how users can input different data or assumptions supporting automatically calculated revised inventory and forecast outputs. The tool enables the user to:

- Input customized running emission rate for 2011 and 2030.

- Input customized VMT data (by county, road type, source type) for 2011 and 2030.

- Adjust assumptions and factors for post-processing emission rate adjustments.

- Eliminate post-processing adjustments completely from the 2030 Federal Policies forecast (in the event that future emission rates are provided through modeling using MOVES2014).

- Adjust factors for accounting for start and extended idle emissions in the inventory and forecast by source type.

- Adjust place type classifications by county for 2011 and 2030.

In all of these flexible input cases, the tool automatically will update calculations and summary data in the report tabs. The "Summary" tab also includes pre-developed pivot tables summarizing regional results by state, source type, place type, and county. A separate user guide is available to address tool specifics.

3.0 Passenger Rail and Ferry

The passenger rail and ferry sector includes all fixed guideway transit systems in the TCI region (light rail, streetcar, heavy rail, and commuter rail), ferry, and Amtrak.

3.1 2011 Inventory

The 2011 inventory is based on publically accessible data from the National Transit Database (revenue miles, passenger miles, and energy consumption by operator and mode), and Amtrak Northeast Corridor Infrastructure Master Plan[8]. Table 3.1 summarizes the input data pulled from these sources.

Table 3.1 Passenger Rail and Ferry Inventory Data (2011)

Operator/Authority/Amtrak Source: 2011 National Transit Database, Table 17 and Table 19	**Electricity (1,000 KWH)**	**Diesel (1,000 gallons)**	**Passenger Miles (1,000s)**
Light Rail Systems			
Massachusetts Bay Transportation Authority (MBTA)	52,076	-	155,207
Southeastern Pennsylvania Transportation Authority (SEPTA)	31,495	-	70,342
Maryland Transit Administration (MTA)	33,578	-	54,518
Port Authority of Allegheny County (Port Authority)	31,232	-	33,623
Niagara Frontier Transportation Authority (NFT Metro)	9,273	-	16,290
New Jersey Transit Corporation (NJ TRANSIT)	32,415	668	100,896
Trolley Bus/Streetcar			
Massachusetts Bay Transportation Authority(MBTA)	5,512	-	6,670
Southeastern Pennsylvania Transportation Authority(SEPTA)	7,959	-	10,763
Ferry Boats			
Massachusetts Bay Transportation Authority (MBTA)	-	1,294	10,204
Casco Bay Island Transit District (CBITD)	-	211	2,616
BillyBey Ferry Company/Metro-North/Port Imperial Ferry/PATH	-	3,577	22,857
New York City Department of Transportation (NYCDOT)	-	4,154	112,410
Heavy Rail			
MTA New York City Transit (NYCT)	1,715,052	-	9,709,823
Washington Metropolitan Area Transit Authority (WMATA)	491,983	-	1,635,967
Massachusetts Bay Transportation Authority (MBTA)	197,322	-	482,503
Southeastern Pennsylvania Transportation Authority (SEPTA)	150,897	-	422,124
Port Authority Trans-Hudson Corporation (PATH)	103,084	-	351,594
Port Authority Transit Corporation (PATCO)	44,227	-	89,770
Maryland Transit Administration (MTA)	46,294	-	57,276
Staten Island Rapid Transit Operating Authority	22,534	-	45,078

[8] http://www.amtrak.com/ccurl/870/270/Northeast-Corridor-Infrastructure-Master-Plan.pdf

Operator/Authority/Amtrak Source: 2011 National Transit Database, Table 17 and Table 19	**Electricity (1,000 KWH)**	**Diesel (1,000 gallons)**	**Passenger Miles (1,000s)**
Commuter Rail			
New Jersey Transit Corporation (NJ TRANSIT)	427,286	15,086	2,031,559
MTA Long Island Rail Road (MTA LIRR)	529,648	7,186	2,217,562
Metro-North Commuter Railroad Company (MTA)	453,983	6,614	1,978,040
Massachusetts Bay Transportation Authority (MBTA)	-	13,430	749,021
Southeastern Pennsylvania Transportation Authority (SEPTA)	193,654	-	517,991
Maryland Transit Administration (MTA)	27,072	2,675	254,517
Pennsylvania Department of Transportation (PENNDOT)	31,933	-	40,025
Northern New England Passenger Rail Authority (NNEPRA)	-	772	37,856
Connecticut Department of Transportation (CDOT)	-	1,366	11,478
Amtrak			
Northeast Corridor (Boston to Washington D.C.)	527,054	-	1,684,066
Keystone or Pennsylvanian (Philadelphia to Harrisburg, PA)	51,293	-	56,864
Adirondack, Empire, Maple Leaf, Ethan Allen Express	-	2,161	53,530
NE Regional or Vermonter (New Haven, CT to Springfield, MA)	17,087	-	13,654

CO_2e emissions from diesel fuel consumption is based on an average emission rate of 22.384 lbs CO_2e per gallon. CO_2e emissions from kilowatt-hours (KWH) of electricity consumed is based on the average pounds CO_2e/megawatt-hour (MWH) for the subregion in which the transit agency resides. This information is sourced from EPAs eGRID database, and varies by subregion:

- NEWE (ME, NH, VT, MA, RI, CT) – 722 lbs CO2e/MWH
- NYUP (NY excluding New York City) – 546 lbs CO2e/MWH
- NYCW (New York City) – 622 lbs CO2e/MWH
- NYLI (NY, Long Island) – 1,336 lbs CO2e/MWH
- RFCE (NJ, DE, MD, PA {excluding Pittsburgh region} – 1,002 lbs CO2e/MWH
- RFCW (Pittsburgh region, SW PA) – 1,503 lbs CO2e/MWH

The results for the 2011 inventory are presented in Table 3.2.

Table 3.2 Passenger Rail and Ferry Inventory Results (2011)

Mode	Annual Passenger Miles (1,000s)	Annual metric tons CO_2e	Avg. grams CO2e/passenger mile
Light Rail	430,876	98,513	228.6
Streetcar	17,434	5,422	311.0
Ferry	148,086	93,857	633.8
Heavy Rail	12,794,135	935,277	73.1
Commuter Rail	7,838,048	1,236,634	157.8
Amtrak	2,067,012	297,339	143.9
Total	**23,295,591**	**2,667,041**	**114.5**

In order to estimate a 2030 emissions forecast, two primary pieces of information are required:

- Forecasted 2030 passenger miles by system and mode, and
- Estimated 2030 locomotive diesel fuel consumption rates and 2030 CO_2e emission rates for electricity generation in the TCI region.

3.2 2030 Forecasted Passenger Miles

Passenger mile growth from 2011 to 2030 is determined based on a number of sources including 2003 to 2012 passenger mile and revenue mile growth from the National Transit Database by operator and mode, and where available, ridership projections from operator specific long-range plans (this information was assembled for large system plans including WMATA, SEPTA, MTA, NJ Transit, and MBTA).

In most cases, the NTD annual growth rate (2003 to 2012) in passenger miles is applied to 2011 passenger mile date to estimate 2030 passenger miles. For systems with high growth in revenue miles in the 2003 to 2012 period (typically greater than 2 percent annually), the passenger mile growth rate through 2030 is adjusted to reflect growth consistent with peer regions with low revenue mile growth. The objective of the 2030 passenger miles estimate is to reflect effectively business-as-usual conditions (i.e., transit systems continue to expand existing services to maintain conditions and meet passenger demand, but there are minimal large-scale capacity/network expansions). The resulting estimate is 34,085,589 annual passenger miles (1000s) in 2030.

For Amtrak, ridership growth projections from the Northeast Corridor Infrastructure Master Plan[6] are assumed consistent with passenger mile growth (an average annual growth rate of 3.2 percent), resulting in 3,172,000 annual passenger miles (1000s) in 2030.

3.3 2030 Forecasted Fuel Consumption and Emission Rates

The 2030 passenger rail and ferry forecast develops emissions estimates for both a 2030 Baseline and 2030 Federal Policies Scenario.

- 2030 Baseline – Diesel fuel consumption rates and GHG emission rates associated with electricity consumed in the TCI region by public transportation and passenger rail remain constant with 2011.

- 2030 Federal Policies – Diesel fuel consumption rates and GHG emission rates associated with electricity consumed in the TCI region by public transportation and passenger rail improve through 2030 consistent with Tier IV locomotive standards and full achievement of Renewable Portfolio Standard (RPS) goals in each state and RGGI target reductions.

RGGI requires a 2.5 percent GHG reduction each year starting in 2015 through 2018, resulting in a 10 percent reduction compared to 2005 (assumed equivalent to 2011) levels by 2018. The Renewable Portfolio Standard (RPS) (per analysis in 2013 MD Greenhouse Gas Reduction Act Plan) anticipates a 7 percent reduction in GHG emissions from 2011 by 2020, with up to an 11 percent reduction with expanded options by 2020. The Maryland analysis represents a reasonable average for the TCI region, as RPS targets in the TCI region generally fall in the 20-25 percent range in the 2020 to 2025 window, with Maryland at the approximate midpoint, 22 percent by 2020. In total, this results in an average 17 percent reduction in pounds CO2e per MWH in the region by 2030.

3.4 Summary Results

Results of the 2011 and 2030 Baseline and Federal Policies analysis are presented in Table 3.3. The 2030 analysis of Amtrak shows the outcome of varying levels of investment in the Northeast Corridor as proposed in the Vision for High-Speed Rail in the Northeast Corridor (Amtrak, 2010)[9] and the Amtrak Vision for the Northeast Corridor – 2012 Update (Amtrak, 2012).[10]

[9] http://www.amtrak.com/ccurl/214/393/A-Vision-for-High-Speed-Rail-in-the-Northeast-Corridor.pdf

[10] http://www.amtrak.com/ccurl/453/325/Amtrak-Vision-for-the-Northeast-Corridor.pdf

Table 3.3 Passenger Rail & Ferry Inventory & Forecast Results

	2011		2030		
Mode	**Passenger Miles (1,000s)**	**metric tons CO_2e**	**Passenger Miles (1,000s)**	**Baseline metric tons CO_2e**	**Federal Policies metric tons CO_2e**
Light Rail	430,876	98,513	580,673	121,437	102,517
Streetcar	17,434	5,422	39,600	13,006	10,795
Ferry	148,086	93,857	178,433	97,770	97,770
Heavy Rail	12,794,135	935,277	20,626,132	1,437,921	1,193,475
Commuter Rail	7,838,048	1,236,634	9,488,749	1,462,645	1,310,607
Intra-City Passenger Rail and Ferry Total	**21,228,579**	**2,369,702**	**30,913,589**	**3,132,778**	**2,715,164**
Amtrak	**2,067,012**	**297,339**	**3,172,001**	**456,291**	**378,721**
HSR Vision (2010)	-	-	*3,996,338*	*574,871*	*477,143*
Next-Gen HSR (2012)	-	-	*4,697,568*	*675,743*	*560,866*
Total (excluding HSR)	**23,295,591**	**2,667,041**	**34,085,589**	**3,589,069**	**3,093,885**

4.0 Freight Rail

FHWAs Freight Analysis Framework (FAF) integrates data from a variety of sources to create a comprehensive view of freight movement among states and major metropolitan areas by all modes of transportation.[11] With data compiled from the 2007 Commodity Flow Survey and other sources, FAF version 3 (FAF^3) provides estimates for tonnage, value, and domestic ton-miles by region or state of origin and destination, commodity type, and mode for 2007, the most recent year (2012), and forecasts through 2040.

Total tons and ton-miles for rail were downloaded from FAF for all states and the District of Columbia. The results were separated into the following three groups of data:

- Rail tons and ton-miles with both an origin and destination in the region (internal trips),
- Rail tons and ton-miles with an origin in the region and destination outside the region (internal-external trips), and
- Rail tons and ton-miles with a destination in the region and origin outside the region (external-internal trips).

For the two external trip groups, only 50 percent of tons and ton-miles are assigned to the region, with the remainder assigned to the other trip end. This is a common practice when

[11] http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/

estimating GHG emissions using a trip-based (consumption) approach instead of the VMT-based (direct) approach. The results of this analysis in terms of total ton-miles by state are presented in Table 4.1.

Table 4.1 Total Region Rail Ton-Miles (millions) (2012 and 2030)

	2012			2030		
State	**Internal**	**Internal-External**	**External-Internal**	**Internal**	**Internal-External**	**External-Internal**
Connecticut	230	869	1,070	104	1,477	1,189
Delaware	72	278	2,801	62	108	1,798
Maine	569	1,149	722	1,107	1,740	862
Maryland	319	1,146	4,225	523	1,369	6,769
Massachusetts	174	967	2,696	155	1,112	3,030
New Hampshire	144	57	295	280	118	399
New Jersey	1,173	3,092	10,069	1,276	4,279	12,824
New York	3,423	5,138	9,536	4,538	8,363	19,615
Pennsylvania	10,373	6,845	15,613	13,886	10,889	31,210
Rhode Island	22	30	162	13	39	121
Vermont	297	640	202	406	179	232
Washington D.C.	0	3	2	0	3	2
Total	**16,795**	**20,213**	**47,393**	**22,349**	**29,676**	**78,052**

The average trip length for the internal-external trips is 921 miles in 2012, while the average trip length for the external-internal trip is 1,070 miles in 2012. The average trip length for internal trips is 252 miles. Most commodities on rail that originate and terminate within the TCI region is intra-industry shipments like shipments from a mine to manufacturer. In most cases, the distances within the region (other than between for example Maryland, Delaware and Northern New England) will not be enough to justify traditional rail shipments.

Note, for no other transportation subsector of I&F are emissions from travel activity outside the TCI region considered. For freight rail, emissions from intra-region trips are reported separately, however in terms of total kilotons transported, intra-region trips only represent 50 percent of the total of kilotons with an origin or destination in the region (eg. trips leaving the region or destined to the region represent the other 50 percent (17 percent internal-external, 33 percent external-internal). According to the FAF 2030 forecast, the intra-region kiloton share decreases to 44 percent of the total. This relative share of total kilotons for intra-region trips reflects the importance of also accounting for external trips.

To estimate emissions associated with each ton-mile, average emission factors for locomotives operating on Class I railroads are applied. In 2012 the emission rate is 28g CO_2e/ton-mile per analysis of nationwide data completed by CS in support of the US DOT Report to Congress - *Transportation's Role in Reducing Greenhouse Gas Emissions*, 2010. In 2030, turnover of most line-haul locomotives so that they meet Tier IV standards and/or the best technology available would result in an average emission rate between 25 and 27 g CO_2e/ ton-mile. The I&F results are presented in Table 4.2.

Table 4.2 Freight Rail Inventory & Forecast Results

	2012		2030	
Freight rail trip pattern	**Ton-miles (millions)**	**Million metric tons CO2e**	**Ton-miles (millions)**	**Million metric tons CO2e**
Intra-Region	16,795	0.47	22,349	0.60
Internal - External	20,213	0.57	29,676	0.80
External - Internal	47,393	1.33	78,052	2.11
Total	**84,402**	**2.36**	**130,076**	**3.51**

5.0 Intra-Region Marine

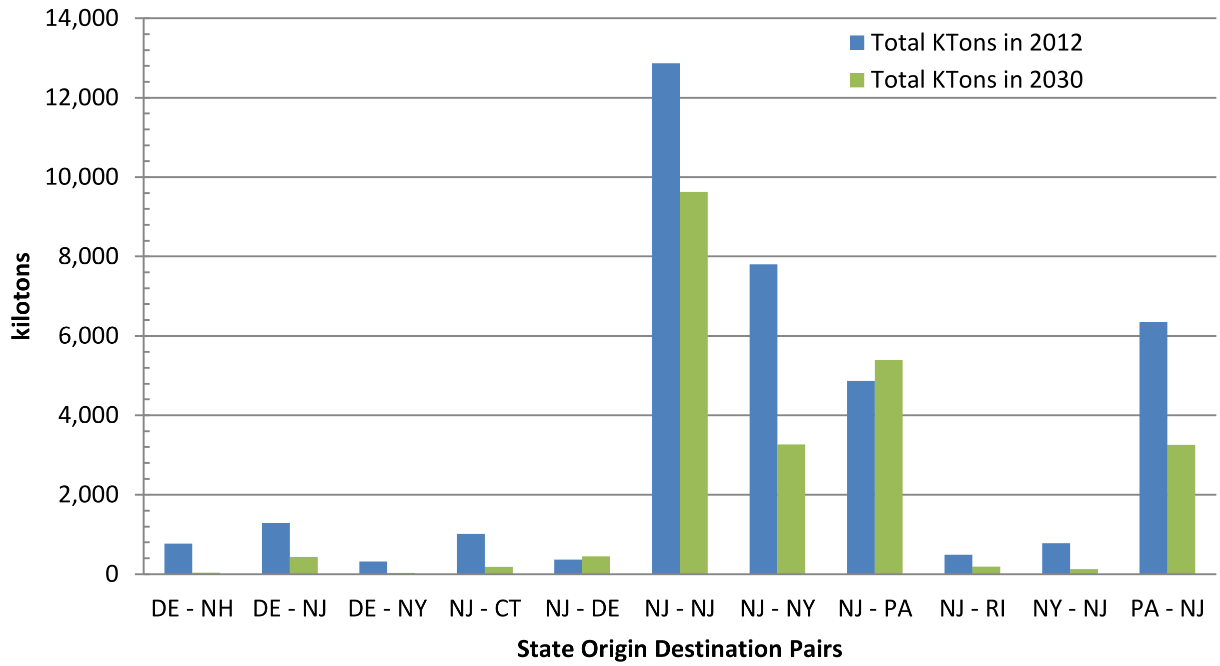
The US Army Corps of Engineers Waterborne Commerce Statistics Center produces annual state-to-state flows by commodity and tonnage.[12] This is used to supplement data from the Freight Analysis Framework (FAF), particularly for intra-state marine movements. The FAF forecasts are used to inform development of the 2030 forecast.

In order to estimate ton-miles, marine distances were calculated by identifying the major port complex in each state and using an online tool that calculated nautical shipping distances between those two port complexes. Intrastate shipments were assumed to be 50 miles, representing a combination of some short sea and some intra-terminal shipments. The 50-mile assumption also applies to shipments between New Jersey and New York, as these are typically occurring all within the PANYNJ complex.

More than half (56 percent) of all intra-region ton miles have an origin or destination in New Jersey, 17 percent have an origin or destination in Pennsylvania, and 11 percent have an origin or destination in New York. The remaining ton-miles by origin-destination are accounted for by Maryland (9 percent), Delaware (5 percent), and the remaining states are less than 0.5 percent. Total tons in 2012 per the FAF data is 36,926,630. FAF projects a 38 percent decrease in total tons from 2012 to 2030. Figure 5.1 presents a summary of state level marine tonnage flows in 2012 and 2030.

[12] http://www.navigationdatacenter.us/wcsc/pdf/pdstcm11.pdf

Figure 5.1 State Level Marine Tonnage Flows (2012 – 2030)



Note: State origin destination pairs with less than 20 kilotons in 2012 are not included in Figure 1.1.

Total tons by state origin destination pair are converted to ton-miles an average efficiency factor is applied of 576 ton miles per gallon in order to estimate total fuel consumption.[13] Based on data from US EPA, for barges, the diesel fuel emissions factor is 10,180 g CO_2e per gallon. For this analysis we presume only diesel fuel is consumed, although, the EPA analysis also presents emission factors for biodiesel (B100) and liquefied natural gas (LNG).[14] The resulting CO2e estimates, assuming the same fuel efficiency and emission factors in 2030 and using tonnage growth rates from FAF, are presented below:

- 2012: 4.066 billion ton-miles = 71,861 metric tons CO_2e
- 2030: 2.068 billion ton-miles = 36,555 metric tons CO_2e

The FAF forecasts do not account for potential mode shift to short-sea shipping, instead the forecasts show shifts from marine to primarily rail and in some cases truck. US DOTs Maritime Administration Marine Highway Program works to incorporate all navigable waterways into the greater U.S. transportation system. USDOT recently funded the East Coast Marine Highway Initiative (ECHMI) as part of the Marine Highway Program. The ECHMI seeks to advance services for shipping in the designated M-95 corridor (parallel to I-95) with the intent to create competitive, reliable, and environmentally responsible alternative to existing surface transportation modes.

[13] Texas Transportation Institute, Center for Ports and Waterways, A Modal Comparison of Domestic Freight Transportation Effects on the General Public, prepared for the U.S. Department of Transportation, Maritime Administration, and National Waterways Foundation, December 2007, p. 42.

[14] http://www.epa.gov/smartwayshipper/forpartners/documents/barge/tool-guide/420b14012.pdf

6.0 Summary

The summary of TCI Region I&F results are provided in Table 6.1 and Figure 6.1.

Table 6.1 Inventory & Forecast Summary Results

Travel Activity		2011	2030
On-Road		**VMT (millions)**	
	Passenger Cars/Trucks	434,994	500,084
	Commercial Trucks	53,274	63,158
	Buses	9,187	10,671
Passenger Rail and Ferry		**PMT (millions)**	
	Light Rail/Streetcar	448	620
	Ferry	148	178
	Heavy Rail	12,794	20,626
	Commuter Rail	7,838	9,489
	Amtrak	2,067	3,172
Freight Rail		**Ton Miles (millions)**	
	Intra-region	16,795	22,349
	Outside-region	67,607	107,727
Commercial Marine		**Ton Miles**	
	Intra-region	4,066	2,068

CO2e Emissions		2011	2030
On-Road		**mmt CO_2e**	
	Passenger Cars/Trucks	194.48	131.40
	Commercial Trucks	47.06	44.67
	Buses	14.75	15.38
Passenger Rail and Ferry		**mmt CO_2e**	
	Light Rail/Streetcar	0.10	0.13
	Ferry	0.09	0.10
	Heavy Rail	0.94	1.44
	Commuter Rail	1.24	1.46
	Amtrak	0.30	0.46
Freight Rail		**mmt CO_2e**	
	Intra-region	0.47	0.60
	Outside-region	1.89	2.91
Commercial Marine		**mmt CO_2e**	
	Intra-region	0.07	0.04
On-Road SUBTOTAL		*256.29*	*191.45*
Passenger Rail and Ferry SUBTOTAL		*2.67*	*3.59*
Freight Rail SUBTOTAL		*2.36*	*3.51*
Commercial Marine SUBTOTAL		*0.07*	*0.04*
TOTAL		**261.39**	**198.58**

Figure 6.1 Inventory & Forecast Summary Result