



**SOUTH FLORIDA EAST COAST (FEC)  
ALTERNATIVES ANALYSIS**

**F.M. NO. 417031-1-22-01**

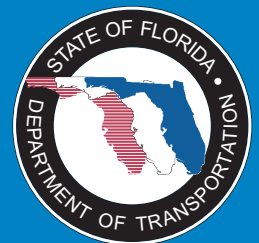
**CONTRACT: C-8F66**

***Phase 2 Air Quality  
Technical Memorandum***

***Prepared by:***



***Gannett Fleming***



***August 2010***



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**To:** Scott Seeburger

**From:** Robert McMullen

**Date:** August 18, 2010

**Subject:** South Florida East Coast Corridor Transit Analysis (SFECCTA) Study:  
Air Quality Technical Memorandum

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## INTRODUCTION

### Purpose

The purpose of this technical memorandum is to conform to the air quality regulations and guidance issued by the Environmental Protection Agency (EPA), the Federal Transit Administration (FTA), the Federal Highway Administration (FHWA), the Florida Department of Environmental Protection (FDEP), and the Florida Department of Transportation (FDOT). The air quality study discussed in this technical memorandum consists of four main components: (1) a screening model analysis to estimate and evaluate carbon monoxide (CO) concentration exceedances (if any) at the most congested roadway intersections in the project area; (2) an emission inventory analysis to inform decisions on potential modal technologies (e.g., Light Rail Transit) under consideration for this project; (3) a GHG emissions inventory of all proposed modal technologies; and (4) a GHG emissions screening of various project alternative elements, based on their carbon dioxide (CO<sub>2</sub>) emissions.

### Project Description

The FDOT initiated the multi-phased South Florida East Coast Corridor Transit Analysis (SFECCTA) study in December 2005 recognizing that the Florida East Coast (FEC) Railway was and is a unique transportation asset that should be evaluated and developed in the context of regional transportation issues, priorities and needs. The SFECCTA study is designed to evaluate the reintroduction of passenger service along a portion of the FEC Railway corridor from Miami to Jupiter. In its second phase, the SFECCTA study continued the Alternative Analysis (AA) – Early Scoping process that was initiated in Phase 1. A discussion of the Phase 1 AA may be found in the Phase 1 Conceptual Alternatives Analysis/Environmental Screening Report (AA/ESR) on the project website (<http://www.sfecstudy.com/>).

Phase 2 of the SFECCTA was initiated in January 2009 and was designated to build upon the Phase 1 AA to refine and further develop through an iterative process the alternatives identified at the conclusion of the first phase. The primary focus of Phase 2 was to identify a locally preferred alternative (LPA) within the study area, in accordance with Federal Transit Administration (FTA) and FDOT project development processes, that could ultimately be submitted to FTA for federal assistance in the form of New Starts funding.

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Figure 1: Project Location Map

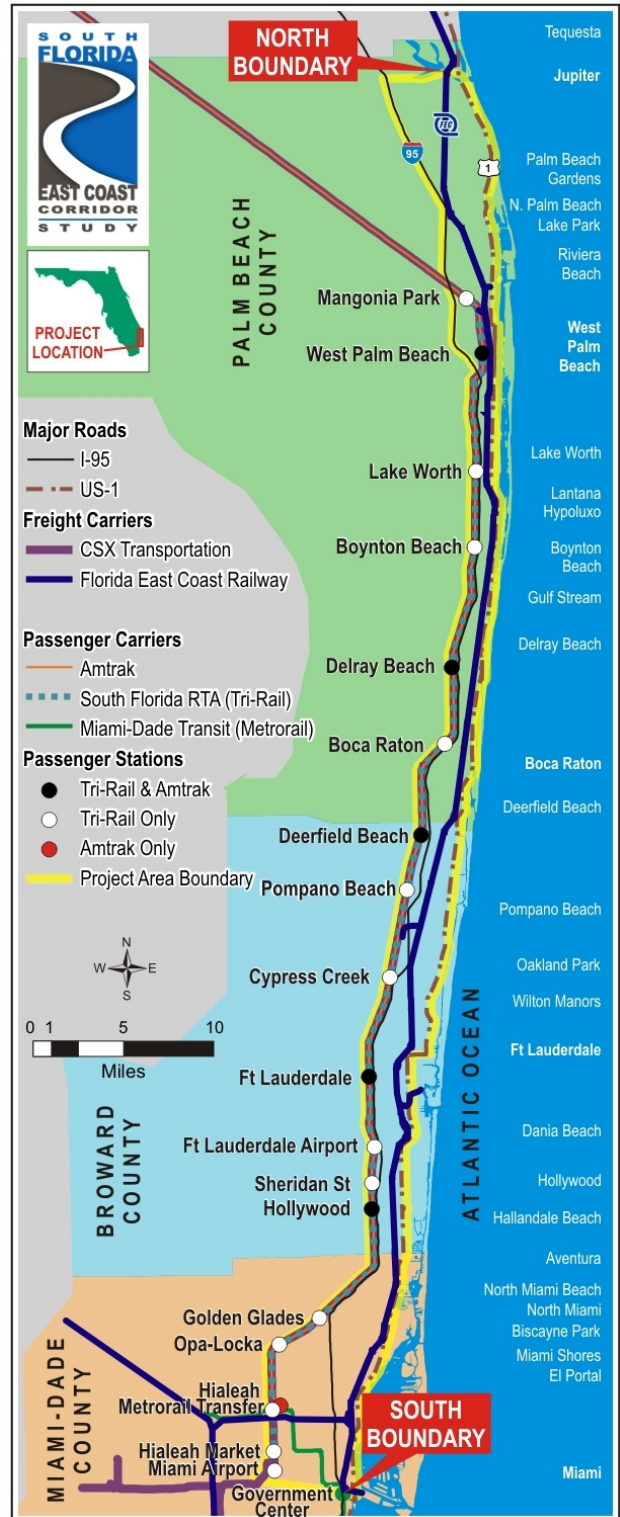
A Phase 2 Draft Detailed Environmental Screening Report (ESR) has been prepared to describe the detailed environmental screening approach conducted as part of the Phase 2 AA and is supported by a series of technical memoranda and reports like the one presented here.

## Project Area

The SFECCTA study project area, illustrated on the Project Location Map (Figure 1), is bounded on the south by Flagler Street, just south of the Miami-Dade Government Center, in the City of Miami and on the north by the southern shoreline of the Loxahatchee River in the Town of Jupiter. The western boundary of the project area runs parallel to and 0.5-miles west of the South Florida Rail Corridor (SFRC)/Tri-Rail corridor from the Miami Intermodal Center (MIC) north to Mangonia Park then continues in a northwesterly direction parallel to and 0.5-mile west of I-95 to the southern shoreline of Southwest Fork of the Loxahatchee River (C-18). The eastern boundary of the project area runs parallel to and 0.5-miles east of Highway US-1 from the Central Business District (CBD) of the City of Miami north to the southern shoreline of the Loxahatchee River in Jupiter.

Within the SFECCTA project area are several unique *study areas* that were developed specifically to define the affected environment and screen/evaluate the various project alternatives. Generally, the affected environment is a Geographic Information System (GIS) inventory of environmental, social, and cultural resources that could be affected by the proposed improvements. The affected environment and screening process are defined and documented in the Phase 2 Draft ESR.

The primary study area, where most of the improvements are expected to occur, is the FEC Railway corridor that extends from the CBD of the City of Miami north to the Town of Jupiter in Palm Beach County (a linear distance of approximately 83 miles). A detailed description of the study areas and environmental screening methodology is provided in Chapter 3 and Appendix A, respectively, of the Draft ESR.



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## Air Quality

Transportation sources that utilize fossil fuels for power produce pollutants. The primary mode of transportation within the SFECCTA study project area is the motor vehicle, both single occupancy vehicles (SOV) and high occupancy vehicles (HOV), and the current operating FEC Railway freight trains. A transit study such as the SFECCTA, that potentially could reduce the vehicle miles traveled (VMT) by motor vehicles in future years, will affect regional fuel use and the amount of pollutants emitted.

The EPA established the National Ambient Air Quality Standards (NAAQS) for six criteria pollutants including carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), ozone (O<sub>3</sub>), lead (Pb), particulate matter (PM), and sulfur dioxide (SO<sub>2</sub>). These NAAQS are summarized in **Table 1**. Primary standards set limits to protect public health, and the secondary standards set limits to protect public welfare. Transportation sources, particularly motor vehicles, are the primary source of CO, oxides of nitrogen (NO<sub>x</sub>), and hydrocarbons (also referred to as volatile organic compounds or VOCs). In the presence of heat and sunlight, NO<sub>x</sub> and VOC chemically react to form O<sub>3</sub>. Particulate matter and SO<sub>2</sub> are primarily emitted from stationary sources that burn fossil fuels (e.g., power plants, industrial processes).

**Table 1. National Ambient Air Quality Standards (NAAQS)**

Pollutant	Primary Standards		Secondary Standards	
	Level	Averaging Time	Level	Averaging Time
Carbon Monoxide	9 ppm (10 mg/m <sup>3</sup> )	8-hour <sup>(1)</sup>	None	
	35 ppm (40 mg/m <sup>3</sup> )	1-hour <sup>(1)</sup>		
Lead	0.15 µg/m <sup>3</sup> <sup>(2)</sup>	Rolling 3-Month Average	Same as Primary	
	1.5 µg/m <sup>3</sup>	Quarterly Average	Same as Primary	
Nitrogen Dioxide	0.053 ppm (100 µg/m <sup>3</sup> )	Annual (Arithmetic Mean)	Same as Primary	
Particulate Matter (PM <sub>10</sub> )	150 µg/m <sup>3</sup>	24-hour <sup>(3)</sup>	Same as Primary	
Particulate Matter (PM <sub>2.5</sub> )	15.0 µg/m <sup>3</sup>	Annual (Arithmetic Mean) <sup>(4)</sup>	Same as Primary	
	35 µg/m <sup>3</sup>	24-hour <sup>(5)</sup>	Same as Primary	
Ozone	0.075 ppm (2008 std)	8-hour <sup>(6)</sup>	Same as Primary	
	0.08 ppm (1997 std)	8-hour <sup>(7)</sup>	Same as Primary	
	0.12 ppm	1-hour <sup>(8)</sup>	Same as Primary	
Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Mean)	0.5ppm (1300 µg/m <sup>3</sup> )	3-hour <sup>(1)</sup>
	0.14 ppm	24-hour <sup>(1)</sup>		

All areas of the United States have been assigned a designation to comply with the NAAQS. Based on air quality monitoring data, an area that has not shown a violation of the NAAQS is designated as “in attainment.” An area that has shown a violation of the NAAQS may be designated as “non-attainment.”

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Areas that were designated non-attainment subsequent to the Clean Air Act Amendments of 1990 (CAAA), but have since been re-designated as in attainment by EPA, are referred to as “maintenance areas”. All counties within the SFECCTA study project area are currently designated as in attainment of the NAAQS for all pollutants. On January 7, 2010, the EPA announced proposed revisions to the NAAQS for the pollutant ozone. These revisions will reduce the primary standard from 0.075 ppm to a value in the range of 0.060 ppm to 0.070 ppm. Implementation of the new standards may cause some areas of the state to be designated nonattainment. The state will make its recommendation of counties for potential nonattainment designation in January 2011.

In the fall of 2009, the EPA published an endangerment finding which ruled that the six basic gases: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydroflourocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF<sub>6</sub>) threaten the public health. This finding is the basis for the regulation of those six gases and their emission under the Clean Air Act. The National Environmental Policy Act (NEPA), in a Center for Environmental Quality guidance document (1997), also provides guidance and the capacity to address GHG emissions through the subject of global climate change.

The study included the existing and future conditions at a planning-level assessment. Further data collection and analyses will continue in subsequent phases of the SFECCTA study in order to refine the analysis on an as-needed basis. For instance, the EPA may issue changes in NAAQS or other regulatory guidelines that will need to be considered.

### **Air Screening Modeling Analysis**

Motor vehicles emit CO at high rates when they are operating at low speeds or idling in queues. Therefore, the potential for adverse air quality impacts is greatest at intersections where traffic is most congested. In accordance with FDOT and EPA guidelines, the most recent available version of the Southeast Regional Planning Model 6 (SERPM6) was used to estimate existing and future traffic volume at the most congested arterial intersections. The model is not designed to provide intersection-specific traffic volumes, but is the best source for directional traffic volumes. These traffic numbers are just estimates and are based on a set of assumptions. Only four-way arterial intersections within one mile of the FEC Railway were analyzed. The analysis was conducted for the existing year 2005 and the design year 2035. The SERPM6 model takes into account that a public transit rail system will be completed in future years within the project area. Hence, the most congested intersections will vary from the existing year (**Table 2** and **Table 3**).

The screening analysis involved evaluation of CO using the “CO Florida 2004” FDOT Intersection Air Quality CO Screening Model to evaluate major intersections for potential CO concentration exceedances, evaluate build versus no-build emissions, and address conformity issues. The CO Florida 2004 default input values for the Southeast Florida region (Palm Beach, Broward, and Miami-Dade Counties) were used for meteorology inputs, MOBILE6.2 parameters, persistence factors, and background CO concentrations. MOBILE6 Vehicle Emission Modeling Software is an emission factor model for predicting gram per mile emissions of Hydrocarbons (HC), Carbon Monoxide (CO), Nitrogen Oxides (NO<sub>x</sub>), Carbon Dioxide (CO<sub>2</sub>), Particulate Matter (PM), and toxics from cars, trucks, and motorcycles under various conditions (<http://www.epa.gov/OMS/m6.htm>). The modeling results are the predicted maximum CO concentration at each intersection. These predicted concentrations were compared to the NAAQS and the Florida Ambient Air Quality Standards for CO. The National and Florida standards are the same for CO.

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Transitway-Highway Interactions

**Table 2** lists the five highest existing traffic volume intersections along the FEC Railway corridor, based on the year 2005 data that was available. These intersections represent the best estimate, given available data, on the current highest volume within Miami-Dade, Broward, and Palm Beach Counties. Based on the “CO Florida 2004” screening model, two intersections did not exceed (“Pass”) the air quality criteria in the existing year (2005). **Table 3** lists the seven most congested four-way arterial intersections along the corridor for the potential design year of 2035. The “CO Florida 2004” screening model results show that all intersections “passed” for the potential design year (i.e., they did not exceed the air quality criteria). This is attributed to the modest increase in traffic volume at these intersections, due to increased use of passenger commuter rail as a mode of transportation in the future.

Lastly, based on the congestion at analyzed intersections and the “CO Florida 2004” screening model results, the traffic volume impacts from the SFECCTA study (presumably due to the interaction of major intersections with at-grade transitway-highway crossing gate closures or traffic generated around station areas) are not expected to exceed the NAAQS for CO.

**Table 2. Existing Year (2005) Highest Traffic volume Intersection on FEC corridor**

Existing Year (2005) Highest Traffic volume Intersection on FEC corridor													
N-S Street	Lanes	Speed	E-W Street	Lanes	Speed	Daily Volume				County	Land use	Total Volume	CO Florida Results
Biscayne Blvd	3	45	NW 163 St	3	40	26,391	31,863	28,688	26,425	MD	Urban	113,367	Fail
S Dixie Hwy	3	40	Atlantic Blvd	3	40	25,657	24,487	22,846	28,673	BR	Urban	101,663	Fail
Australian Ave	2	45	Okeechobee Rd	3	45	20,894	21,261	20,781	22,202	PB	Urban	85,138	Pass
A1A	2	45	PGA Blvd	3	55	11,578	18,155	31,516	32,403	PB	Urban	93,652	Fail
N Dixie Hwy	2	35	Hallandale Beach Blvd	3	40	19,377	14,364	24,773	20,552	BR	Urban	79,066	Pass

**Table 3. Future Year (2035) Highest Traffic volume Intersection on FEC corridor**

Future Year (2035) Highest Traffic volume Intersection on FEC corridor													
N-S Street	Lanes	Speed	E-W Street	Lanes	Speed	Daily Volume				County	Land use	Total Volume	CO Florida Results
Federal Hwy	3	35	SE 17 St	2	35	29,314	26,167	21,601	20,000	BR	Urban	97,082	Pass
Federal Hwy	3	35	SE 24 St	3	40	24,850	29,186	19,014	19,000	BR	Urban	92,050	Pass
Federal Hwy	2	35	Hallandale Beach Blvd	3	40	29,834	29,800	25,260	25,695	BR	Urban	110,589	Pass
Military Trail	3	45	45th St	3	45	28,763	27,443	37,204	24,881	PB	Suburban	118,291	Pass
Biscayne Blvd	3	45	NW 163 St	3	35	38,871	40,008	35,218	30,470	MD	Urban	144,567	Pass
S Dixie Hwy	3	40	Atlantic Blvd	3	40	25,424	24,994	26,511	27,146	BR	Urban	104,075	Pass

**Modal Technologies – Emissions Inventory**

An emission inventory of transit vehicles being screened in Phase 2 is included in order to compare the relative impacts of the project modal technology alternatives in accordance with EPA, FDOT and FDEP guidelines as mandated under NEPA. Because the SFECCTA study project area is within an attainment area for any criteria air pollutant, the EPA Transportation Conformity Rule does not apply and the emission inventory is not required for conformity purposes. However, the emission inventory will be used as part of the environmental screening for modal technology alternatives.

The emissions inventory is being developed for Regional Rail Transit (RGR) Push-Pull locomotives, RGR Diesel Multiple Unit (DMU) railcars, Light Rail Transit (LRT) DMU railcars, and Bus Rapid Transit (BRT)/Regional Bus (RGB) vehicles. Emissions are calculated for CO, HC, NO<sub>x</sub>, and PM. Emission factors

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for modal technologies are calculated from engine and emissions data provided by locomotive, railcar, and vehicle manufacturers.

A literature review was accomplished in order to get an example of typical emissions levels from each of the modal technology alternatives. **Table 4** shows the different emissions from the different modal technologies. It is clear that the electric powered technologies would not produce any emissions, and that the emissions will be confined to the power generation stations. In addition, the regional diesel emissions do meet EPA Tier 2 standards. The LRT vehicles and buses have significantly very low emissions and this could be attributed to the latest catalysts and filters/traps that have made the latest diesel engines so clean; the actual volume of PM is becoming too small to measure accurately. Furthermore, during subsequent phases of the SFECCTA study, an emissions inventory will be carried forward in the selection of a LPA.

**Table 4. Modal Technology Emissions Inventory**

	Different Type Vehicle Emissions (g/bhp/hr)					
	Regional Rail (push/Pull) <sup>1</sup>	Regional Rail (DMU) <sup>2</sup>	Rail Rapid Transit (Electric)	Light Rail (Diesel) <sup>3</sup>	Light Rail (Electric)	Buses (Diesel) <sup>4</sup>
NOx	5.23	4.99	0.0	N/A	0.0	2.5
HC	0.28	0.14	0.0	0.0	0.0	
CO	1.43	0.99	0.0	0.1	0.0	N/A
PM	0.19	0.05	0.0	0.0	0.0	0.05

NOx: Nitrogen Oxides; HC: Hydrocarbon; CO: Carbon Monoxide; PM: Particulate Matter; N/A: Not Available; g/bhp/hr: gram/brake horsepower/hour

- 1) Modal Technologies Tech Memo submitted 11/23/2009
- 2) Colorado Railcar/US Railcar DMU
- 3) California Air Resources Board Cummins Inc., Certification 2/5/2009
- 4) National Renewable Energy Laboratory at the APTA Bus and Paratransit Conference, 5/17/2005

## Greenhouse Gas (CO<sub>2</sub>) Emissions

The proposed improvements of the SFECCTA study and the implementation of modal technologies along the FEC Railway will potentially impact the regional volume of anthropogenic GHG released into the atmosphere. The impact on GHG emissions can be divided into two categories: emissions produced by transit and emissions displaced by transit.

Emissions produced by transit vehicles are considered a debit to the net GHG emissions and are primarily due to mobile combustion. Each type of modal technology/transit vehicle transports a unique volume of passengers by consuming a unique amount of energy or fuel. The result is the emission of GHG, regardless of whether the modal technology is electric or diesel powered. This also includes emissions from indirect, non-mobile sources like on-site combustion (e.g., furnaces) or electricity generation.

Emissions displaced by transit vehicles are considered a credit to the net GHG emissions through the reduction of Vehicle Miles Traveled (VMT) from private automobiles. Displaced emissions can be divided into three subcategories: mode shift to transit, congestion relief, and a land-use multiplier. A mode shift to transit is a reduction in private automobiles as transit becomes a more viable alternative. Congestion relief is the result of improved personal vehicle fuel efficiency from reduced congestion due to the availability of transit services. The land-use multiplier is transit's effect on land use patterns which promote shorter trips, walking, cycling the reduction of private automobile use and ownership. All of these factors are the result of transit use reducing private automobile operation and reducing GHG emissions.

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On February 8<sup>th</sup>, 2010 the Council on Environmental Quality (CEQ) released draft guidance on the consideration of GHGs. The draft guidance explains to Federal agencies how they should consider the impacts of GHG emissions and climate change when considering the impacts of a proposed action under NEPA. This includes a threshold of 25,000 metric tons of carbon dioxide (CO<sub>2</sub>) equivalent annual emissions, which if exceeded by a proposed action will trigger a quantitative analysis within the NEPA process. For proposed actions with annual emissions below the threshold, the CEQ encourages Federal agencies to still consider conducting similar analysis.

As part of the SFECCTA study environmental screening process, the proposed modal technologies were inventoried and screened, respectively, by their production of CO<sub>2</sub> required to deliver the same volume of passengers over the same distance. It is the intent of the inventory and this screening to provide guidance on selecting a preferred modal technology based solely on the merit of minimizing the project's subsequent GHG emissions. Of the six major GHGs only CO<sub>2</sub> was calculated since it is the primary gas produced in the creation and consumption of energy related to transit vehicles. Emission displacement factors, like congestion relief and a land-use multiplier, were not included in the calculations at this time, but should be in subsequent phases of the study. The mode shift to transit was calculated and presented as the amount of VMTs reduced by the build-alternative as compared to the no build alternative. Only emissions related to operations were included in the calculations and emissions related to capital cost of transit vehicles were excluded (capital cost emissions are related to the manufacturing and transportation of a transit vehicle).

### Greenhouse Gas Emissions Inventory of Modal Technologies

In order to provide premium transit service along the SFECCTA study area, various transit modal technology alternatives are being considered (see Chapter 2 of the ESR). The GHG emissions inventory includes RGR Push-Pull locomotives, RGR DMU and Electric Multiple Units (EMU) railcars, LRT DMU and EMU railcars, Rail Rapid Transit (RRT) railcars, BRT/RGB vehicles, and private passenger vehicles (light and medium utility vehicles). GHG emissions are calculated only for CO<sub>2</sub> since it is the primary GHG emitted through fuel consumption.

Each modal technology has specific energy demand characteristics. Those characteristics include fuel type and a fuel consumption rate per mile traveled or per hour of operation. GHG emission factors for diesel powered modal technologies are calculated from fuel consumption data provided by the locomotive, railcar, and vehicle manufacturers. Modal technologies that source power from an electric grid produce GHG emissions through the consumption of electricity. That electricity that is generated at a fuel burning power station emits its own GHG emissions. The relationship between regional electricity production and GHG emissions was provided with a high degree of accuracy through the EPA's eGRIDweb database ([www.http://cfpub.epa.gov/egridweb/view](http://cfpub.epa.gov/egridweb/view)). With these factors, the amount of energy consumed by various modal technologies to deliver the forecasted volume of ridership over a given time period can be calculated.

Energy consumption can be converted into CO<sub>2</sub> emissions per fuel type, thus providing the volume of emission that each technology type will produce to deliver the same volume of ridership within the project study area during a given time period. This is also known as a GHG emissions inventory, which can be calculated for each modal technology. Guidance for these calculations was provided by the American Public Transportation Association (APTA) Standards Development Programs' report titled

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*Quantifying Greenhouse Gas Emissions from Transit* (August, 2009). The equations used to derive the results of the inventory are listed below:

$$N_1 \times N_2 = X$$

Where,

$N_1$  = unit of energy consumed per mile traveled

- units expressed as either liquid fuel consumed (gal) or electricity consumed (kWh)

$N_2$  = pounds of carbon dioxide produced per unit of energy consumed

- 1 gallon of diesel fuel consumed produces 22lbs of CO<sub>2</sub> emissions (based on EPA420-F-05-001 February 2005)
- 1 kWh of electricity consumed from the SFECCTA study area regional electric grid produces 0.871 lbs of CO<sub>2</sub> (EPA eGRIDweb)
- 1 gallon of LPG consumed equals 12.8 lbs of CO<sub>2</sub> emissions (EIA's database)
- 1 gallon of gasoline consumed equals 19.4 lbs of CO<sub>2</sub> emissions (based on EPA420-F-05-001 February 2005)

$X$  = pounds of carbon dioxide produced per mile traveled

$$X \div N_3 = Y$$

Where,

$N_3$  = Passenger seating capacity of single modal transit vehicle (consist)

- Based on estimated seating capacity of each transit vehicle

$Y$  = pounds of carbon dioxide produced per passenger

Research into the equivalency of CO<sub>2</sub> emissions per kilowatt-hour of electrical power produced from the South Florida electrical grid was conducted to reach a reasonable rate of 0.871 pounds of CO<sub>2</sub> emissions per kilowatt-hour. Developing an accurate emissions inventory for the SFECCTA study has and will continue to be an iterative process, anticipated to continue into subsequent phases of the study as a final design on the LPA is developed.

The GHG emissions inventory results of the different modal technologies indicate that the most energy efficient and lowest GHG emissions producing modal technologies, based on a per-mile per-passenger criteria, are:

1. Type 2 EMU - 0.014 lbs of CO<sub>2</sub> / passenger / mile
2. Type 1 EMU and Overhead Electric Locomotive (EPP) - 0.015 lbs of CO<sub>2</sub> / passenger / mile
3. Type 3 EMU - 0.018 lbs of CO<sub>2</sub> / passenger / mile
4. RRT vehicles with electrified third rail - 0.022 lbs of CO<sub>2</sub> / passenger / mile

The least energy efficient and highest GHG emissions producing modal technologies are:

1. Personal Passenger Vehicles - 0.243 lbs of CO<sub>2</sub> / passenger / mile

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2. BRT Diesel - 0.140 lbs CO<sub>2</sub> / passenger / mile
3. Type 1 and Type 3 DMU – 0.130 lbs of CO<sub>2</sub> / passenger / mile
4. Type 2 DMU – 0.117 lbs of CO<sub>2</sub> / passenger / mile
5. Diesel locomotive - 0.108 lbs of CO<sub>2</sub> / passenger / mile
6. BRT Liquid Propane Gas (LPG) - 0.101 lbs of CO<sub>2</sub> / passenger / mile

**Table 5** is the GHG emissions inventory of the different modal technologies that have been screened. It begins by breaking down the various modal technologies into various modes and sub modes. The table also includes the fuel type of each vehicle and the emissions rate per mile.

### Greenhouse Gas Emissions Screening of the Build Alternatives

Utilizing the results of the GHG emissions inventory of modal technologies a GHG emission screening was conducted for the four build alternatives and the no-build alternative. The emissions calculations are based on the amount of estimated CO<sub>2</sub> that each alternative will emit in order to deliver the anticipated daily volume of passengers. The two main differentiating factors between the four build alternatives are the type of modal technology utilized and the alignment of the corridors. A complete description of the different build alternatives, including the proposed modal technologies and corridor alignments that comprise them, is presented in Chapter 2 of the *ESR*. The volume of estimated CO<sub>2</sub> was calculated using the following equation:

$$X \times N_5 \times N_6 \times N_7 = Z$$

Where,

**X** = pounds of carbon dioxide produced per vehicle mile traveled.

- Per transit vehicle.

**N<sub>5</sub>** = Number of units per consist (a consist being a group of rail vehicles that make up a train).

**N<sub>6</sub>** = approximate distance of the proposed transitway length (miles).

- Estimate of distance between probable corridor termini and does include east/west connections for the DMU and DPP alternatives but not for the BRT and TSM alternatives.
- Important to note that number is only an estimate and will likely change in subsequent phases of the project.

**N<sub>7</sub>** = number of consists traversing the corridor daily.

- Based on an 18 hour weekday operational schedule with 6 hours of peak headway and 12 hours of off-peak headway.
- Based on both northbound and southbound movement.

**Z** = pounds of carbon dioxide produced per day.

Table 5. Modal Technology Greenhouse Gas Emissions Inventory

Modal Technology Greenhouse Gas Emissions Inventory									
Transit Mode & Sub-Mode		Modal Technology	Fuel Type	Consumption / mile	lbs CO2 emissions / mile	Passenger Volume	(lbs CO2 emissions/mile) / Passenger	Sources	
Regional Rail Transit (RGR)	FRA Compliant RGR	Push Pull Locomotive and Coaches	Diesel Locomotive (DPP)	Diesel	2.18 gal	48.6	450	0.108	Colorado Railcar manufacturer's literature, 2004 LTK Engineering study for SMART, various other sources
			Overhead Electric Locomotive (EPP)	Electric	7.36 kWh	6.9	450	0.015	Energy consumption and related air pollution for Scandinavian electric passenger trains, Report KTH/AVE 2006:46. Stockholm, Sweden 2006
			Dual Power Diesel-Electric Locomotive (DEPP)	Diesel - Electric	NA	NA	NA	NA	NA
	Self Propelled Multiple Units	Diesel Multiple Unit (Type 1 DMU)	Diesel	0.5 - 0.67 gal	12.9	100	0.129	Energy consumption and related air pollution for Scandinavian electric passenger trains, Report KTH/AVE 2006:46. Stockholm, Sweden 2006	
		Overhead Electric Multiple Unit (Type 1 EMU)	Electric	1.9 kWh	1.79	120	0.015	Colorado Railcar manufacturer's literature, 2004 LTK Engineering study for SMART, various other sources	
	Non FRA Compliant RGR	Diesel Multiple Unit (Type 2 DMU)	Diesel	0.5 - 0.55 gal	11.7	100	0.117	Energy consumption and related air pollution for Scandinavian electric passenger trains, Report KTH/AVE 2006:46. Stockholm, Sweden 2006	
		Overhead Electric Multiple Unit (Type 2 EMU)	Electric	1.75 kWh	1.6	120	0.014	Energy consumption and related air pollution for Scandinavian electric passenger trains, Report KTH/AVE 2006:46. Stockholm, Sweden 2006	
Light Rail Transit (LRT)	Diesel Multiple Unit (Type 3 DMU)		Diesel	0.5 - 0.55 gal	11.7	90	0.130	Energy consumption and related air pollution for Scandinavian electric passenger trains, Report KTH/AVE 2006:46. Stockholm, Sweden 2006	
	Overhead Electric Multiple Unit (Type 3 EMU)		Electric	1.75 kWh	1.6	90	0.018	Colorado Railcar manufacturer's literature, 2004 LTK Engineering study for SMART, various other sources, Energy consumption and related air pollution for Scandinavian electric passenger trains, Report KTH/AVE 2006:46. Stockholm, Sweden 2006	
Rail Rapid Transit (RRT)	Electrified Third Rail		Electric	2.3 kWh	2.2	100	0.022	London Underground Environmental Report 2005. Environment Canada fact sheet	
Bus Rapid Transit (BRT)	Clean Diesel		Diesel	0.36 gal	8	57	0.140	CDOT -Third Quarter CTTRANSIT Demonstration and Evaluation of Hybrid Diesel Electric Transit Buses January, February & March 2004 Report No. CT-170-1884-3-04-5. Victoria transportation policy institute - <a href="http://www.vpi.org/tca/tca05.pdf">http://www.vpi.org/tca/tca05.pdf</a>	
	Hybrid		Diesel - Electric	0.2 gal	4.5	57	0.079	CDOT -Third Quarter CTTRANSIT Demonstration and Evaluation of Hybrid Diesel Electric Transit Buses January, February & March 2004 Report No. CT-170-1884-3-04-5	
	Alternative Fuels		LPG (Liquid Propane Gas)	0.45 gal	5.76	57	0.101	CLIMATE LEADERS GREENHOUSE GAS INVENTORY PROTOCOL OFFSET PROJECT METHODOLOGY, Project Type: Transit Bus Efficiency", August 2008 Version 1.3. Climate Protection Partnerships Division/Climate Change Division Office of Atmospheric Programs U.S. Environment	
Private Passenger Vehicle (Light & Medium Utility Vehicles)			Gasoline	0.05 gal	0.97	4	0.243	EPA Website	

**Assumptions:**

- 1 gallon of diesel fuel consumed produces 22lbs of CO<sub>2</sub> emissions (based on EPA420-F-05-001 February 2005)
- 1 kWh of electricity consumed from the SFECCTA regional grid produces 0.871 lbs of CO<sub>2</sub> (EPA eGRIDweb)
- 1 gallon of LPG consumed equals 12.8 lbs of CO<sub>2</sub> emissions (US Energy Information Administration's database)
- 1 gallon of gasoline consumed equals 19.4 lbs of CO<sub>2</sub> emissions (based on EPA420-F-05-001 February 2005)
- 1 DPP consist is comprised of three 150 passenger cars
- The average DMU & EMU has a capacity of 156 passengers

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The results of the analysis, shown in **Table 6**, indicate that the Integrated Rail (IR) alternatives (one and two, which utilize DMUs and DPP), produce a larger volume of daily CO<sub>2</sub> emissions when compared to alternatives four (TSM) and three (BRT).

**Table 6. Daily Greenhouse Gas Emissions Screening of Build Alternatives**

Daily Greenhouse Gas Emissions Screening of Build Alternatives						
Alternative Elements	Unit Type	Number of Units	Emissions Rate (lbs CO <sub>2</sub> / mile) / Unit	Distance Traveled	Daily Headway	Daily Emissions (lbs CO <sub>2</sub> )
<b>1. Integrated Rail - Diesel Multiple Unit (DMU)</b>						
FEC Local	DMU	4	12.9	69	96	341,798
Flagler Flyer	DMU	4	12.9	85	96	421,056
Seaboard Flyer	Diesel Locomotive (push-pull)	1	48.6	84	24	97,978
Airport Flyer	Diesel Locomotive (push-pull)	1	48.6	35	96	163,296
<b>Total:</b>						<b>1,024,128</b>
<b>2. Integrated Rail - Diesel Push Pull (DPP)</b>						
FEC Local	Diesel Locomotive (push-pull)	1	48.6	69	96	321,926
Flagler Flyer	Diesel Locomotive (push-pull)	1	48.6	85	96	396,576
Seaboard Flyer	Diesel Locomotive (push-pull)	1	48.6	84	24	97,978
Airport Flyer	Diesel Locomotive (push-pull)	1	48.6	35	96	163,296
<b>Total:</b>						<b>979,776</b>
<b>3. Bus Rapid Transit (BRT)</b>						
Route 1	Diesel-Hybrid Bus	1	4.5	17.3	48	3,737
Route 2	Diesel-Hybrid Bus	1	4.5	30.3	48	6,545
Route 3	Diesel-Hybrid Bus	1	4.5	23.7	48	5,119
Route 4	Diesel-Hybrid Bus	1	4.5	26.56	48	5,737
Route 5	Diesel-Hybrid Bus	1	4.5	40.86	24	4,413
Route 6	Diesel-Hybrid Bus	1	4.5	26.56	24	2,868
<b>Total:</b>						<b>28,419</b>
<b>4. Transportation System Management (TSM)</b>						
Route 1	Diesel-Hybrid Bus	1	4.5	17.3	48	3,737
Route 2	Diesel-Hybrid Bus	1	4.5	31.25	48	6,750
Route 3	Diesel-Hybrid Bus	1	4.5	23.93	48	5,169
Route 4	Diesel-Hybrid Bus	1	4.5	14.37	48	3,104
Route 5	Diesel-Hybrid Bus	1	4.5	14.6	48	3,154
Route 6	Diesel Bus	1	8	45.3	24	8,698
Route 7	Diesel Bus	1	8	29	24	5,568
Route 8	Diesel Bus	1	8	14.1	24	2,707
<b>Total:</b>						<b>38,886</b>
<b>No-Build Alternative</b>						
Personal Vehicle	Light & Medium Utility Vehicles	N/A	0.93	278,608*	N/A	259,105
<b>Total:</b>						<b>259,105</b>

N/A – Not Available

\* Based on the increase of daily vehicle miles traveled if none of the preferred build alternatives are implemented.

**Assumptions:**

- 1 gallon of diesel fuel consumed produces 22lbs of CO<sub>2</sub> emissions (based on EPA420-F-05-001 February 2005)
- 1 gallon of LPG consumed equals 12.8 lbs of CO<sub>2</sub> emissions (US Energy Information Administration's database)
- 1 gallon of gasoline consumed equals 19.4 lbs of CO<sub>2</sub> emissions (based on EPA420-F-05-001 February 2005)

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The differentiating factors between the alternatives are: the type of modal technology (which includes a unique emissions rate), the daily distance traveled, and the daily headway (frequency of departures). For example, alternatives one and two travel along identical corridors at the same frequency, but alternative one utilizes a combination of DMUs and DPP locomotives while alternative two utilizes DPP locomotives solely. The difference in modal technology equals roughly 35,000 lbs of addition daily CO<sub>2</sub> emissions from the DMU/DPP alternative, over the DPP alternative.

DMUs and DPP locomotives, in terms of rail technology, are heavy and require a large amount of energy in order to stop, start, and reach their optimal operating speed. That train’s energy, for both DPP locomotives and DMUs, is generated onboard by a large diesel engine that powers an electric drive system. The BRT and TSM alternatives utilize buses as the primary technology to deliver service along two unique corridors alignments. Buses, as a modal technology, are much lighter than a DMU or DPP locomotive and operate using a significantly smaller diesel engine which is more efficient. A typical diesel bus emits 8 lbs of CO<sub>2</sub> per mile, a DMU emits 12.9 lbs per mile, and a DPP locomotive emits 48.6 lbs per mile. Throughout the course of daily operations, this difference in CO<sub>2</sub> emissions adds up.

Modeling indicates that an increase of 278,608 VMTs will occur if a preferred build alternative is not implemented. This equals 0.17% of the expected daily total (161,407,700 VMTs) which is an insignificant value when compared to the total, but it is equal to roughly 130 short tons of daily CO<sub>2</sub> emissions. The no-build alternative emissions value of 130 short tons represents a greater potential impact of increased CO<sub>2</sub> emissions when compared to either the BRT and TSM alternatives.

For ease of comparison, **Table 7** presents the values in the unit measurement of Short Tons per Day. An imperial Short Ton has the value of 2,000 pounds.

**Table 7. Daily Greenhouse Gas Emissions Screening of Build Alternatives Summary**

<b>Daily Greenhouse Gas Emissions Screening of Build Alternatives</b>		
<b>Alternative</b>	<b>CO<sub>2</sub> Emissions (lbs) / Day</b>	<b>CO<sub>2</sub> Emissions (Short Tons)* / Day</b>
<b>1. Integrated Rail - DMU</b>	<b>1,024,128</b>	<b>512.1</b>
<b>2. Integrated Rail - DPP</b>	<b>979,776</b>	<b>489.9</b>
<b>3. BRT</b>	<b>28,419</b>	<b>14.2</b>
<b>4. TSM</b>	<b>38,886</b>	<b>19.4</b>
<b>No Build</b>	<b>259,105</b>	<b>129.6</b>

\* 1 short ton is equal to 2,200 pounds

**Biodiesel**

Many transit systems today have considered the incorporation of alternative (renewable) fuels into their fleet operations. Therefore, an assessment of on one such renewable fuel, Biodiesel, is warranted due to its current and future use as a viable alternative fuel. Biodiesel is a type of diesel fuel that is derived from natural, renewable sources such as plants (vegetable oils) and animal sources (meat processing renderings). Biodiesel can also be derived from waste cooking oil, once it undergoes processing. Biodiesel is intended to be used in standard diesel engines

## MEMORANDUM

either alone or as a blend with traditional, petroleum-based diesel. Biodiesel fuel typically costs more than petroleum-based diesel (10 to 20 cents per gallon more) except where local governments provide a subsidy. The majority of global biodiesel production, 85%, occurs in Europe, but American production has increased during the past decade providing U.S. consumers with access to domestically produced biodiesel.

The emissions factor for biodiesel and petroleum based diesel varies slightly. In comparison, pure biodiesel (B100) produces 20.8 lbs of CO<sub>2</sub> per gallon of fuel while regular diesel produces 22.3 lbs of CO<sub>2</sub> per gallon of fuel. This represents a minor difference, roughly 7%, in direct emissions which is not significant. However, when considering indirect emissions (emissions related to fuel production) biodiesel represents an average reduction of 57% in GHG emissions as compared to petroleum-based diesel (Chapter 2.6 of the EPA's *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis*). Currently the South Florida Regional Transportation Authority has mandated the use of biodiesel in the operations of their Tri-Rail locomotives; following Florida Governor Charlie Crist's executive orders aimed at reducing GHG emissions and conserving energy (which went into effect July, 2007).

### Summary

The entire range of modal technologies was initially considered for the SFECCTA study. However, the final project detailed alternatives have focused on using Diesel Push-Pull Locomotives, Diesel Multiple Units, a combination of both, or buses as the technology of choice. Comparatively, DPP Locomotives and DMUs emit a greater volume of CO<sub>2</sub> than other technologies, but are able to carry a much greater load of passengers than buses or personal vehicles. For the SFECCTA study, a DPP would be in a consist with three 150 passenger carriages providing total capacity for 450 passengers (seated). The DMUs would be in groups of three to four, depending on demand, and emit close to the same volume of CO<sub>2</sub> as a DPP while providing equivalent passenger volume.

The BRT and TSM alternatives utilize buses as a preferred modal technology. Buses are much more fuel efficient than both DPP locomotives and DMUs but they carry fewer passengers (about an eighth) so more units must be operated in order to handle the daily passenger load. Even with this greater volume of units operating daily, the TSM and BRT alternatives emit a lot less CO<sub>2</sub> than alternative one and two.

It is important to note that alternatives one and two have more destinations and routes than alternatives three and four (see Chapter 2 of the *ESR*). For example, alternatives one and two have four different routes: the FEC Local, the Flagler Flyer, the Airport Flyer, and the Seaboard Flyer while the alternatives three and four have only one primary routes running north to south, both adjacent to the existing FEC north-south mainline and along Interstate 95. This greater coverage of service also contributes to the higher CO<sub>2</sub> emissions.

The no-build alternative's emissions value of 130 short tons exemplifies the impact that the transportation sector and personal vehicle use has on the net production of CO<sub>2</sub> in our atmosphere at both a regional and global level. However, it is not anticipated that this project will have a significant impact to the local, regional, or global levels of GHG emissions.

The values presented in **Table 8** indicate that two of the alternatives, alternatives one (DMU) and two (DPP), will exceed the CEQ threshold of 25,000 metric tons of carbon dioxide equivalent annual emissions. Alternative three (BRT) is close to the CEQ threshold, with a value of 21,040

metric tons. This will prompt a more detailed analysis of GHG emissions as the NEPA process continues during subsequent phases of the SFECCTA study. It is also very possible that all alternatives will exceed the CEQ threshold when considerations like: construction impacts; operations & maintenance facilities; and transit stations are incorporated into the GHG emissions analysis during later phases of the project study.

**Table 8. Annual Greenhouse Gas Emissions  
Screening of Build Alternatives Summary**

<b>Annual Greenhouse Gas Emissions Screening of Build Alternatives</b>		
<b>Alternative</b>	<b>CO<sub>2</sub> Emissions Short Tons / Year</b>	<b>CO<sub>2</sub> Emissions Metric Tons / Year</b>
<b>1. Integrated Rail - DMU</b>	<b>150,870</b>	<b>136,867</b>
<b>2. Integrated Rail - DPP</b>	<b>144,337</b>	<b>130,940</b>
<b>3. BRT</b>	<b>4,187</b>	<b>3,798</b>
<b>4. TSM</b>	<b>5,729</b>	<b>5,197</b>
<b>No Build</b>	<b>38,170</b>	<b>34,628</b>

**Assumptions:**

1 Short Ton equals 0.907184 Metric Tons

Annual calculations include typical work days (Monday - Friday) and weekends (Saturday & Sunday)

Weekend service is calculated as 33% of typical work day service.

## References

American Public Transportation Association Standard Development Program. Quantifying Greenhouse Gas Emissions from Transit. 14 August 2009

California Air Resources Board. On-Road Motor Vehicle Certification. 5 January, 2009.

Judy, Leslie. Chandler, Kevin. "Early Results from DOE/NREL Transit Bus Evaluations" Powerpoint presentation for the National Renewable Energy Laboratory APTA Bus and Paratransit Conference. May 2005.

United States Environmental Protection Agency. MOBILE6 Vehicle Emission Modeling Software. 2 Nov. 2009 <http://www.epa.gov/OMS/m6.htm>.

United States Environmental Protection Agency. eGRIDweb. 11 Nov. 2009  
<http://cfpub.epa.gov/egridweb/view>.

United States Environmental Protection Agency. Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis. February 2010  
[www.epa.gov/otaq/renewablefuels/420r10006.pdf](http://www.epa.gov/otaq/renewablefuels/420r10006.pdf)

United States Energy Information Administration. Voluntary Reporting of Greenhouse Gases Program. <http://www.eia.doe.gov/oiaf/1605/coefficients.html>

United States Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998. EPA 236-R-00-001, Washington, DC, April 2000.